Precision Livestock Farming '11

Edited by

C. Lokhorst, D. Berckmans

PRECISION LIVESTOCK FARMING '11

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Editorial

This is the 5th ECPLF conference and today the topic of Precision Livestock Farming looks more interesting than ever before. Worldwide livestock production is faced with some serious problems that are coming together just now. The worldwide demand for meat products is expected to increase with over 40 % in the next 15 years. There are serious concerns about animal health in relation to human health while worries about animal welfare are still increasing. Finally there is the problem of environmental load due to animal production.

At the same time the number of farmers is decreasing which means that normally livestock farms must be expected to become even bigger. The consequence is that a farmer has less time to do audio-visual observation of individual animals as his grandfather used to do. To guarantee accurate and continuous animal monitoring we need reliable and affordable technology. Now we enter the time that biology meets and maybe needs technology. Precision Livestock Farming is one possible way to support the farmers and several other stakeholders in the livestock production chain.

PLF treats livestock production as a set of interlinked processes at different levels, which act together in a complex network. All these processes can be traced, monitored and controlled and have to deal with time variation, non-linearity, location variation and different contextual situations. We have to deal with biological processes and their variation. Processes suitable for this PLF approach are very wide going from variables measured at level of an individual animal in a pen till for example the generated money flow at chain level. Each process can be considered for this approach at condition that process outputs and inputs can be measured continuously. That is where the modern technology (sensors, contactless sensing by image and sound, wireless data transmission, strong and affordable computing power, traceability techniques etc.) comes in to push this development of smart farming. Examples of variables that are now considered in research include animal growth, the output of milk and eggs, monitoring endemic diseases, aspects of animal behaviour, and the physical environment of a livestock building, such as its thermal micro-environment and emissions of gaseous pollutants such as ammonia.

The ambition of the organizers is that we share knowledge and experiences and have good discussions in the different sessions so that we make progress in this exciting field. To share the information all participants receive a DVD with all papers beside the hard covered proceedings of ECPLF '11.We hope you enjoy the papers and the discussions and finally we want to encourage the authors to upgrade their papers and submit them to peer reviewed journals.

Kees Lokhorst and Daniel Berckmans

Section 1
Activity Dairy

Wireless Sensor Application for Dairy Cow Activity Monitoring

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Abstract
Within the Wirelessly Accessible Sensor Populations (WASP) project a research technology prototype has been build of an advanced Wireless Sensor Network (WSN) enabling Smart Dairy Farming. The current integrated WASP solution demonstrated in herd health control test bed can be well used as a research tool for animal and human behaviour scientists to enable data acquisition for periods up to several weeks to study behaviour and, in the end, come up with better models and treatments. Within the WASP test bed for Smart Dairy Farming, the focus has been on remote monitoring of activity-related problems like claw health and locomotion. Encouraged by the large-scale herd control deployment whose operation is limited to 10 to 12 days, we performed an exercise to assess whether it seems feasible to monitor a large number of cows over a period of a year without replacing the 8Ah batteries. Through this exercise, we wanted to get a feeling on application and deployment trade-offs like 1) acceptable time between packets generated at application level, 2) acceptable number of battery-powered mobile sensor nodes, 3) required number and positioning of battery- and/or mains-powered forwarder nodes and 4) required number and positioning of sink nodes, while considering application Quality of Service constraints in terms of size (and hence energy capacity) of batteries, packet delivery ratio and packet delivery latency.

Keywords: wireless sensor network, test bed, herd control, locomotion, application

Introduction
The infrastructure for ambient intelligence envisioned by researchers and industry in Europe, will consist of a myriad of wireless sensors working in collaboration. Much research in the academic world focuses on technology for Wireless Sensor Networks (WSN). However, industry is reluctant to use the results derived from academic research, principally because there is a mismatch between research at the application level and the sensor node and network level. The WASP project (EU FP6 project IST-034963 www.wasp-project.org) aims to rectify this imbalance by covering every link in the chain from hardware (for sensors, processors, communication, and packaging) to the information distribution and selection of applications. The main emphasis in the project lies in the self-organization and the services which connect the application to the sensor network. The nodes themselves also need research, because there is a strong link between the flexibility required and the hardware design. The applications need to be researched, because the properties of the used services will influence the configuration of both sensor network and application for optimum efficiency and functionality. Many of the design decisions inherent to the development cannot be handled in isolation as they depend on the hardware costs involved in making a sensor and the market size for sensors of a given

type. The general goal of the project is the provision of a complete system view for building large populations of collaborating objects. The WASP results will be well suited for adoption by small and medium enterprises (SMEs). The consortium will define an active program to approach the appropriate SMEs and to familiarize them with the WASP results. A promising application field for WSN is livestock. To give individual animals in increasing herd sizes the required attention farmers are introducing individual animal monitoring systems based upon sensor technology.

Method: The WASP methodology

The WASP methodology connects Wireless Sensor Networks to Web based applications. To be able to build and support the chain from sensor hardware to the real world applications the WASP methodology is build up in different layers. The left side of Figure 1 shows from bottom to top the WSN layers: node, network, router, gateway and back-end with the enterprise integration component (EIC) and application platform. The application developer and the system integrator can choose in which layer to incorporate what data storage and intelligence. For example, accelerometer data can be used to monitor claw health of dairy cows. If step and movement of a cow is analysed on the farm management system, all data has to be transmitted. However, if the data is already analysed on the node then only average step and movement information has to be transmitted. This makes it possible to work with trade-offs (accuracy, energy) and to optimize the application for a specific situation. Figure 1 also shows that for each layer several components and/or services can be developed, allowing the application developer to choose between components. To support node-level application development, a dedicated programming model ECA (Event-Condition-Action) has been developed within the WASP project. However, the WASP system is flexible enough to make use of other programming models like uDSSP which has been demonstrated to work in parallel to ECA.

Results

In the WASP project, hardware and software components and programming models have developed by the project partners: Philips Research, CEFRIEL, IMEC-NL, CSEM, TU Eindhoven, European Microsoft Innovation Center, Health Telematic Network, Fraunhofer-Gesellschaft, Wageningen UR Livestock Research, Imperial College, ST Microelectronics, INRIA, EPFL, Centro Ricerche Fiat, TU Kaiserslautern, RWTH Aachen, SAP and University of Paderborn. In this section, a brief description of results obtained is provided. An extensive description has been made available on the WASP website (www.wasp-project.org).

<u>Herd control application driver</u>

The herd control applications within WASP are based on the anticipated increase in size of dairy farms around 2015 when the current milk quota system will be abandoned within the EU and today's small-scale (50 to 100 cow) farms may no longer be cost competitive. Besides the increase in farm sizes, also more effort is needed to monitor the welfare of cows and to early warn for upcoming diseases. For all these reasons, good observation of individual cow behaviour is needed. The so-called Smart Dairy Farming (SDF) concept aims to enable cost-efficient operation of large-scale (150 to 500 cow) dairy farms by automated monitoring of individual cows to identify cows that need attention in an early stage. Such cows are most expensive in food, labour, and

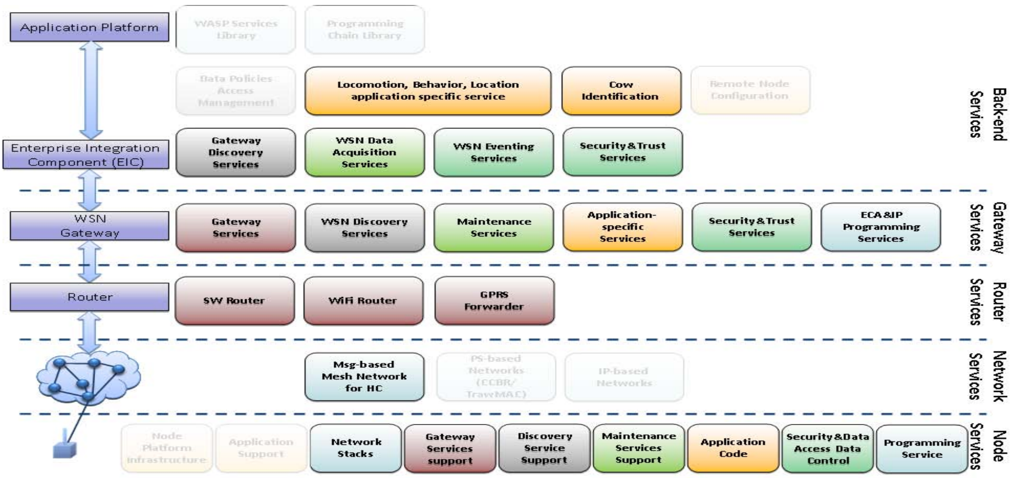

Figure 1. Schematic view of the different layers of the WSN and their components (services).

veterinary & medicine costs and usually suffer from a loss in milk production and increased risk for premature carry-off for slaughter.

The implications of the Smart Dairy Farming concept are several. If individual animals and the awareness of their variation are set as a basic element and the international and interesting development in Information and Communication Technology will be integrated in 'real time' management of livestock production chains, then a lot of topics can benefit. These topics have all their specific characteristics. Some of them are mentioned below.

Production efficiency and energy - In daily management it is important to use the expensive production factors such as labour, food, concentrates in an efficient and sustainable way. Production is closely related to energy and the carbon dioxide foot print. The focus on individual animals makes it possible to deal with their differences. There is a huge potential in this. Variation of 30 to 40% in production efficiency is still present. This becomes very important if production factors become scarce. A second part of production efficiency is to give individual animals the attention they need. This will also be a bridge to new or changed cooperation in the production chains. New services can be developed.

Animal welfare - Animal welfare becomes more and more objective. Measuring programmes are being developed and this will be the basis for intensive communication with society. It also can be a basis for new products. These objective animal welfare programmes are based on farm visits that take place at regular moments. The first sign can be seen that there will become a need for operational checks of animal welfare, since welfare is very sensitive for the context in which animals live. The SDF concept and the tools can be helpful in developing these realtime objective animal welfare characteristics.

Animal health - Discussions in the domain of animal health have different characteristics. From the perspective of individual animals and farmers there should be a strong emphasis on

timely detection through early warning of farm related diseases. Reduction of these health problems probably will influence longevity of animals on the farm. Cooperation with service providers and veterinarian practitioners will be beneficial for both. A lot of discussions also focus on contagious diseases. National programmes and cooperation in the animal disease chain might benefit from real time animal data. However, for this, national or regional monitoring specific attention should be paid to regional modelling and location based animal data. This will lead to a more preventive and risk based monitoring task. Also, in times of crisis this information will help to react quicker and more precise. The herd control scenario selected in WASP falls within this topic and, more specifically, focussed on remote monitoring of activity and locomotion of individual cows as early indicator for claw health problems.
Product quality and food safety - Product quality is also individual animal related. So far this topic is not much in discussion, but can become important when product diversification becomes more prominent. Animal specific information can become the basis for new food chains. This will have logistic consequences that should be handled by using modern ICT based support systems. The SDF concept can feed the present used quality systems with new real time elements. Then also in livestock production chains the concept of quality based tracing and tracking becomes possible.
Environmental protection and regional development - This topic has also a high importance. The connection to the SDF concept is very close related to the whereabouts of individual animal activities. Individual activities of animals are in essence the source of environmental issues. Use of food, concentrates and manuring are context and animal related. This takes place in a specific region. New concepts of farming become possible. Interaction with protected areas such as Natura 2000 regions will provide operational management. For this topic also the location awareness and the real time integration in the regional system are important. Of course not all these aspect were used in the WASP prototype. But the relevance of observing cow activity behaviour and, more specific, the locomotion behaviour is made clear.

<u>Herd control test bed</u>

Within the WASP test bed for herd health control, the focus has been on remote monitoring of activity-related problems like claw health. Throughout various integration sessions in a dairy test farm in Lelystad (The Netherlands), of which an impression can be found in Figure 2, the components and tools have been gradually introduced and tested, thereby validating and refining the WASP system. The final achievement has been the successful deployment of a WASP prototype as indicated in Figure 3.

In the prototype illustrated in
Figure 3, a large-scale network of in total 79 nodes has been successfully deployed which involved 27 real cows (each wearing two nodes) 10 “virtual cows” (nodes attached on a test wheel to simulation motion and thereby to stress test the deployment), 14 stationary forwarder nodes and 1 base station node. In a separate large-scale laboratory trial a group of 127 nodes was used.
Various deployments tools have been used to remotely monitor the services installation on nodes (node monitor), the network topology (topology monitor), and network performance and node stability (statistics monitor) during run-time. Besides monitoring, also node settings can be remotely changed.

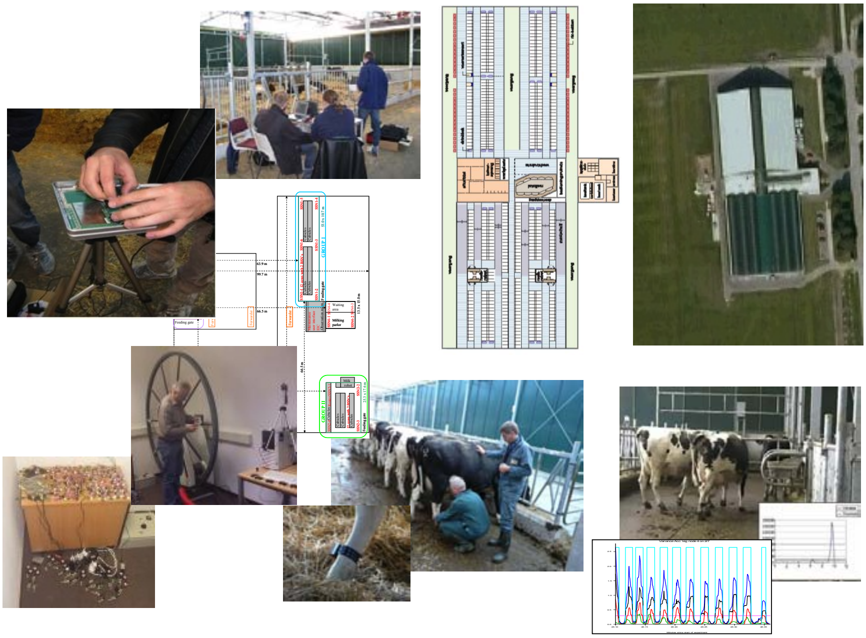

Figure 2. Impression of the herd control test bed development to validate and refine the WASP architecture and implementation during various integration sessions in the dairy test farm in Lelystad (The Netherlands)

For the interaction with the end user, the animal behaviour researchers of WUR developed and tested a prototypical Dairy Farm Information System. This Farm Information System is built upon a generic business mediation layer that was used to collect and store data from the experiments and to perform subsequent operations including establishing data trustworthiness.

From the various Smart Dairy Farm topics sketched in the previous section, our test scenario addressed animal health and, more specifically, focussed on remote monitoring of cow activity behaviour and locomotion to early detect claw health problems for individual cows. Measurements are performed with a 3D accelerator sensor that is integrated in the WASP sensor node. The measurement interval, duration and the frequency are adaptive to the behaviour of the animal. Cow activity behaviour is translated to different modes that are used during the testing phase:

- **MODE 0:** continuous stream of 3D values, 3x10 or 3x50 measuring values per second;
- **MODE I**: Data that the cow is laying (one value, e.g. ‘1’);
- **MODE II**: Data that the cow is standing (one value, e.g. ‘2’);
- **MODE III**: Data that the cow is walking (one value, e.g. ‘3’);
- **MODE IV**: Step duration, length, swing (amplitude of the sideward movement) and amplitude (four values)

MODE 0 will not be activated during default operation, but has been implemented to check proper accelerometer operation by the WSN system integrator and for raw data collection by the animal behaviour scientist for off-line (activity classifier and locomotion) algorithm development.

MODES I, II, and III offer the option of switching to raw 3D-accelerometer data with a frequency of 10 Hz and an interval length of 1 s (10x3 measuring values) and in MODE IV there is an option of switching to raw 3D-accelerometer data with a frequency of 50 Hz and a interval length of 10 s (1500 measuring values).. The feasibility of using 3D accelerometers in a wireless sensor network (WSN) for determining the locomotion of the feet of a cow was explored; a procedure to distinguish steps and to derive step parameters (length and time) was developed. It is possible to detect steps and to derive step parameters. The algorithm seems to be effective and has been tested using a test wheel and on raw data collection from three cows.

Up-scaling from a first successful small-scale (15 nodes) deployment, showing the basic WASP system functionality, to the final large-scale (79 nodes) deployment proved rather cumbersome as we encountered (seemingly non-deterministic) node stability issues that, in the end, were caused by an accumulation of several sources on sensor node level. A big benefit of the integrated WASP system proved to be that, since debug facilities of sensor node deployed in an actual test bed are extremely limited, the ability to build and adapt remote monitoring tools to assess during run-time installed node services, node stability, network performance (packet delivery) and topology enabled to trace to origin of multiple sources. In its current state, we are confident that the integrated WASP system can serve as research tool for animal behaviour scientists at WUR to enable data acquisition for period up to several weeks to study behaviour and, in the end, come up with better models and treatments.

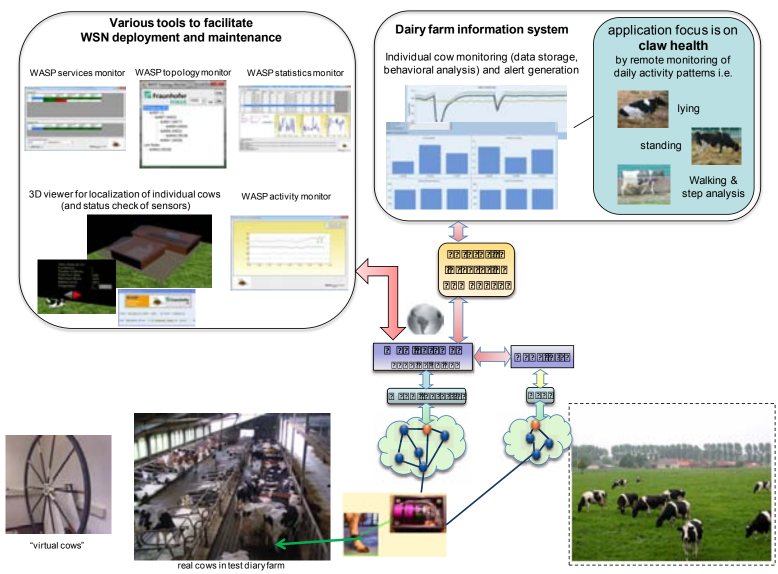

Figure 3. Herd control test bed setup for which the indoor case has been successfully demonstrated within WASP.

Throughout WASP run time, the herd control concept has been discussed with members of the Smart Dairy Farming (SDF) study group within the Netherlands, involving Friesland Campina, CRV, Agrifirm and the NOM. These discussions contributed to the further plans of the SDF study group and assisted in selection of priorities, like “real-time” cow observations, and follow-up projects. The final herd control test bed scenario and results have also been discussed with this SDF consortium. Among several application-oriented questions, the steps needed to go from a research tool to industrial farm management information tool were of interest. Here, our thorough analysis of encountered test bed problems and solutions proved very valuable insights to this community.

Application and deployment trade-offs

Encouraged by the large-scale herd control deployment whose operation is limited to 10 to 12 days, we performed an exercise to assess whether it seems feasible to monitor a large number of cows over a period of a year without replacing the 8Ah batteries. Through this exercise, we wanted to get a feeling on application and deployment trade-offs like

- acceptable time between packets generated at application level
- acceptable number of battery-powered mobile sensor nodes
- required number and positioning of battery- and/or mains-powered forwarder nodes
- required number and positioning of sink nodes while considering application QoS metrics constraints on
- size (and hence energy capacity) of batteries
- packet delivery ratio
- packet delivery latency

Figure illustrates two application categories and their associated time between (application) packets that are useful to monitor both healthy cows (sending health reports to the farm information system at low periodicity) and cows that need attention (and send frequent health reports and information about their location).

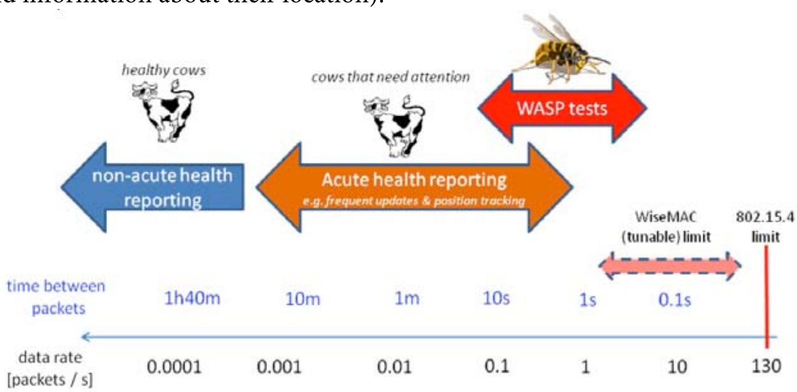

Figure 4. Application ranges for herd control

The figure also indicates the application traffic typically generated in the WASP tests that are deliberately in a regime to stress test the sensor network capacity and the amount of data that can be send to the WASP gateway and enterprise system.

The sink-to-router serial connection can handle up to around 9000 packets and, subsequent, router-to-gateway and gateway-to-backend links are not likely to form a capacity bottleneck as long as the right (IP-backbone) infrastructure is installed. The WASP gateway has shown to be capable of dealing with quite some traffic when using a modern PC and, hence, the major challenge is in deploying a wireless sensor network with manageable amount of sinks & forwarders.

Simulation results for a group of 10 cows and 50 cows are depicted in the Figure 6 below where the QoS metrics used before, i.e. average packet delivery ratio, average packet delivery latency, and average power consumption, are shown as a function of time between application packets. The results reflect that at relative long time intervals between packets, QoS performance is best which can be understood well since this corresponds to a low-traffic condition. At decreasing time intervals between packets, traffic density and, hence, competition for the radio channel increases which leads to degradation of QoS performance.

For 10 cows (i.e. 20 cow nodes), the QoS metrics are acceptable for the application requirements, but when sending packets at time intervals shorter than 30s, packet delivery starts to drop below 90%, latency goes up to minutes, and power consumption breaks the 3mW constraint of (battery-powered) operation of 1 year (= 8Ah / (364 days per year *24 h per day) * 3V). For 50 cows (i.e. 100 cow nodes), the time between packets needs to be significantly increased to far above 1000s (>17 minutes) to get acceptable QoS performance including a one year operation time.

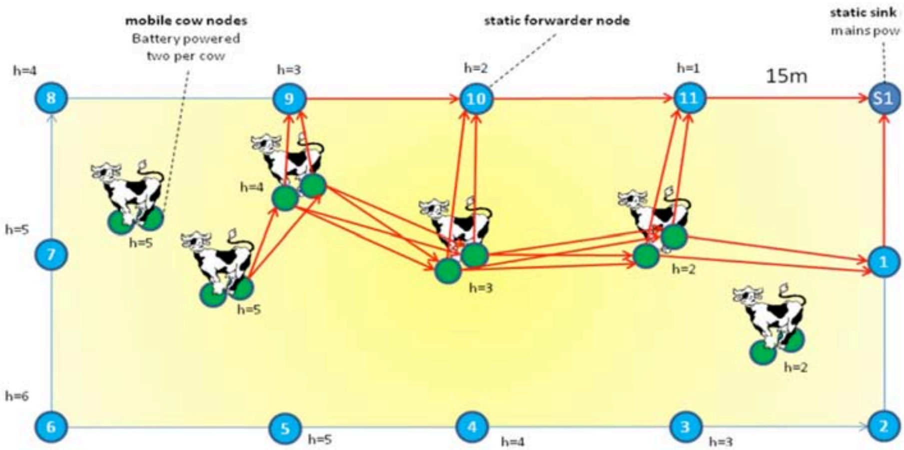

Figure 5. Simulation setup to assess application & deployment trade-offs for herd control

Note that this QoS performance is already fine for non-acute reporting (say once or twice a day) for the majority of cows while enabling acute monitoring for a few cows. Further QoS improvements can be obtained by (cross-layer) optimization of the (Gradient) routing and (WiseMAC) Medium Access Protocols which, due to the various technical issues encountered during integration, has hardly been pursued.

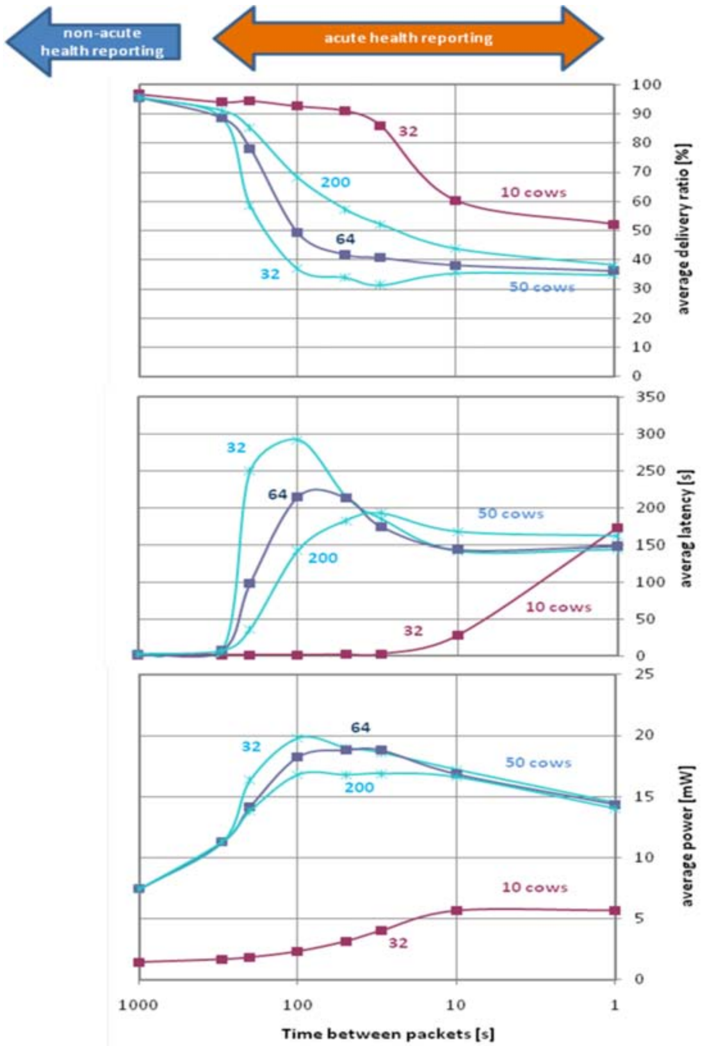

Figure 6. Simulation results for the Herd Control setting depicted in Figure 5. The numbers (32, 64, 200) next to the curves indicate the duplicate filter entries for Gradient.

For example, currently Gradient Routing only has a rather basic mechanism to filter duplicate packets that are so characteristic of broadcast-based routing protocols. This duplicate filter tracks whether a message from a given source with a given sequence number has already been forwarded and, if so, can be dropped. However, given memory constraints, only a limited number of message identifiers can be tracked. In large-scale deployments, the number of sources can outnumber the duplicate filter entries and thereby degrade filtering quality. This is illustrated for the 50 cow simulations in Figure 6 where simulations are shown for 32 (default used in the test bed), 64, and 200 duplicate filter entries.

Although stack optimization is always beneficial, QoS performance can readily be improved by adding multiple hardware routers to the deployment to provide an additional sink e.g. at forwarder #6 in Figure 5. The WASP IP infrastructure allows for the deployment of multiple (hardware and software) sinks and, thereby, to divert traffic going to a single sink although adding routers evidently comes at additional (hardware) costs. Another manner to significantly improve QoS performance would be to deploy mains-connected forwarders if allowed in the application environment.

Concluding remarks

Within WASP a Research technology prototype has been build of the advanced WSN system. WASP developments have been driven by three application domains. For the Herd Control applications, technology prototypes have been developed in an iterative way and tested for relevant application scenarios. The current integrated WASP solution demonstrated in the herd control test bed can be well used as a research tool for animal behaviour scientists at Wageningen UR Livestock Research to enable data acquisition for periods up to several weeks to study behaviour and, in the end, come up with better models and treatments. This understanding is essential to quantify benefits and costs and, thereby, to motivate any next steps from the current WASP research technology prototypes towards industrial application prototypes and, subsequent, commercial solutions.

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References

Martijn Bennebroek, Peter van der Stok, Oscar Garcia (PRE), Kees Lokhorst, Pieter Hogewerf (WUR), Alessio Corongiu (CRF), Andreas Lachenmann, Matthias Neugebauer (EMIC), Junaid Ansari (RWTH), Laurent von Allmen, Jean-Dominique Decotignie (CSEM), Marcel Steine, Richard Verhoeven, Johan Lukkien (TUe), Matthias Andree, Holger Karl (UPB), Ramón Serna Oliver and Gerhard Fohler (TUKL), Danilo Blasi, Fabio de Ambroggi (STM), Frank Bouwens (IMEC-NL), Alessio Carenini, Gianpaolo Cugola (CEFRIEL), Antoine Fraboulet, Michael Hauspie (INRIA), Benny Lo, Louis Atallah (ICL) Bjoern Riemer, Mario Schuster, Christian Flügel, Carsten Stocklöw (FHG), François Ingelrest (EPFL), Alberto Bosisio (HTN), Laurent Gomez (SAP), 2010. Final Project Conclusions , WASP D8.4, 107 pp.

Estimation of Daily Activity Dynamics of Heifers with Linear Mixed Models

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Abstract

The goal of the study at hand is to map the daily activity dynamics of heifers. A special characteristic of our analysis is that the data has been gathered in a production environment. Our evaluations reveal that the description of the activity dynamics can be realized with a linear mixed model. The model selection process emphasizes that both fixed (*hour of the day*month*) and random effects (*animal*, *animal*hour of the day*) are required for modeling the activity patterns for the daily dynamics. Consequently, we can map month-specific and animal-specific curves. The results are prerequisites for further studies on the estrus detection based on activity data.

Keywords: heifers, activity measurement, growth curves, statistical models

Introduction

Rapid developments in the fields of hard- and software as well as more subject-specific knowledge gained over the last decades allow for the increasingly advanced support of agricultural production management. Considering today's larger production sites, the shrinking number of employees, and the generally rising competitive pressure, this is urgently required. Given the preeminent importance of dairy cows on the one hand and the high development status of process technology on the other hand, management programs have reached a high level of maturity. This is true for both the support of milk production and the monitoring and control of feeding, health, and reproduction processes. For the support of health and reproduction control, sensors for measuring movement activities play a key role. When using the movement activity for estrus detection purposes, we exploit the fact that the estrus period is marked by increased movement activity (Kiddy, 1977; Liu and Spahr, 1993; Van Eerdenburg *et al*., 1996). Extensive studies, matured sensors for the activity detection, and the application of Artificial Intelligence methods have led to practically feasible systems (De Mol *et al*., 1999; De Mol and Woldt, 2001; Firk *et al*., 2002; Firk *et al*., 2003).
In contrast, the development of heifer management systems is considerably less advanced. Another notable fact is that analysis results for using movement activity for estrus detection purposes do exist, but their scope is much smaller (Williams *et al*., 1981; Sakaguchi *et al*., 2007; Løvendahl and Chagunda, 2009). In particular, there is a lack of results on categorizing the movement data in order to support the decision-making process in operational management programs. The results of the study at hand shall help close this gap.

The initial goal of our research here is to describe the activity dynamics in dependence on the *hour of the day* (HOD) under production conditions. In particular, we want to quantify the significance of animal-specific differences. In this context, we check the applicability of a linear mixed model. Above all, our results shall return a justified statement on what comparison scale to use as reference for the observed activity data per animal. Our analyses are prerequisites for the estrus detection based on activity data. In future work, we will examine Artificial Intelligence methods, such as fuzzy systems, to further support this decision-making process.

Material and methods

The results presented here are based on a data set acquired from heifers of a milk-producing operational site during the period from February 2010 to August 2010. The activity measurement was realized in the form of recording hourly activity values with the technology of DeLaval's ALPRO system. For the analyses at hand, we dispose of a data set from 189 heifers with average measurement duration of approx. 107 days. The average number of activity values per animal and day is 23.77. In order to ensure that the animals are in the post-puberty phase (activity data for estrus detection purposes are only meaningful for this phase), we only consider animals with a body weight of at least 300 kg. For the population examined here, this corresponds to an estimated age of at least 300 days. Per the operational site's conditions, the animals are grouped in herds of 30 to 50 animals.
According to our research goal here, our task is to describe the activity pattern per day. The data foundation is given by the hourly activity values per animal. The inclusion of the considered effects was factual-logically motivated. For the data modeling, we examine the influential factors listed below:

- fixed qualitative effects: HOD, test day, month,
- random qualitative effects: animal, animal*HOD.

The evaluation model to be applied was chosen with the help of statistical model selection methods. Our measure for the quality of the model's fitting is Akaike's information criterion (AIC) (Akaike, 1969; Mielenz *et al.*, 2006). The model selection can be described with two levels. The expectation structure is determined by using AIC and the *Maximum Likelihood* (ML) method (Burnham and Anderson, 2002). The choice of the covariance structure based on the best expectation model is then again performed with the help of AIC, but this time, it relies on the optimized likelihood derived with the *Restricted Maximum Likelihood* (REML) method (Burnham and Anderson, 2002). The evaluation was performed in SAS 9.2. Based on the estimated values of fixed and random effects of the covariance matrix as well as on their estimation errors from procedure MIXED, we calculated the corresponding two-sided confidence intervals. These confidence intervals were calculated to a confidence level of 95 %.

Results

Table 1 presents the results of the model selection. There, the quality criterion for the expectation structure of the third variant is smallest. Based on this, we introduce the random effects *animal* and *animal*HOD* into the covariance structure. As a result of the model selection, we favor the sixth variant.

Table 1. Results of the model selection for the expectation and covariance structure.

Variant	Fixed effects	Random effects	Method	AIC
1	HOD	residual	ML	4591587
2	HOD, test day	residual	ML	4587449
3	HOD*month	residual	ML	4562593
4	HOD*month	residual	REML	4561974
5	HOD*month	animal, residual	REML	4557328
6	HOD*month	animal, animal*HOD, residual	REML	4533973

*HOD=hour of the day

Figures 1 and 2 show examples for the month-specific activity curves of the daily dynamics. The estimated expectation values reveal that there is a higher average activity level for August compared to the months of July and February, respectively. This difference is much more significant for February (Figure 2) than it is for July (Figure 1).

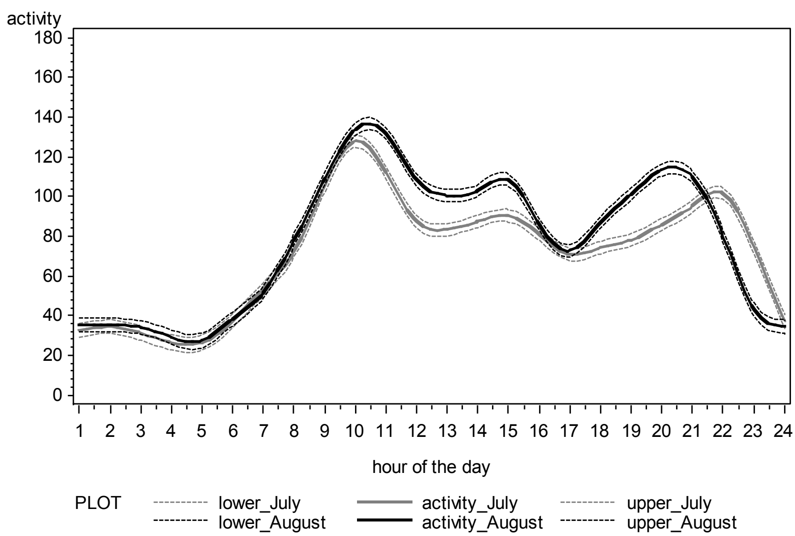

Figure 1. Daily activity dynamics for July and August as well as their two-sided confidence interval (P=0.95).

Figure 2 also shows that the daily dynamics curve for February is generally flatter than the one for August. The other monthly curves for the daily dynamics are also very distinctive. For adjacent months, these tend to be more similar than for months that lie further apart.

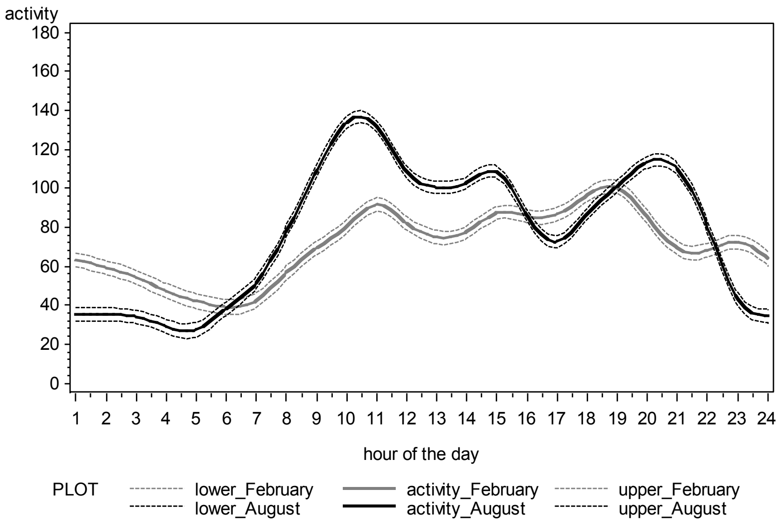

Figure 2. Daily activity dynamics for February and August as well as their two-sided confidence interval (P=0.95).

Figure 3 shows an example for the activity pattern of the daily dynamics of two animals. Both patterns refer to the month of August. In general, we note that there are differences in height and in the pattern between these activity curves. Animal A is marked by a higher activity level than animal B at all times. The corresponding confidence intervals do not overlap completely. A striking feature is that the patterns of animal A and animal B run in parallel during several phases – despite their different height and activity. For the other animals, we can also derive animal-specific curves that dispose of a similar behavior like the one illustrated in this example.

Figure 4 shows the month-specific activity curve of animal A in July and August. There, it becomes clear that the confidence intervals overlap with the exception of only a few points in time and that they only differ slightly from each other. When modeling additional months, we find higher similarity for adjacent months per animal than for the curves of months that lie further apart.

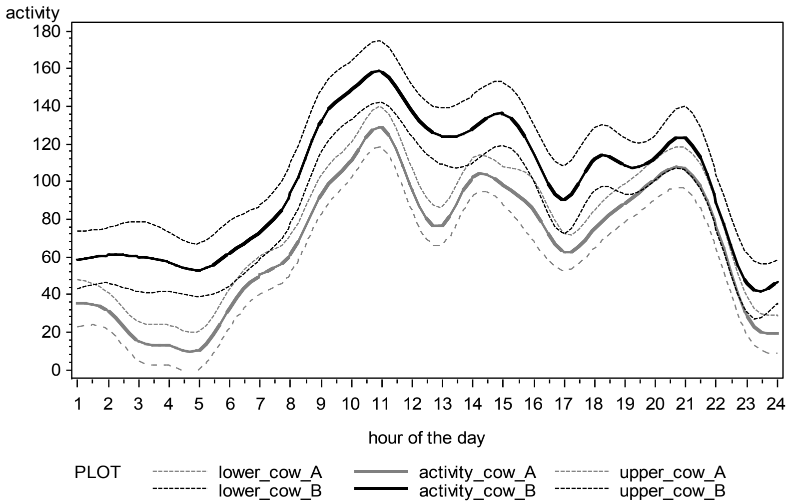

Figure 3. Daily activity dynamics of animal A and animal B for the month of August as well as their two-sided confidence interval (P=0.95).

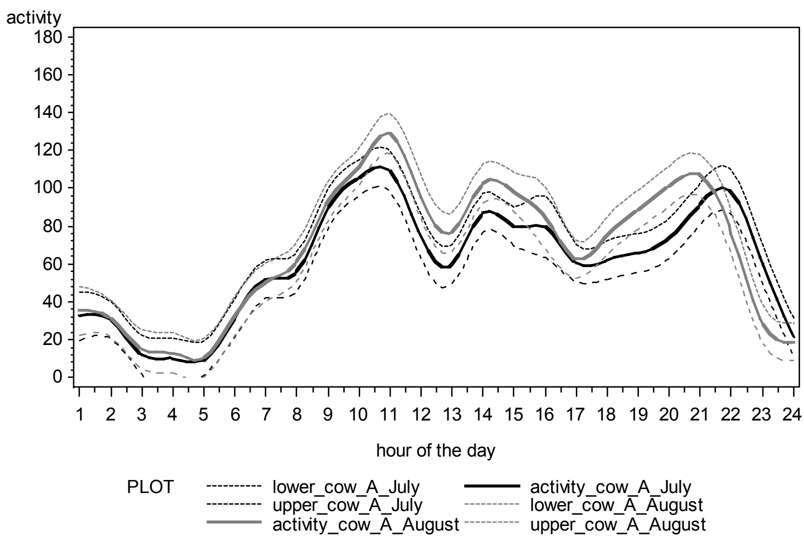

Figure 4. Daily activity dynamics of animal A in July and August with the two-sided confidence interval (P=0.95).

Discussion

The goal of the study at hand is to describe the daily activity dynamics in dependence on the time of day. In this context, the key idea is to use higher movement activities during the estrus period for estrus detection purposes (Kiddy, 1977; Van Eerdenburg *et al*., 1996; Liu and Spahr, 1993). As Figures 1 to 4 illustrated, the daily dynamics are marked by highly distinctive patterns. Our own research on the description of activity based on sliding mean values for consecutive hours turned out to be a rather ill-suited comparison scale – despite variable reference and comparison periods – when using the observed activity data for estrus detection purposes. This led to our motivation to conduct the study at hand.

Such application of a linear mixed model and of analytical criteria for the statistical model development (Akaike, 1969; Mielenz *et al*., 2006) results in the necessity to consider the fixed effects *HOD*month* as well as the random effects *animal* and *animal*HOD*. From the examples shown in Figures 1 and 2, it becomes clear that – aside from the hour of the day – the month certainly affects the daily activity curves. This impact is visible both in the activity level and in the curve's shape. For example, the activity intensity for adjacent months (Figure 1) tends to be more similar than for months that are further apart, such as February and August (Figure 2). The same is true for the curve's shape: for adjacent months, the curves run more or less in parallel. These results make sense if we recognize that the consideration of different months means that various environmental effects affecting the activity, such as the number of daylight, hours per day or the temperature, are included in our analyses.

The comparison of animal-specific activity curves (Figure 3) also reveals differences in the height of the activity level and in the curve's shape amongst individual animals. These differences are more distinctive for some animals and less distinctive for others, but a general similar tendency is found for all animals. Since the month has verifiable impact on the daily dynamics here, a comparison between different animals is only meaningful when performed for the same month.

Figure 4 shows an animal-specific activity curve for different months. Since Figures 3 and 4 both refer to the same month (August) and to the same animal (animal A), the illustrated curves can be compared. We see that the daily dynamics curves for one animal are more similar for adjacent months – both in terms of the activity level and the general shape of the curves – than they are for different animals in the same month. This tendency is found for all examined animals.

Furthermore, the confidence intervals for the same confidence level (P=0.95) are narrower for the month-specific curves (Figures 1 and 2) than for the animal-specific curves (Figures 3 and 4). This signifies that the estimated values for individual animals are subject to more scatter than those for individual months, which also contain a larger number of included values, and thus lead to the derivation of additional interval bounds.

Based on the presented results, we can illustrate the daily activity dynamics while including the effects *HOD*month*, *animal*, and *animal*HOD*. Both between months and between animals, we find significant differences at certain times of the day. Since further analyses require an animal-specific decision-making process, the indicated differences in the animal- and month-specific curves, respectively, point to the necessity to consider the mentioned effects. Thus, the selected model represents a promising starting point for future experiments on estrus detection.

Initially, it may sound absurd to apply a linear mixed model for evaluating the activity data and to derive confidence intervals for our estimations, since the activity data represents counts that are normally modeled by distributions such as the Poisson distribution or the negative binomial distribution (McCulloch and Searle, 2001). In contrast, for linear mixed models, we postulate a normal distribution for the random effects. Our analyses revealed, however, that our preferred model allows the assumption of a symmetric distribution for all random effects (*animal*, *animal*HOD* and *residual*). For those, we find an approximate normal distribution, which led to our motivation to apply this model. The most important advantage of this approach is the ability to benefit from the high degree of flexibility when designing the model within the class of linear mixed models.

Conclusions

The observation data gathered with our system for the activity estimation of heifers show distinctive daily dynamics. Such dynamics depend both on the individual animal and on the month of analysis. To describe the dynamics, the linear mixed model represents a feasible evaluation approach. Further research on the animal-specific decision-making for estrus detection based on movement activity must consider the analysis results at hand and thus necessitates the consideration of animal-specific curves. With the described modeling approach, we thus dispose of a method to map both month- and animal-specific curves and evaluate hours of the daily activity dynamics of heifers.

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References

Akaike, H., 1969: Fitting autoregressive models for prediction. Annals of the Institute of Statistical Mathematics **21** 243-247.

Burnham, K.P., Anderson, D.R. 2002. Model selection and multimodel inference, second edition, Springer, New York.

De Mol, R.M., Keen, A., Kroeze, G.H., Achten, J.M.F.H. 1999. Description of a detection model for oestrus and diseases in dairy cattle based on time series analysis combined with a Kalman filter. Computers and Electronics in Agriculture **22** 171-185.

De Mol, R.M., Woldt, W.E. 2001. Application of Fuzzy Logic in Automated Cow Status Monitoring. Journal of Dairy Science **84** 400-410.

Firk, R., Stamer, E., Junge, W., Krieter, J. 2002. Automation of oestrus detection in dairy cows: a review. Livestock Production Science **75** 219-232.

Firk, R., Stamer, E., Junge, W., Krieter, J. 2003. Oestrus detection in dairy cows based on serial measurements using univariate and multivariate analysis. Archiv für Tierzucht **46** 127-142.

Kiddy, C.A. 1977. Variation in physical activity as an indicator of oestrus in dairy cows. Journal of Dairy Science **60** 235-243.

Liu, X., Spahr, S.L. 1993. Automated Electronic Acivity Measurement for Detection of Estrus in Dairy Cattle. Journal of Dairy Science **76** 2906-2912.

Løvendahl, P., Chagunda, M.G.G. 2009. Short communication: Genetic variation in estrus activity traits. Journal of Dairy Science **92** 4683-4688.

McCulloch, C.E., Searle, S.R. 2001: Generalized, Linear and Mixed Models. John Wiley & Sons.

Mielenz, N., Spilke, J., Krejcova, H., Schüler, L. 2006. Statistical analysis of test-day milk yields using random regression models for the comparison of feeding groups during the lactation period. Archives of Animal Nutrition **60** 341-357.

SAS, 2008. SAS Institute Inc., Cary, NC, USA.

Sakaguchi, M., Fujiki, R., Yabuuchi, K., Takahashi, Y., Aoki, M. 2007. Reliability of estrous detection in Holstein heifers using a radiotelemetric pedometer located on the neck or legs under different rearing conditions. Journal of Reproduction and Development **53** 819-828.

Van Eerdenburg, F.J., Loeffler, H.S., van Vliet, J.H. 1996. Detection of oestrus in dairy cows: A new approach to an old problem. Vet. Q. **18** 52–54.

Williams, W.F., Yver, D.R., Gross, T.S. 1981. Comparison of estrus detection techniques in dairy heifers. Journal of Dairy Science **64** 1738-1741.

Lying patterns of high producing dairy cows during transition time characterised individually by behaviour sensors

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Abstract

The objectives of this study were to analyse behaviour variables of healthy cows during transition time in relation to age, environmental conditions and production performance to serve as a 'baseline' for diversions that indicate welfare or health problems. The trial was conducted from 2007 to 2010 in three commercial dairy farms and included 210 healthy multiparous cows during the first 28 days after calving. Lying time increases significantly with age and is significantly higher in winter than in summer. Positive and negative correlations between milk production and lying time are strongly affected by calving season, in opposite proportions between summer and winter.

Keywords: dairy cows, lying behaviour, transition time, sensors

Introduction

An animal expresses its physiological and well-being status by its behaviour. Changes in behaviour, e.g. lying behaviour or feeding behaviour, can be associated with health problems, welfare, production and therefore with the profitability of the farm (e.g. Huzzey *et al.*, 2005; Cooper *et al.*, 2008; Bewley *et al.*, 2010).
The most sensitive period during lactation is the transition time because a cow, after calving, increases milk production with a significant metabolic burden (Goff & Horst, 1997). In this period the majority of health problems occur (Ingvartsen, 2006).
There are studies that relate lying behaviour to welfare (e.g. Haley *et al.*, 2000; Fisher *et al.*, 2003; Cooper *et al.*, 2007) and production (Fregonesi & Leaver, 2001; Bewley *et al.*, 2010). The amount of time spent lying down resting is considered to make a significant contribution to dairy cow welfare and comfort (Fisher *et al.*, 2003), because cows have a strong behavioural need to rest and attempt to maintain a rather constant lying time (Metz, 1985; Munksgaard *et al.*, 2005). When lying time is disturbed, dairy cows cannot recuperate sufficient, they can be frustrated (Munksgaard & Simonsen, 1996), they may experience discomfort or pain and an increased risk for health problems such as lameness (Juarez *et al.*, 2003, Ito *et al.*, 2010). It was shown by Arazi *et al.* (2010) that there were significant alterations in lying time during transition time when milk production increased from zero up to more than 50 kg/day within a short period of 4 weeks. However, no attempt was made to study lying time and/or other

behavioural variables during transition time in relation to the age of the cow (lactation number), calving season (summer or winter) and production level when cows are selected for dealing with the metabolic burden without getting sick. Other factors that may affect behaviour are individual temperament and social hierarchy in the herd.

One of the reasons for the lack of information in this respect was that in the past, behaviour had to be recorded manually (Perera *et al.*, 1986; Fregonesi & Leaver, 2001) or with video recordings (e.g. Halachmi *et al.*, 2000, Overton *et al.*, 2002; Munksgaard *et al.*, 2005). This was time consuming and subjective. The development of dairy farming to more intensive production systems, with large numbers of cows per herd and the use of automatic milking units and feeders increased the need for integrated monitoring systems and sensors to get a wider range of information (Frost *et al.*, 1997, Halachmi *et al.*, 2000). Recently commercial behaviour sensors became available, allowing continuous monitoring of behaviour variables in order to detect health and welfare problems (Livshin *et al.*, 2005). Hence the possibilities for behavioural studies increased considerably (Tolkamp *et al.*, 2010).

The objectives of the present study were to analyse behaviour variables (lying time, lying bouts, maximal steps per hour, restlessness) of healthy cows during transition time in relation to age of the cow, environmental conditions and production performance. In the future, these results may be used as a 'baseline' for detection of alterations in behaviour that indicate health problems.

Material and Methods

Animals and housing

The study involved 210 healthy multiparous Israeli Holstein cows in three commercial dairy farms of varying size (60 milking cows – 250 milking cows) in Israel. For 34 cows more than one lactation was included in the experiment. In total there were 245 lactations in the dataset. Only healthy cows during the first 28 days after calving were selected for this study. A healthy cow was considered as one (1) that did not have a reported occurrence of a metabolic, digestive or any other disorder during the first 28 days after calving, (2) that had a normal lactation curve increasing gradually with no "collapses" during the period of 28 days after calving, (3) that did not suffer from lameness and injuries.

54.6 % of the cows in the original data were excluded from the trial due to "collapses" in the lactation curve, reported sickness, lameness and injuries in the first 28 days after calving. 4.2 % of the cows were excluded from the trial because they were not yet 28 days after calving.

The cows were housed in fully roofed open cowsheds and were milked thrice daily in a herring bone milking parlour. All cows were fed a TMR according to NRC (NRC 2001) recommendations. Food was distributed once a day.

The cooling procedure starts gradually in April when the cows are cooled in the waiting area before milking. As summer progresses, the cows are cooled between morning and noon milking and between noon and evening milking too. In the hottest period of the year, the cows are also cooled between evening and morning milking. The cooling procedure stops gradually according to the climate. The distance between the cowshed and the waiting area before milking is at most 35 m. For climate data see Table 1.

Sensors

Data were recorded with AfiFarm® Dairy Herd Management software. Maximal number of steps per hour, lying bouts and lying time were recorded by a behaviour sensor tag (Pedometer Plus™) that was fitted to the hind leg of each cow. The sensor provides maximal number of steps per hour, lying bouts - number of times a cow lies down and stands up again, and lying time is the total amount of minutes a cow lies down per 24h. Milk production per cow was measured by electronic milk meters. Body weight was measured automatically when cows walked over the weighing scale located at the exit of the milking parlour (AfiWeigh™). All sensors and software used are the product of S.A.E. Afikim (Kibbutz Afikim, Israel).

Table 1. Average climate data for the years 2008, 2009 and 2010 from Gimzo station, 100 m height (E 34 56, N 31 55) (IMS, 2010).

Month	**Temperature (°C)**			**RH (%)**
	Minimum	Maximum	Average	
January	2.1	23.3	12.3	62.8
February	3.4	27.3	13.1	66.8
March	3.5	25.0	15.7	64.7
April	4.8	36.6	18.0	61.3
May	8.2	36.5	20.5	59.7
June	13.2	39.3	24.5	59.2
July	16.6	35.9	26.2	63.6
August	16.9	36.0	26.9	65.6
September	15.6	36.1	25.1	63.6
October	13.4	37.9	22.6	61.3
November	7.6	31.2	17.4	63.7
December	5.8	26.5	15.0	61.1

Database

Data included in this study were collected during the years 2007, 2008, 2009 and 2010. The trial was carried out for the first 28 days after calving.

The data were divided into four groups: (1) second lactation cows that calved in the summer (April – September), (2) second lactation cows that calved in the winter (October – March), (3) cows with three or more lactations that calved in summer and (4) cows with three or more lactations that calved in winter.

The data were analysed also in relation to the correlation between lying time and milk production. Each group was divided into two subgroups. One subgroup included the cows that have a negative correlation between milk production and lying time. The other subgroup included the cows with a positive correlation.

Figure 1 shows sketches of a positive and negative correlation. Because of similarity in most of the variables, the cows with two lactations and the cows with three or more lactations were joined. Maximal number of steps per hour and lying time data in estrus were excluded because estrus usually increases maximal number of steps per hour and reduces lying time (Livshin *et al.*, 2005). The number of lactations in each group and subgroup are summarised in Table 2.

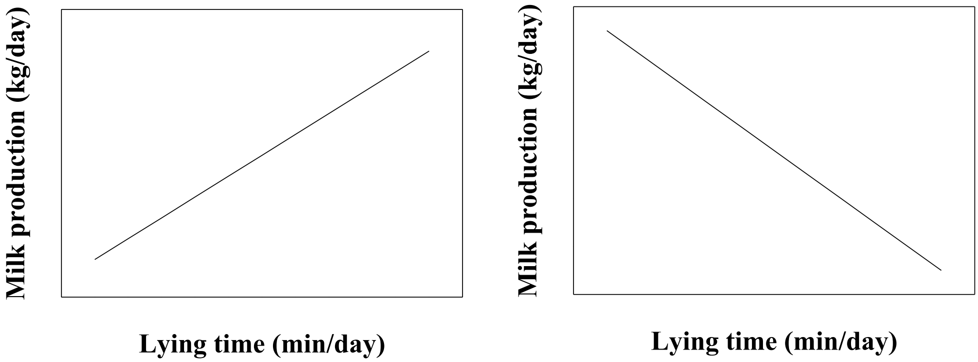

Figure 1. Sketches of positive correlation between milk production and lying time (left) and negative correlation between milk production and lying time (right).

Table 2. Number of lactations in dataset, according to calving season (summer - winter) and correlation (positive - negative) between milk production (MP) and lying time (LT)

	Calving Season		**Correlation MP-LT**			
			Positive		Negative	
			50 %		50 %	
	Summer	Winter	Summer		Winter	
			Positive	Negative	Positive	Negative
Lactation 2	79	41	62 (44 %)	78 (56 %)	60 (57 %)	46 (43 %)
Lactation 3 and more	61	65				

Statistical analysis

Per group, daily averages were taken from the five analysed parameters: milk production, maximal number of steps per hour, body weight, lying bouts and lying time.
To see if there was a correlation between milk production and lying time, data from the first 28 days after calving were analysed for each cow and group in Matlab (Matlab 6.1, MathWorks, Natick, Massachusetts, U.S.A.). To compare the groups and subgroups, unpaired student t-tests with non-equal variance were used in Excel (Microsoft Office Excel 2007, Microsoft, Redmond, Washington, U.S.A.). Statistical significance was declared at a probability level of $P < 0.05$.

Results

The age of the cow (lactation number), environmental conditions (summer and winter) and production performance (milk production and body weight) affected behaviour of the cows in this study.

Lactation number

For cows that calved in winter as well as those calved in summer, lying time and body weight were significantly ($P < 0.05$) lower for second lactation cows than for cows with three or more lactations (Table 3). The amount of lying bouts for cows that calved in winter was significantly ($P < 0.05$) lower for second lactation cows than for cows with three or more lactations (Table 3). In summer, the amount of lying bouts was similar for second lactation cows and for cows with three or more lactations (Table 3). Milk production and maximal number of steps per hour were similar for all summer calving cows and for all winter calving cows (Table 3).

Calving season

The time a cow lied down per day was significantly ($P < 0.05$) higher in winter than in summer for all cows (Table 3, Figure 3). During the first 4 to 5 days after calving, the cow spent less time lying down than later in lactation (Table 3, Figure 3), which is negatively correlated with the maximal number of steps per hour (Table 3, Figure 4, Table 4). For the whole period of 28 days after calving, the maximal number of steps is slightly negatively correlated with lying time (Table 4).

The maximal number of steps per hour was significantly ($P < 0.05$) higher in summer than in winter for cows with three or more lactations (Table 3, Figure 4). For second lactation cows, the maximal number of steps per hour was slightly higher (Table 3, Figure 4) and the amount of lying bouts was significantly ($P < 0.05$) higher in summer than in winter (Table 3). For cows with three or more lactations the amount of lying bouts was significantly ($P < 0.05$) lower in summer than in winter (Table 3).

Body weight of second lactation cows is significantly ($P < 0.05$) lower in summer than in winter. For cows with three or more lactations, there was no difference in body weight between summer and winter (Table 3).

For both second lactation cows and cows with three or more lactations, the difference in milk production was not significantly different in winter compared to summer for a period of 28 days after calving (Table 3).

Table 3. Milk production (MP), maximal number of steps per hour, lying bouts (LB), lying time (LT) of 79 cows with two lactations in summer, 61 cows with three or more lactations in summer, and 41 cows with two lactations in winter, 65 cows with three or more lactations in winter. For body weight (BW), there were data in in summer only for 59 cows with two lactations and 35 cows with three or more lactations. In winter, there were data only for 29 cows with two lactations and 46 cows with three or more lactations.

Lactation number	**2**		**3 and more**	
	Mean	STD	Mean	STD
			Summer	
MP (kg/day)	40.4	6.7	43.2	6.7
Maximal number of steps per hour (steps/hour)	175	20	172^{B}	21
LB (times/day)	11.2^{A}	0.5	11.0^{A}	0.4
LT (min/day)	**491^{cC}**	17	**520^{cC}**	25
BW (kg)	624^{cB}	16	687^{c}	19
			Winter	
MP (kg/day)	41.1	7.7	43.5	8.3
Maximal number of steps per hour (steps/hour)	165	24	155^{B}	23
LB (times/day)	10.8^{aA}	0.5	11.4^{aA}	0.8
LT (min/day)	**531^{cC}**	25	**579^{cC}**	38
BW (kg)	644^{cB}	17	693^{c}	19

a, b, c: significant difference between columns ($P < 0.05$, 0.005, 0.0001, respectively)
A, B, C: significant difference between rows ($P < 0.05$, 0.005, 0.0001, respectively)

Table 4. Correlation between activity and lying time for the first 28 days after calving

Lactation number	**Summer**	**Winter**
2	-0.17	-0.30
3 and more	-0.29	-0.31

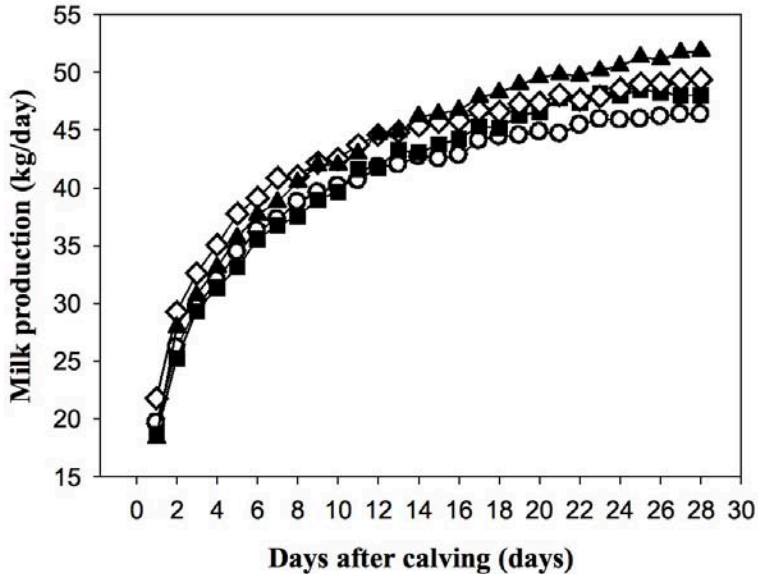

Figure 2. Summer and winter milk production of cows with two lactations and with three or more lactations (○ Summer – Lactation 2, ▪ Winter – Lactation 2, ◊ Summer – Lactation 3 and more, ▲Winter – Lactation 3 and more).

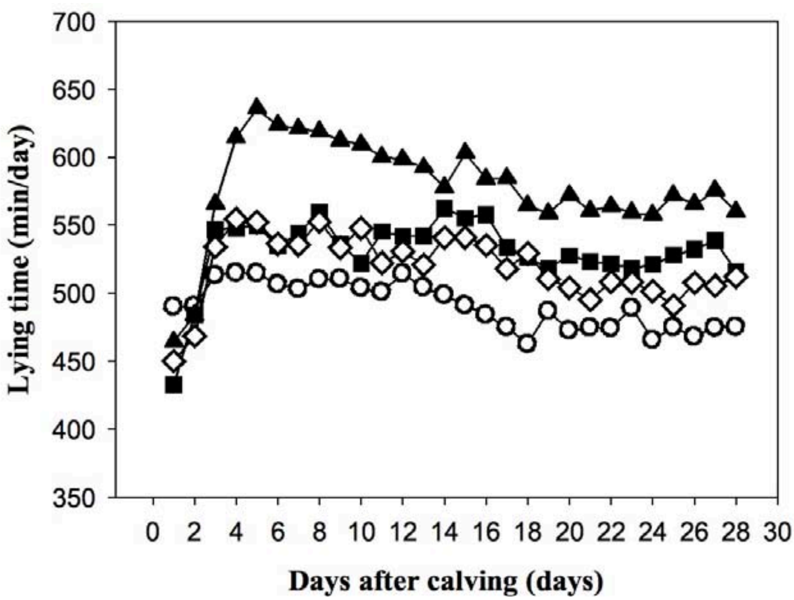

Figure 3. Summer and winter lying time of cows with two lactations and with three or more lactations (○ Summer – Lactation 2, ▪ Winter – Lactation 2, ◊ Summer – Lactation 3 and more, ▲Winter – Lactation 3 and more).

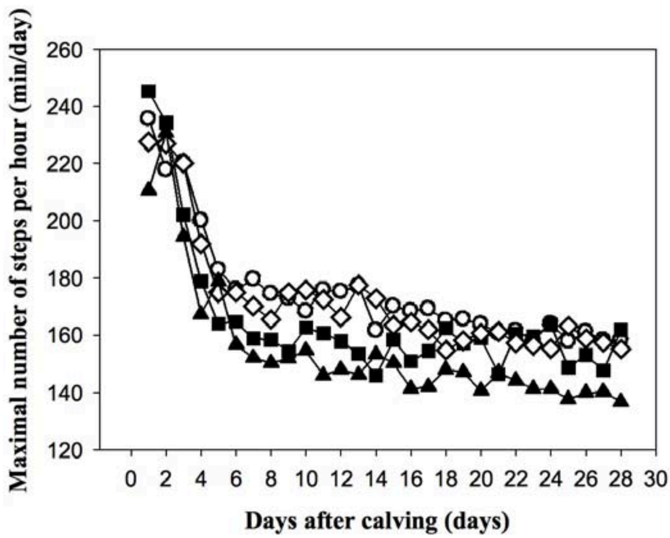

Figure 4. Maximal number of steps per hour in winter and summer of cows with two lactations and with three or more lactations (○ Summer – Lactation 2, ▪ Winter – Lactation 2, ◊ Summer – Lactation 3 and more, ▲Winter – Lactation 3 and more).

<u>Correlation between milk production and lying time</u>

Two groups were made: one with a positive correlation and one with a negative correlation between milk production and lying time during the first 28 days after calving (Table 2).
For summer calving cows, the group with the positive correlation between milk production and lying time had significantly ($P < 0.05$) more lying bouts than the group with a negative correlation and the body weight was significantly ($P < 0.05$) higher (Table 5). Milk production, maximal number of steps per hour and lying time were not significantly different between the two groups (Table 5). However, analysing the pattern of lying time during this period revealed a significant difference (
Figure 5). After 4 days of adaptation after calving the lying time of both groups was similar till day 10 after calving. From day 10 the lying time of negatively milk production and lying time correlated cows declined whereas the lying time for the positive correlated cows remained more or less constant.

For winter calving cows, lying time and the amount of lying bouts were significantly ($P < 0.05$) higher for positively correlated cows than for negatively correlated cows (Table 5). Milk production, maximal number of steps and body weight were not significantly different for cows with a positive correlation and cows with a negative correlation between milk production and lying time (Table 5).
Analysing the pattern of lying time revealed a significant difference (Figure 6). After 4 days of adaptation after calving, the lying time of negatively milk production and lying time correlated cows declined from day 8 post partum and it remained more or less constant for the positively correlated cows.

Table 5. Milk production (MP), maximal number of steps per hour, lying bouts (LB), lying time (LT) and correlation coefficients. The correlation (corrcoef) is between MP and LT. There were in summer 62 cows with a positive correlation between milk production and lying time and 78 cows with a negative correlation. In winter, there were 60 cows with a positive correlation between milk production and lying time and 46 cows with a negative correlation. For body weight (BW), there were in summer only data for 39 cows with a positive correlation and 56 cows with a negative correlation, and in winter, for 44 cows with a positive correlation and 30 cows with a negative correlation.

	Positive correlation		**Negative correlation**	
	Mean	STD	Mean	STD
		Summer		
MP (kg/day)	41.9	6.7	41.4	6.7
Maximal number of steps per hour (steps/hour)	170	23	177	18
LB (number/day)	11.3[a]	0.5	10.9[a]	0.6
LT (min/day)	513	25	498	32
BW (kg)	665[c]	21	635[c]	13
Corrcoef	0.14		-0.20	
		Winter		
MP (kg/day)	42.1	8.0	43.8	8.1
Maximal number of steps per hour (steps/hour)	160	26	158	19
LB (number/day)	11.3[a]	0.6	10.8[a]	0.7
LT (min/day)	**573**[b]	47	**539**[b]	37
BW (kg)	677	18	671	17
Corrcoef	0.20		-0.27	

a, b, c: significant difference between columns (P <.05, .005, .0001, respectively)

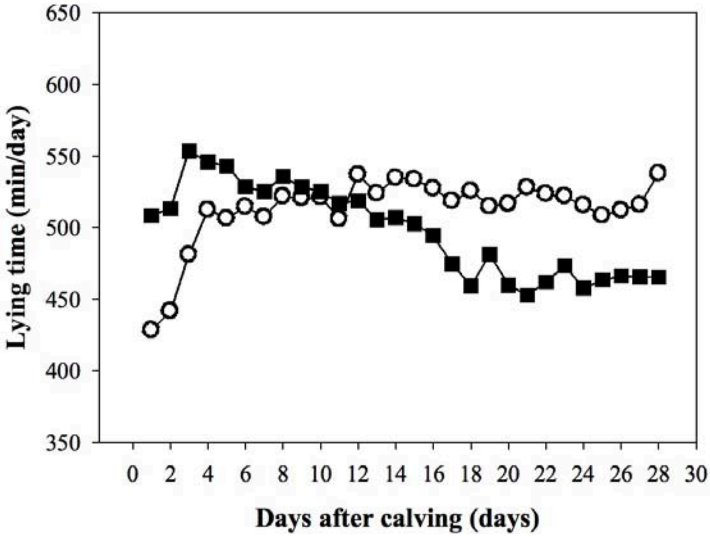

Figure 5. Lying time of summer calving cows with positive and negative correlation between milk production and lying time (○ Positive correlation, ▪ Negative correlation).

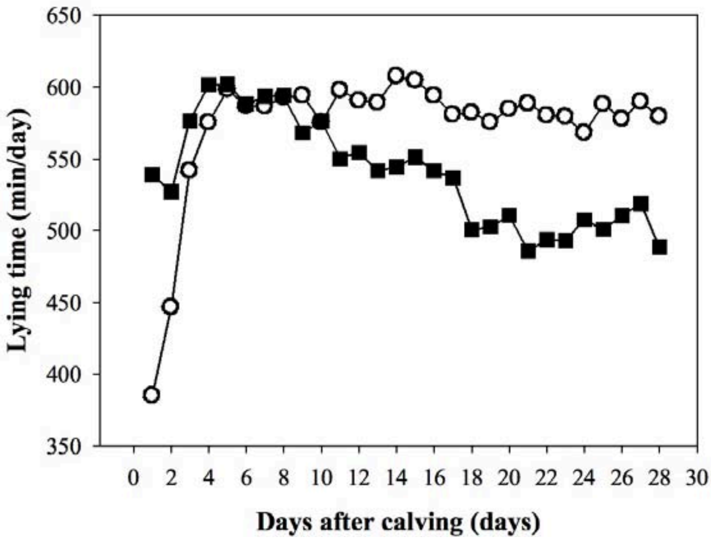

Figure 6. Lying time of winter calving cows with positive and negative correlation between milk production and lying time (○ Positive correlation, ▪ Negative correlation).

Discussion

Lying time is considered as a welfare (e.g. Haley *et al.*, 2000; Fisher *et al.*, 2003; Cooper *et al.*, 2007) and production (Fregonesi & Leaver, 2001; Bewley *et al.*, 2010) indicator. However, most of the studies were carried out during periods of established lactation, leaving out the most sensitive period during lactation, the transition time.

Arazi *et al.* (2010) described significant changes in lying time during transition, when analysing data of several herds, without any selection of lactation number, health status and calving season. Our results are in agreement with those found by Arazi *et al.* (2010) for the first few days after calving, but not for the whole transition period. This can be related to the fact that our study included only healthy, second lactation onward cows with no metabolic, digestive or reproductive disorders, lameness or other injuries.

In the presented study, it was found that all cows were gradually increasing lying time and were more active after calving during the first few days in lactation. The decline in lying time started later. Blackie *et al.* (2006) also showed that the maximal number of steps per hour in the first week was significantly higher than later in lactation. This could be a result of the physiological status due to an increase in milk production with a significant metabolic burden (Goff & Horst, 1997) and removal of the calf as well as the discomfort due to the new environment (Blackie *et al.*, 2006) and social hierarchy (Von Keyserlingk *et al.*, 2008) because of transfer to the group of lactating cows.

Lying time increases with age, as well as body weight. The fact that body weight has a positive correlation with age in commercial herds was already shown (Maltz *et al.*, 1991). So, a reason for increasing lying time with age might be the increased body weight, the increased milk production or both.

For summer calving cows, there were no significant differences between milk production, maximal number of steps per hour and lying bouts in second and third or more lactation cows. However, for winter calvers, when there is no heat stress, the milk production is slightly lower and the amount of lying bouts is significantly ($P < 0.05$) lower in second lactation cows, while maximal number of steps per hour is slightly higher compared to third or more lactation cows. This indicates that when the cows are not under heat stress, behaviour is affected mainly by the production process and inner herd activities (interactions between animals), while during summer the environmental conditions have stronger effect on the behaviour of the cows. This is in agreement with the findings of Perera *et al.* (1986), Cook *et al.* (2007) and Arazi *et al.* (2010) who found that during summer, cows lie down less time than during winter, probably related to need of air movement around the body for cooling. Therefore the higher maximal number of steps per hour and lower lying time in summer compared to winter in this study may be attributed to summer heat stress, which negatively affects the performance, production efficiency and welfare of the cows (ICBA, 2009; Avendaño-Reyes *et al.*, 2010). The higher maximal number of steps per hour in summer compared to winter in this study is in contrast with Edwards and Tozer (2004) who showed that healthy cows walk more in winter (study in Florida, no cooling procedure). We have to take into consideration the possibility that cooling systems (sprinkling and ventilation) used during the summer in Israel involves a movement of cows to the waiting area of the milking parlour and force cooling them between milkings.

This obviously causes more walking and less time to lie down than when they are not cooled. However, in our study the cows' pen was not more than 50 m from the milking parlour so this effect is assumed to be minimal.

Chaplin and Munksgaard (2001) found that second lactation cows have a higher lying time than cows in third lactation. This contradiction with our results may be due to the housing conditions of the cows in the study of Chaplin and Munksgaard (2001). They were entirely different (tied stalls) than in our work. Comparing the maximal number of steps per hour of cows across lactations, Edwards and Tozer (2004) found that maximal number of steps per hour is decreasing when a cow is older and Bewley *et al.* (2010) found no differences in parity, but they recorded behaviour only for 5.3±0.1 days and they compared cows in first lactation with older cows.

The amount of lying bouts in this study was similar to those reported in other recent studies (Bewley *et al.*, 2010 (11±3.9); Drissler *et al.*, 2005 (10.67-11.92); Endres & Barberg, 2007 (11.0±3.2)).

In this study we carefully selected only healthy cows and cows that had a continuous increase in milk production from calving throughout the entire period, indicating that the metabolic constraint was overcome with minimal stress. Including data of unhealthy cows (54.6 % of the original data) may interfere with the results, as behaviour can change due to diseases. Therefore, the findings that even among these cows half had negative correlation between milk production and lying time, for all categories of lactation, production, and calving season are very significant.

Grant (2009) showed a positive correlation between milk yield and resting time (Figure 7). However, Fregonesi and Leaver (2001) showed that higher producing cows have higher metabolic requirements, and spend more time eating and less time lying down than lower-producing cattle. In this study, there was no significant difference in milk production for the first 28 days after calving between cows with a higher lying time and cows with a lower lying time (positively and negatively milk production and lying time correlated cows respectively). However, a period of 28 days may be too short to see a difference in milk production.

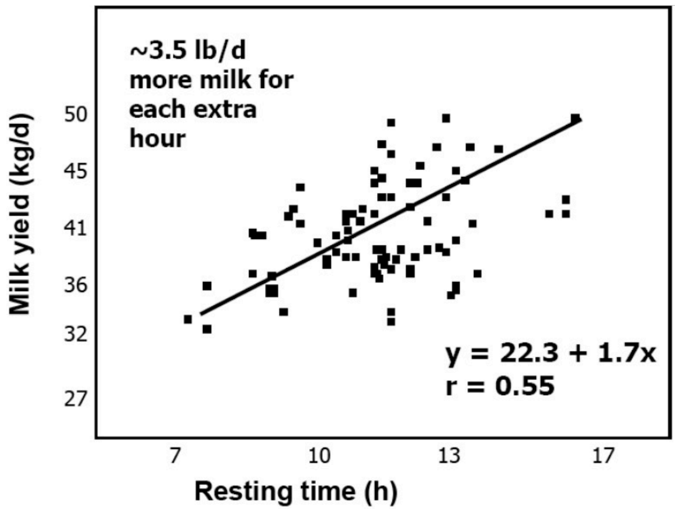

Figure 7. The relation between milk yield and resting time (from Grant, 2009).

A negative correlation between milk production and lying time in the transition period is in accordance with Arazi *et al.* (2010) and Bewley *et al.* (2010). Arazi *et al.* (2010) found that typical lying behaviour shows a decrease in lying time during the first 25 days after calving and that the correlation between milk production and lying behaviour was negative during this period. However, their observations did not distinguish between lactation number, season or metabolic stress. Bewley *et al.* (2010) depicted a trend of decreasing lying time with increasing production level in the first 28 days after calving, but argues that "this was an observational study of cows of varying physiological states".

In this study, the proportion of positively and negatively milk production and lying time correlated cows was both 50% when all cows are considered. But this is affected by calving season, where in summer the proportion is 44 % and 56 % positively and negatively correlated respectively, while in winter, it is the opposite, 57 % and 43 %. This indicates that under any circumstances for any kind of decision, the correlation between milk production and lying time (and probably other behavioural variables as well) and the calving season should be brought into consideration as well.

Conclusions

Lying and activity patterns of healthy cows in the commercial dairy farm measured during transition time are affected by calving season and lactation number. Positive and negative correlations between lying time and milk production are strongly affected by calving season, in opposite proportions between summer and winter. In future work, the results presented in this paper may be used as a 'baseline' for detection of alterations in behaviour that indicate welfare or health problems. Other recent available off-the-shelf sensors will be used for the same purpose, in a different perspective.

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References

Arazi, A., Ishay, E. and Aizinbud, E. 2010. The use of a new sensor (Behaviour tag) for improving heat detection, health and welfare monitoring in different rearing conditions. In: Farm Animal Breeding, Identification, Production Recording and Management: Proceedings of the 37th ICAR Biennial Session in Riga (Latvia), edited by Skujina, E., Galvanoska, E., Leray, O. & Mosconi, C., ICAR, Rome, Italy, pp. 113-127.

Avendaño-Reyes, L., Álvarez-Valenzuela, F.D., Correa-Calderón, A., Algánder-Sandoval, A., Rodríguez-González, E., Pérez-Velázquez, R., Macías-Cruz, U., Díaz-Molina, R., Robinson, P.H. and Fadel, J.G. 2010. Comparison of three cooling management systems to reduce heat stress in lactating Holstein cows during hot and dry ambient conditions. Livestock Science 132(1-3) 48-52.

Bewley, J.M., Boyce, R.E., Hockin, J., Munksgaard, L., Eicher, S.D., Einstein, M.E. and Schutz, M.M. 2010. Influence of milk yield, stage of lactation, and body condition on dairy cattle lying behaviour measured using an automated activity monitoring sensor. Journal of Dairy Research 77(1) 1-6.

Blackie, N., Scaife J. R., and Bleach, E. C. L. 2006. Lying behaviour and activity of early lactation Holstein dairy cattle measured using an activity monitor. Cattle Practice 14 139-142.

Chaplin, S. and Munksgaard, L. 2001. Evaluation of a simple method for assessment of rising behavior in tethered dairy cows. Animal Science 72 191-197.

Cook, N.B., Mentink, R.L., Bennett, R.B. and Burgi, K. 2007. The Effect of Heat Stress and Lameness on Time Budgets of Lactating Dairy Cows. Journal of Dairy Science 90(4) 1674-1682.

Cooper, M.D., Arney, D.R. and Phillips, C.J.C. 2007. Two- or Four-Hour Lying Deprivation on the Behavior of Lactating Dairy Cows. Journal of Dairy Science 90(3) 1149-1158.

Drissler, M., Gaworski, M., Tucker, C.B. and Weary, D.M. 2005. Freestall Maintenance: Effects on Lying Behavior of Dairy Cattle. Journal of Dairy Science 88(7) 2381-2387.

Edwards, J.L. and Tozer, P.R. 2004. Using Activity and Milk Yield as Predictors of Fresh Cow Disorders. Journal of Dairy Science 87(2) 524-531.

Endres, M.I. and Barberg, A.E. 2007. Behavior of Dairy Cows in an Alternative Bedded-Pack Housing System. Journal of Dairy Science 90(9) 4192-4200.

Fisher, A.D., Stewart, M., Verker, G.A., Morrow, C.J. and Matthews, L.R. 2003. The effects of surface type on lying behaviour and stress responses of dairy cows during periodic weather-induced removal from pasture. Applied Animal Behaviour Science 81(1) 1-11.

Fregonesi, J.A. and Leaver, J.L. 2001. Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems. Livestock Production Science 68(2-3) 205-216.

Frost, A.R., Schofield, C.P., Beaulah, S.A., Mottram, T.T., Lines, J.A. and Wathes, C.M. 1997. A review of livestock monitoring and the need for integrated systems. Computers and Electronics in Agriculture 17(2) 139-159.

Goff, J.P. and Horst, R.L. 1997. Physiologiscal changes at parturition and their relationship to metabolic disorders. Journal of Dairy Science 80(7) 1260-1268.

Grant, R. 2009. Stocking Density and Time Budgets. Proceedings of the Western Dairy Management Conference 2009, Reno, NV, pp. 5-17. Available at: <http://www.wdmc.org/2009/Stocking%20Density%20and%20Time%20Budgets.pdf> [Accessed 18 January 2011].

Halachmi, I., Metz, J.H.M., Maltz, E., Dijkhuizen, A.A. and Speelma, L. 2000. Designing the Optimal Robotic Milking Barn, Part 1: Quantifying Facility Usage. Journal of Agricultural Engineering Research 76(1) 37-49.

Haley, D.B., Rushen, J. and de Passillé, A.M. 1999. Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. Canadian Journal of Animal Science 80(2) 257-263.

Huzzey, J.M., von Keyserlingk, M.A.G. and Weary, D.M. 2005. Changes in Feeding, Drinking, and Standing Behavior of Dairy cows during the Transition Period. Journal of Dairy Science 88(7) 2454-2461.

IMS. 2010. Israel Meteorological Service (IMS). Agrometeorology. P.O.Box 25 Bet-Dagan, Israel.

Israel Cattle Breeders Association. 2009. The Dairy Industry in Israel 2009. Israel Cattle Breeders Association (ICBA). 38900 Caesaria Industrial Park, P.O.B. 3015, Israel.

Ingvartsen, K.L. 2006. Feeding- and management-related diseases in the transition cow. Physiological adaptations around calving and strategies to reduce feeding-related diseases. Animal Feed Science and Technology 126(3-4) 175-213.

Ito, K., von Keyserlingk, M.A.G. and Weary, D.M. 2010. Lying behavior as an indicator of lameness in dairy cows. Journal of Dairy Science 93(8) 3553-3560.

Juarez, S.T., Robinson, P.H., DePeters, E.J. and Price, E.O. 2003. Impact of lameness on behavior and productivity of lactating Holstein cows. Applied Animal Behaviour Science 83(1) 1-14.

Livshin, N., Antler, A., Zion, B., Stojanovski, G., Bunevski, G. and Maltz, E. 2005. Lying behaviour of dairy cows under different housing systems and physiological conditions. In: Precision Livestock Farming ,05: Proceedings of the 2nd European Conference on Precision Livestock Farming in Uppsala (Sweden), edited by Cox, S., Wageningen Academic Publishers, Wageningen, The Netherlands, pp 305-311.

Maltz, E., Kroll, O., Sagi, R., Devir, S., Spahr, S.L. and Genizi, A. 1991. Milk yield, parity and cow potential for computerized concentrates supplementation strategy. Journal of Dairy Science 74(7) 2277-2289.

Metz, J.H.M. 1985. The reaction of cows to short-term deprivation of lying. Applied Animal Behaviour Science 13(4) 30-307.

Munksgaard, L., Jensen, M.B., Pedersen, L.J., Hansen, S.W. and Matthews, L. 2005. Quantifying behavioural priorities – effects of time constraints on behaviour of dairy cows, *Bos taurus*. Applied Animal Behaviour Science 92(1-2) 3-14.

Munksgaard, L. and Simonsen, H.B. 1996. Behavioral and pituitary adrenal-axis responses of dairy cows to social isolation and deprivation of lying down. Journal of Animal Science 74(4) 769-778.

NRC. (2001). National Research Council (NRC). Nutrient Requirements of Dairy Cattle. 7th rev. Ed. National Academy Press, Washington, DC.

Overton, M.W., Sischo, W.M., Temple, G.D. and. Moore, D.A. 2002. Using Time-Lapse Video Photography to Assess Dairy Cattle Lying Behavior in a Free-Stall Barn. Journal of Dairy Science 85(9) 2407–2413.

Perera, K.S., Gwazdauskas, F.C., Pearson, R.E. and Brumback, T.B. 1986. Effect of Season and Stage of Lactation on Performance of Holsteins. Journal of Dairy Science 69(1) 228-236.

Tolkamp, B.J., Haskell, M.J., Langford, F.M., Roberts, D.J. and Morgan, C.A. 2010. Are cows more likely to lie down the longer they stand? Applied Animal Behaviour Science 124(1-2) 1-10.

Von Keyserlingk, M.A.G., Olenick, D. and Weary, D.M. 2008. Acute Behavioral Effects of Regrouping Dairy Cows. Journal of Dairy Science 91(3) 1011-1016.

Recognition of activity pattern in dairy production by electronic devices for early detection of disturbances in animal health

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Abstract

Early-detection of disturbances of animal health is a very important task for the farmers management and the veterinary advise. For the dairy sector many different sensors are available by several companies. In our investigation different pedometers were tested for normal pattern detection and early recognition of lamnesses. Also rumination sensors were tested for calf rearing and for dairy cows at the new research dairy „Frankenforst" of the University Bonn. Pattern detection sems to be a successful method for decision support considering individual variation and activity levels of specific animals.

Keywords: Health management, activity sensor, pedometer, rumination sensor

Introduction

Early-detection of disturbances of animal health is a very important task for the farmers management and also for the veterinary services. Fertility problems, mastitis and lamenesses are the main reason for animal losses in intensive german dairy production.

For the dairy sector many different sensors are available from several companies. The "animal activity" variable can be measured at different levels of information, which are available to some extent:

Activity expressed as the "locomotion" parameter:
- Recording of the number of steps using pedometers (collar and foot transponder);
- Recording of movement in pens over the course of a day using "video analyses",
- Digital image processing (particularly for small-scale ethological hypotheses),
- Recording of location, length of stay and change frequency of location using an electronic tracking device (e.g. by the system of ABATEC).

Activity expressed as the "feed consumption" parameter:
- Recording of the individual number of visits and the feed consumption by an automatic grain feeder,
- Recording of the individual number of visits and the feed consumption at a feeding trough for TMR.

Activity expressed as the "water consumption" parameter:
- Recording of the individual number of visits and of the water intake at a water trough.

Activity expressed as the "rumination activity" parameter:

- Recording of the number of rumination minutes per day by an acoustic rumination measurement system (called VocalTag); (BAR and SOLOMON, 2010).

In numerous investigations, it was shown that it is possible under constant management conditions to detect patterns of animal activity (LIVSHIN *et al.*, 2005). Under natural conditions, cows exhibit the highest feeding and movement activity in the morning and evening hour. They are subject to the light/dark changes of the daily periodicity (BRUNSCH and BREHME, 2002). For the detection of the activity pattern in the known documents, visual observations were partially performed which, however, were highly time consuming and can be evaluated as partly not objective. In the last 15 years, so-called pedometers have come more frequently into use as technical aids.

If an activity pattern could be recognised in the investigations, it was further possible to detect deviations from "normal behaviour" with the aid of the pedometer data. Up to the present, such deviation could be observed shortly before calving (MALTZ & ANTLER, 2007), during an oestrus and during sickness. For these situations, it is possible in most cases to determine a change in behaviour by means of sensors. For example the cows´ normal behaviour changed significantly within 24 hours prior to calving, resulting in an increase of daily steps and restlessness as well as a decrease in lying time (MALTZ and ANTLER, 2007). It has been seen that changes in cow's behaviour are strong indicators of their health and welfare problems (LIVSHIN *et al.*, 2005). The descriptions in the literature differ greatly from one another; however, almost all authors agree that a high predictive value for indication of oestrus can be achieved in this manner (TILLET *et al.*, 1997; FROST *et al.*, 1997; DOLUSCHITZ and SPILKE, 2002). This is shown in an investigation by WANGLER (2003) which indicates that only 5 % of all cows have no increase in activity on the day of their oestrus. Stress leads to reduced fertility by interfering with mechanisms controlling oestrous behaviour and reproductive function. It reduces intensity and duration of oestrous related behavioural activation and thus increases the risk for silent ovulations and missing inseminations (VON BORELL *et al.*, 2007).

The so-called ALT pedometers represent the newest generation of pedometers. In addition to recording the animals' activity, the resting times of the individual animal can be detected. With the ALT-Pedometer it is possible to record the environmental temperature, the lying time as well as the analogical recording of activity (BREHME *et al.*, 2008).

Cows adapt a very constant pattern of lying behaviour under a normal daily management routine (BRUNSCH and BREHME, 2002; LIVSHIN *et al.*, 2005). During the noontime, they take a longer rest period. Depending on the weather, feed supply, age and sex, cattle recline some 7-12 hours per day (BRUNSCH and BREHME, 2002). The individual differences in lying times are much smaller than those in activity levels. Although it is possible that the lying time is reduced in different housing systems, the cows maintain the same proportions of lying time between milkings (LIVSHIN *et al.*, 2005). Because the lying behaviour is often considered as an indicator of cow comfort, different housing systems can be compared by means of this parameter (LIVSHIN *et al.*, 2005).

Investigations of the authors working group

Material and methods

A new experimental dairy barn was established in 2008 at the research station Frankenforst. The new dairy stable has replaced the previous tie-stalls and to extend the herd size from 24 to 65 cows. The new free stall barn comprises a double-row cubicle house with an outward oriented feed table and a separate milking house. The exercise area in the shed has solid floors equipped with dung scrapers; in the feeding area, rubber mattings are provided. The weighing feeders allow for the precise quantification of feed intake. Together with the cow:feeder ratio of 2:1, the use of partial or total mixed rations (TMR) offers adequate feeding of all animals. Electronic controlled concentrate feeders guarantee for the individual performance-based feeding, in particular for high yields in the early lactation. For the water supply, four drinking bowls in which the individual intake is recorded are provided in the feeding area.

The milking house contains a grand scale collecting yard and a double-four in-line milking parlour in which cows are milked twice daily. In addition, the milking parlour comprises a central under level installation pit and two further pits adjacent to each milking line to allow for approaching the cows from two sides during experiments. In the outlet, a balance and a selection device for a stress-free separation of individual cows is provided. The selection area comprises six boxes littered with straw and equipped with safety feeding racks. The design of the cow barn allows to keep two groups entirely separated without any blind alleys. An electronic tracking system (ABATEC) was installed to observe individual dairy cows within the stable in order to monitor spatial and time related activities. For scientific analysis the data management system "KuhDaM" is used. Data transfer is organized automatically by internet in the night hours.

The actual herd size is 65 and comprises exclusively German Holstein Friesians. To extend the herd from the old tie-stall, pregnant or lactating heifers from external sources were bought in. Currently about 70% of the animals are in their first lactation; the entire herd thus comprises animals from their first up to fifth lactation.

A partial mixed ration is offered twice daily by means of a mobile mixer-feeder. The main feed components are silages from maize, grass and sugar beet pulp which are supplemented by soybean and rape seed meals and a mineral-vitamin premix.

The barn provides unique possibilities to monitor individual animals. An IS-PDF system (**I**nformation **S**ystem **P**recision **D**airy **F**arming) has been approved that comprises the following research equipment:

1. A local positioning system to observe individual dairy cows within the stable in order to monitor spatial and time related activities.
2. A recording system to quantify the amount and frequency of feed and water intake of individual dairy cows.
3. A research-oriented milking parlour to establish the individual milking parameters of cows and other physiological characteristics during the milking process.
4. The data management system "KuhDaM" for experimental purposes concerned with dairy cow husbandry and the compilation and processing of data related to individual animals.

These experimental facilities are meanwhile almost completely established. They provide an modern infrastructure for the dairy related projects.

Results

Different projects actually are running. First results can be shown. For recording of the biorhythms in an investigation of calves, 150 calves from two different farms were fitted with pedometers (BREER and BÜSCHER, 2006). It was thereby possible to recognise typical activity patterns within the groups of calves. Especially in the morning and evening hours, high levels of activity were observed. Obviously light radiation and management measures such as animal control and feed distribution have an influence on the biorhythms of the calves.

Furthermore, it was possible with the aid of the pedometer data to register a developing health disorder at least two days before it was recognised by the owner of the animal and to start the first treatment as a result. The success of the treatment could be confirmed in the following days by the increasing activity.

The authors are presently supporting a project which is investigating the recognition of lameness with the aid of technical parameters (ALSAAOD and BÜSCHER, 2009). Within the framework of this work, ALT pedometers were used for the recording of activity data and a locomotion scoring performed in parallel. Initially, it was determined that, with the aid of these pedometers, strong individual differences between the activities of the animals could be recorded. Therefore, it is important to evaluate this characteristic at the level of the individual animals. In the first results, the pedometer data showed a change in the activity behaviour before it could be visually confirmed. Figure 1 shows the pattern of reduced activity and of increased lying time over several days. On October 12th the individual lying time started to increase. Problems could first be visually detected on October, 17th.

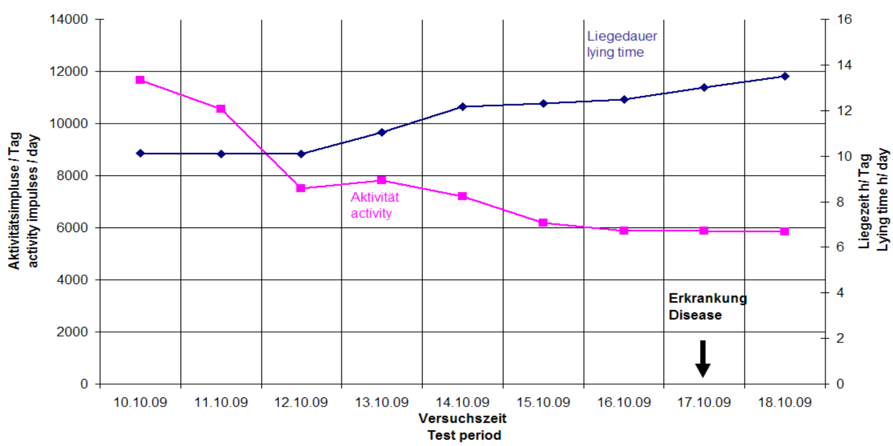

Figure 1. Mean number of activity impulses in i/day (ALSAAOD and BÜSCHER, 2009). The lameness was defined as scoring level change from 2 to 3

In two concluded bachelor theses, the application and evaluation of VocalTag rumination sensors are examined. Used for cows, the displayed rumination pattern at the time of the oestrus as well as for a change of feed are considered. The first results show an additional utilisation of these sensor values for the more exact recognition of oestrus.

In the second thesis, an experiment was conducted with two calves of a farm which were fitted with VocalTag sensors. The calves were provided daily with seven litres milk by means of an automatic feeder. The TMR of the dairy herd was made available ad libitum. The measurements began on the 23rd of February. At this point in time, the calves were four and six weeks old. On the 5th of March, the farmer began the changeover of the silage for the duration of a week from the second cutting to the third cutting which was clearly reflected in the rumination efforts of both calves (Fig. 2). The results of these bachelor theses are not published yet.

VocalTag-Sensors were also tested by 10 cows (Frankenforst dairy) over a whole winter period. A high individual variation of activity values for locomotion and rumination can be confirmed. For dairy cows it seems to be normal, that the main rumination activity can be measured in the late evening and early morning hours. Figure 3 shows that over the day locomotion activity is high while rumination activity is relatively low.

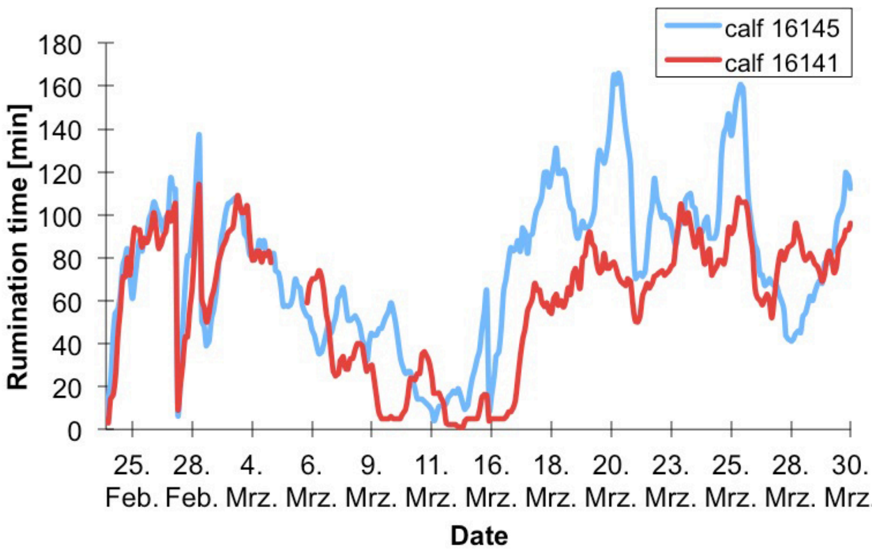

Figure 2. Rumination time of two calves during feed change, not published

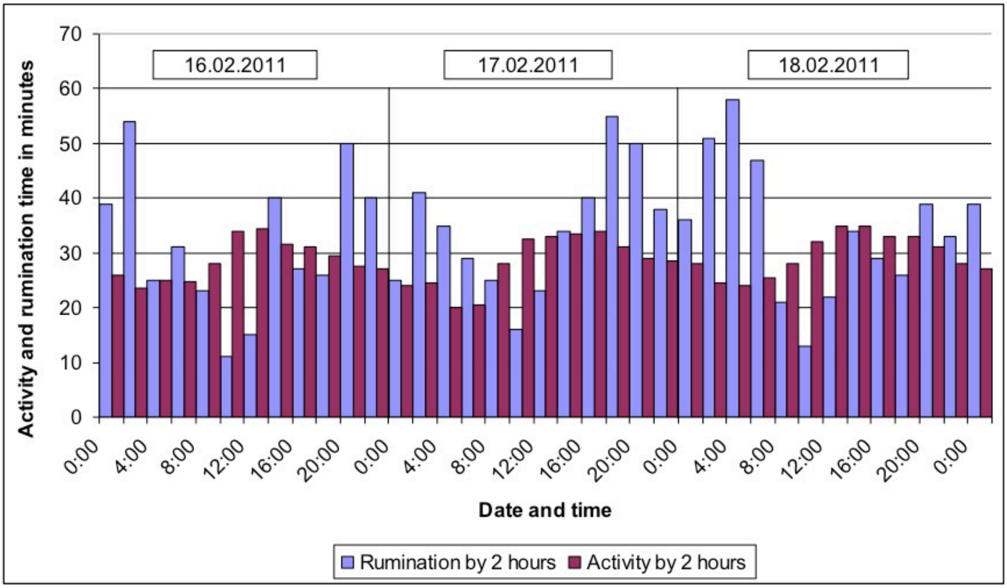

Figure 3. Typical daily pattern of rumination and locomotion activity of cow number 41 (Frankenforst dairy) observed with a VocalTag device.

Conclusion

The application of digital information technologies for monitoring animal activity parameters in dairy farm offers new possibilties for herds management and for the advising services. New sensors and variables have to be observed and analyzed for a long term perspective before they can be used for decision support on farm level. Pattern detection is a new method to consider individual variation and activity levels of a specific animal. Hardware and software compatibility is not given. New sensor applications demand also communication solutions between the companies and management software systems. Machine learning methods seem to be necessary for early detection of health disturbances as well as a good architecture of the collected database.

References

Alsaaod, M. & W. Büscher (2009b): Early lameness detection in dairy cows with electronic activity sensors. Landtechnik 64 (6):413-416.

Bar, D. & R. Solomon (2010): Rumination Collars: What Can They Tell Us. The first North American Conference on Precision Dairy Management, March 2010, Toronto, Canada.

Breer, D. & W. Büscher (2006): Calf Activity Measurement, Landtechnik, Volume 5:274-275.

Brehme, U., Stollberg, U., Holz, R. & Th. Schleusener (2008): ALT pedometer – New sensor-aided measurement system for improvement in oestrus detection. Computers and Electronics in Agriculture 62:73-80.

Brunsch, R. & U. Brehme (2002): Tiergerechte Ausrüstung und Kriterien für die Einschätzung des Wohlbefindens. Seite 32-41 im Tagungsband DGfZ Nr. 27, III. Brandenburger Nutztierforum „Tierkomfort“, 06. November 2002, Brandenburg, Germany.

Doluschitz, R. & J. Spilke (2002): Agrarinformatik, Verlag Eugen Ulmer GmbH, Stuttgart, ISBN 3-8252-2230-6.

Frost, A. R., Scholfied, C. P., Beaulah, S. A., Mottram, T. T., Lines J. A. & C. M. Wathes (1997): A review of livestock monitoring and the need for integrated systems. Computers and Electronics in Agriculture 17:139-159.

Livshin, N., Antler, A., Zion, B., Stojanovski, G., Bunevski, G. & E. Maltz (2005): Lying behaviour of dairy cows under different housing systems and physiological conditions. Page 305-311 in Proc. 2nd ECPLF, June 2005, Uppsala, Sweden.

Maltz, E. & A. Antler (2007): A practical way to detect approaching calving of the dairy cow by a behaviour sensor. Page 141-146 in Proc. 3 rd European Conference on Precision livestock farming. Skiathos, Greece. Edited by S. Cox, Academic Publishers.

Tillett, R. D., Onyango, C. M. & J. A. Marchant (1997): Using model-based image processing to track animal movements. Computers and Electronics in Agriculture 17:249-261.

Von Borell, E., Dobson, H. & A. Prunier (2007): Stress, behaviour and reproductive performance in female cattle and pigs. Horm. Behav. 52:130-138.

Wangler, A. (2003): Nutzung von Pedometern in der Brunsterkennung. Hrsg.: Landesforschungsanstalt für Landwirtschaft und Fischerei M-V.

Section 2
Behaviour/Feed Dairy

Number of calves per feed trough affects calves' feeding behavior and production

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Abstract

The needed 'feeding-space-for-animal' plays a role in (1) the farm design process, (2) managing decisions concerning seasonal animal inventory, (3) public perception - since space for animal is an animal welfare issue, (4) in a research station where individual feeding troughs are located on weighing scales – how many animals should be allocated to one feeding station without interfering production or behaviour ?. A common practice is the number of troughs is at-least number of animals. In some cases 20% higher. However the consequence of enlarging the 'feeding-space-for-animal (FSFA)' has not yet being scientifically fully explored.

Twelve Holstein-Friesian male calves were held in one single group. Six calves were allocated to one single feeding trough per 6 calves (so called the 6:1 treatment) while the other six calves were allocated 1 feeding trough per 1 calf (so called 1:1 treatment). Computer controlled TMR feeding system monitored every meal and pneumatic cylinders controlled the calves' access to the feed places.

The experiment lasted from June to October 2010, at the ARO's northern research station - Newe Yaar . The crossover experiment design included (a) prior to each monitoring period - 3-4 weeks adaptation to the feeding troughs allocation, and (b) crossover: after the first monitoring period the 1:1 calves switched to 6:1 treatment and vice versa. (c) 60970 meals and 17160 ruminate bouts were analysed by Matlab statistical toolbox.

The difference between individual animals, gain per intake ratio, reached 28%. Results suggest that social interaction and computation prolonged a meal time and encouraged the animals to consume more kg feed per a meal. As a consequence, the final kg was higher.

The conclusion is that simple, low-cost, manipulation in feeding behaviour can significantly increase production.

Keywords: dry matter intake (DMI), feed efficiency (FE), Total Mixed Ratio (TMR)

* Equal contribution

Introduction

A majority of research investigates how changes in feed composition impacts feed efficiency (FE) and dry matter intake (DMI).

However, FE and DMI of group-housed cattle is also affected by feeding behaviour, which is modulated by feed bunk management and social interactions.

Farmers can use feeding behaviour to improve FE, DMI, and farm profitability.

The impact of feed bunk management (e.g., space for an animal, bar or headlock design, frequency of fresh feed delivery, and social competition for food and group composition) on the feeding behaviour of group-housed cattle will be discussed below:

Cattle housed indoors typically have 9 to 14 feeding sessions, or meals, over the course of the day (Dado and Allen, 1994; Tolkamp *et al.*, 2000; Fregonesi and Leaver, 2001; Grant and Albright, 2001; Phillips and Rind, 2001a; DeVries *et al.*, 2003b). A dramatic increase in feed alley activity occurred immediately following delivery of fresh feed. Daily feeding patterns of group-housed dairy cows is largely influenced by timing of fresh feed delivery, rather than the times of sunrise and sunset, or return from the milking parlor (DeVries and von Keyserlingk, 2005).

The cows have a tendency to synchronize their behaviour, especially when fresh feed is delivered, impacts the number of cows attempting to eat at the same time. Accessibility of feed may be more important than actual amounts of nutrients provided (Grant and Albright, 2001).

Initial research suggested that overcrowding at the feed bunk did not reduce eating time (Collis *et al.*, 1980; Friend *et al.*, 1977; Wierenga and Hopster, 1990). Later research has reported that increasing feeding space increases feeding activity (DeVries *et al.*, 2004) and overcrowding feedbank reduced feeding times (Batchelder, 2000; Huzzey *et al.*, 2006).

24 inches of bunk space per cow has traditionally been regarded as adequate (Grant and Albright, 2001), total daily feeding time has increased when feed bunk space increased from 25 to 36 inches/cow (DeVries and von Keyserlingk, 2006).

In conclusion, the mentioned above studies report that (1) ***feeding behaviour*** is an important economic factor for livestock enterprise since - feed intake, health, welfare, performance, and farm profitability are all influenced by ***feeding behavior***. (2) ***Feeding behavior*** of group-housed cattle can be influenced by feed space for an animal and physical separation between neighbouring animals.

The mentioned above studies did not dramatically increase the number of calves per feed trough in order to affect calves' feeding behaviour, and did not provide physical separation between neighbouring animals.

The hypothesis of the current study is that in a computational environment (6:1), a calf that will eventually obtain a feed trough will eat less frequent meals but larger meals. This manipulated behaviour may increase production.

This hypothesis was tested by means of:

(1) Building a monitoring facility that can measure automatically (a) each meal – time and eaten amount, (b) body weight via a frequent visited walk-through scale, (c) ruminating time and activity of the each individual animal kept in a group.
(2) Six calves were allocated to one single feeding trough (6:1 treatment) while the other five were allocated free access to five feeding troughs (1:1 treatment).
(3) Cross-over design. The calves were switched treatments during the experiment.
(4) Computer controlled TMR feeding system monitored every meal and pneumatic cylinders controlled the calves' access to the each feed trough.

Materials and methods

<u>Treatments and animals</u>

Twelve Holstein-Friesian male calves were held in a single pen. Six calves were allocated one single feeding trough ('*6:1 treatment*') while the other five calves were allocated to 5 feeding troughs i.e. one feeding trough available per each calf ('*1:1 treatment*').

The experiment lasted from June to October 2010.

The calves initially were 5 months old.

The experiment design included:

(a) 3-4 weeks for familiarization prior to each monitoring period, and
(b) crossover: after the first monitoring period the *1:1* and the *6:1* calves switched treatments.
(c) The location of the feeding trough that was allocated to the many calves (*6:1*) was placed in centre of the feeding lane (Fig).

Double-blinded randomised experiment design. The farm workers could not know which calf belongs to which treatment. There was no any visible sign, attached, to the animals. The different treatments could be distinguished only in the management computer accessible only to the principle researcher (PR, I.Halachmi) and, on the PR absence, to the farm manager. Therefore, it can be said that the calves received exactly the same handling from the farm workers, and therefore double-blinded randomised, can be said, was incorporated into the experiment design.

Two calves did not finish the experiment. One was bitten by a poisonous snake and the second calf got pneumonia. Luckily, they were one calf from each treatment and both incidents happened at the same week. One ill calf per a group is our regular mortality rate. The 11 animals is the number of the animals that finished the experiment (originally 13 animals).

A regular TMR feed (Metabolic energy (ME)=2.7, crude protein (cp)=0.13, DM=0.75) was delivered once per day at 07:00 by a tractor driven mixer wagon.

Monitoring facility and housing,

The monitoring facility was built at the ARO's northern research station - Newe Yaar, Valley of Jezreel, Israel.
The system design adopted an older version of that system that is developed by the ARO in the ARO main campus in Bet Dagan, system specifications were reported by Halachmi *et al.*(1998).
The computer controlled TMR feeding system monitored every meal and pneumatic cylinders controlled the calves' access to the feed places.
The system can be seen in figure 1. The system was located in an old open cowshed. One-way gates directed the calve traffic from the feeding lane via the walk-through scale (SCR Engineering Ltd) so body weight (BW) was monitored few times per day.
The floor is the original clay soil that gradually covered with dry manure. The total yard area was 40 m^2 per animal from which about third is covered by 5 meter high roof.

Figure 1. The monitoring system. The feeding troughs were placed on weighing scales. A larger feeding trough (1) was located at the centre of the feeding lane, aiming at the 6:1 calf treatment. Six regular feeding troughs (2) were located along the feeding lane aiming at the 1:1 treatment. Pneumatic cylinder controlled the calves access by moving the horizontal bar (3) slowly and gently upward or downward so only a calf x can eat in trough number y, where x and y are defined in the computer. IR identification system (SCR engineering Ltd) were located above the calves. The collar includes activity and ruminating sensors (SCR engineering Ltd).

There was 1.5 meter space between two couples of feed troughs.

There was physical separation – metal sheets - between the calves, in the yard along the calves. Therefore, after a calf had entered a stall, he is relatively protected from his comrades. Calf displacement was unlikely.

Statistics

60970 meals, 17160 ruminate bouts and 9470 body weights (walk-trough scale passages) were analysed by Matlab statistical toolbox. (Coleman *et al.*, 1999). Matlab performs Hypothesis tests by TTEST function. Where the desired significance level ALPHA=0.05, TAIL=0, Unpaired t-test.

GLM was performed by using SPSS. The fixed factor was 'treatment', the covariates were the period (before or after the cross over) and initial BW. The independent variable was: BW gain. The potential explanatory variables were:, average meal length in minutes, variance of the meal length in minutes, kg of feed eaten per a meal, daily feed intake (kg/day), number of meals per day.

Results.

The covariate, *cross over*, was not significantly related to the BW gain, $F(1,11)=0.261$, $p=0.625$. The covariate, *initial bw*, was not significantly related to the BW gain, $F(1,11)=4.509$, $p=0.071$. After controlling the effect of *cross over* and *initial bw*, the effect of treatment on *BW gain* was significant [$F(3,11)=4.917$, $p=0.038$]. The effect of treatment on final BW was significant [$F(3,11)=54.42$, $p=0.00$]. The effect of treatment on kg intake per a single meal was significant [$F(3,11)=9.2$, $p=0.01$], The effect of treatment on kg intake per a single meal was significant [$F(3,11)=7.65$, $p=0.01$]. The other numeric results are presented in table 1.

Table 1. The effect of altering feed space on feeding behaviour and production.

	treatments	Mean	Std. Deviation	F(3,11)	Sig.
BW Gain	1:1	1.36	0.28	4.92	0.04
	6:1	1.55	0.24		
Final BW	1:1	482	46.30	54.42	0.00
	6:1	532	21.40		
Minutes per meal. Ave	1:1	6.84	2.00	0.89	0.49
	6:1	8.48	1.07		
Minutes per meal. Std	1:1	2.32	1.07	1.25	0.36
	6:1	3.10	0.54		
Minutes per meal. Max	1:1	12.76	3.85	3.51	0.08
	6:1	18.02	1.34		
Kg per meal. Ave	1:1	1.00	0.27	9.22	0.01

	6:1	1.35	0.35		
Kg per meal.std	1:1	0.36	0.21	2.26	0.17
	6:1	0.48	0.17		
Kg per meal.max	1:1	1.90	0.62	7.65	0.01
	6:1	2.58	0.56		
Daily food intake. Ave	1:1	10.97	2.17	6.31	0.02
	6:1	14.06	4.76		
Daily food intake. Std	1:1	3.41	0.47	51.64	0.00
	6:1	5.59	1.81		
Daily food intake. Max	1:1	17.55	2.30	29.47	0.00
	6:1	26.77	7.08		
No. of meals. Ave	1:1	10.92	5.35	2.88	0.11
	6:1	10.45	6.19		
No. of meals. Std	1:1	3.86	0.65	40.69	0.00
	6:1	5.12	2.38		
No. of meals. Max	1:1	20.00	5.83	4.92	0.04
	6:1	23.50	9.69		
Ruminating time. Ave	1:1	42.00	5.34	3.06	0.10
	6:1	42.33	3.27		
Ruminating time. Std	1:1	13.00	2.65	11.76	0.00
	6:1	7.17	4.75		
Ruminating time. Max	1:1	75.00	10.08	5.14	0.03
	6:1	61.83	13.39		

Discussion

Why the *6:1 calves* produced more BW?

(1) Perhaps larger meals (and less frequent) make the calves to earn more BW.

(2) Cows frequently sort TMR components throughout the day (Bal *et al.*, 2000; Kononoff *et al.*, 2003; DeVries *et al.*, 2005; Leonardi *et al.*, 2005). Therefore, cows forced to delay feeding due to overcrowding may consume unsorted diet. In addtion, when cows cannot eat when they desire, they may over-eat at the next meal (Shaver, 1997, 2002; Cook *et al.*, 2004). The improved production maybe related to (1) the unsorted diet and (2) over eating when there is an available feeding position.

In the literature, maximum utilization of the feed bunk (all feeding positions simultaneously occupied) may be rarely observed (e.g., Mentink and Cook, 2006). The distance between neighbours while feeding is influenced by social rank (Manson and Appleby, 1990).

In our facility in Newe Yaar there is 1.5 meter space between two couples of feed troughs. In addition to the physical separation it results that after fresh feed delivered – all the feeding position were occupied.

Increased aggression in the feeding area with overcrowding has been noted by a number of researchers (Olofsson, 1999; DeVries *et al.*, 2004; DeVries and von Keyserlingk, 2006; Huzzey *et al.*, 2006). Aggression could have consequences for hoof lesion development and lameness and severe claw-horn lesion scores than cows that did not engage in such encounters (Leonard *et al.*, 1998). Shaver (2002).

In our research, the calves were walking on soft floor, soil or dry manure, open cowshed with almost no concrete. Aggressive displacement is prevented by the physical separation between the feeding stalls.

Reduced access to feed will have differing impacts on individual cows within a group. High ranking cows may eat more, while low ranking cows may delay eating (Olofsson, 1999; Wierenga and Hopster, 1990). Cows of lower social status experienced the greatest decreases in number of feed bunk displacements per day (DeVries and von Keyserlingk, 2006). Huzzey *et al.* (2006) found cows ranked lower in the social hierarchy at the feed bunk were displaced more often when feeding. Huzzey *et al.* (2006) reports that Headlocks may provide some protection against competitive interactions at the feed bunk by offering physical separation between adjacent cows.

In our research, a feed bunk displacement is unlikely due to the construction of physical separations between neighbouring feeding positions.

Conclusions.

Monitoring system was designed and implemented, the system measured cow individual's meals, body weight, ruminating time and cow individual activity.

Feed bank management (allocating six calves per one feed trough) was tested. The effected feeding behaviour:

- More kg per meal. Ave 1.35 vs. 1.00 kg/meal
- Higher Daily food intake. Ave 14.06 vs. 10.97
- Higher variability in No. of meals per day std = 5.12 vs. 3.86 meals per day
- Less variability in ruminating time std = 7.17 vs. 13.00 min./day
- Less maximum of ruminating time/day std = 75.00 vs. 61.83 min./day

The effected performances:

- Higher BW Gain 1.55 vs 1.36 kg/day
- Higher Final BW 532 vs. 482 kg

The onus is now on the industry to implement the above, but before the findings can be taken into consideration in relation to: (1) farm design, (2) managing short-time seasonal animal inventory, (3) public perception concerning space-for-animal, (4) research stations - how many calves can be allocated to a given monitoring system; further experiments are advised: (a) during longer period (no crossover during the growing period), (b) with other breeds than Holstein- Friesian; (c) older, lactating cows, (e) more animals.

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References

Bal, M.A., R.D. Shaver, A.G. Jirovec, K.J. Shinners, and J.G. Coors. 2000. Crop processing and chop length of corn silage: Effects on intake, digestion, and milk production by dairy cows. J. Dairy Sci. 83: 1264-1273.

Batchelder, T.L. 2000. The impact of head gates and overcrowding on production and behavior patterns of lactating dairy cows. In: Proceedings from the Conference 'Dairy Housing and Equipment Systems: Managing and Planning for Profitability', Camp Hill, Pennsylvania, pp 325-330.

Bolinger, D.J., J.L. Albright, J. Morrow-Tesch, S.J. Kenyon, and M.D. Cunningham. 1997. The effects of restraint using self-locking stanchions on dairy cows in relation to behavior, feed intake, physiological parameters, health, and milk yield. J. Dairy Sci. 80: 2411-2417.

Collis, K.A., M.J. Vagg, P.T. Gleed, C.M. Copp, and B.F. Sansom. 1980. The effects of reducing manger space on dairy cow behaviour and production. Vet. Rec. 107: 197-198.

Cook, N.B. 2003. Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. J. Am. Vet. Med. Assoc. 223: 1324-1328.

Cook, N.B., K.V. Nordlund, and G.R. Oetzel. 2004. Environmental influences on claw horn lesions associated with laminitis and subacute ruminal acidosis in dairy cows. J. Dairy Sci. 87(E. Suppl.): E36-E46.

Cooper, M.D., D.R. Arney, and C.J.C. Phillips. 2007. Two- or four-hour lying deprivation on the behavior of lactating dairy cows. J. Dairy Sci. 90: 1149-1158.

Dado, R.G., and M.S. Allen. 1994. Variation in and relationships among feeding, chewing, and drinking variables for lactating dairy cows. J. Dairy Sci. 77: 132-144.

DeVries, T.J., and M.A.G. von Keyserlingk. 2005. Time of feed delivery affects the feeding and lying patterns of dairy cows. J. Dairy Sci. 88: 625-631.

DeVries, T.J., and M.A.G. von Keyserlingk. 2006. Feed stalls affect the social and feeding behavior of lactating dairy cows. J. Dairy Sci. 89: 3522-3531.

DeVries, T.J., M.A.G. von Keyserlingk, and K.A. Beauchemin. 2003a. Short Communication: Diurnal feeding pattern of lactating dairy cows. J. Dairy Sci. 56: 4079-4082.

DeVries, T.J., M.A.G. von Keyserlingk, and K.A. Beauchemin. 2005. Frequency of feed delivery affects the behavior of lactating dairy cows. J. Dairy Sci. 88: 3553-3562.

DeVries, T.J., M.A.G. von Keyserlingk, and D.M. Weary. 2004. Effect of feeding space on the inter-cow distance, aggression, and feeding behavior of free-stall housed lactating dairy cows. J. Dairy Sci. 87: 1432-1438.

DeVries, T.J., M.A.G. von Keyserlingk, D.M. Weary, and K.A. Beauchemin. 2003b. Measuring the feeding behavior of lactating dairy cows in early to peak lactation. J. Dairy Sci. 86: 3354-3361.

Endres, M.I., T.J. DeVries, M.A.G. von Keyserlingk, and D.M. Weary. 2005. Short Communication: Effect of feed barrier design on the behavior of loose-housed lactating dairy cows. J. Dairy Sci. 88: 2377-2380.

Fregonesi, J.A., and J.D. Leaver. 2001. Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems. Livest. Prod. Sci. 68: 205-216.

Fregonesi, J.A., C.B. Tucker, D.M. Weary, F.C. Flower, and T. Vittie. 2004. Effect of rubber flooring in front of the feed bunk on the time budgets of dairy cattle. J. Dairy Sci. 87: 1203-1207.

French, N., and J.J. Kennelly. 1990. Effects of feeding frequency on ruminal parameters, plasma insulin, milk yield, and milk composition in Holstein cows. J. Dairy Sci. 73: 1857-1863.

Friend, T.H., C.E. Polan, and M.L. McGilliard. 1977. Free stall and feed bunk requirements relative to behavior, production and individual feed intake in dairy cows. J. Dairy Sci. 60: 108-116.

Grant, R.J., and J.L. Albright. 2001. Effect of animal grouping on feeding behavior and intake of dairy cattle. J. Dairy Sci. 84(E. Suppl.): E156-E163.

Halachmi I; Edan Y; Maltz E; Peiper U M; Brukental I; Moalem U (1998) A real-time control system for individual dairy cow food intake. Computers and Electronics in Agriculture 20: 131-144

Huzzey, J.M., T.J. DeVries, P. Valois, and M.A.G. von Keyserlingk. 2006. Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle. J. DairySci. 89: 126-133.

Kononoff, P.J., A.J. Heinrichs, and H.A. Lehman. 2003. The effect of corn silage particle size on eating behavior, chewing activities, and rumen fermentation in lactating dairy cows. J. Dairy Sci. 86: 3343-3353.

Krohn, C.C., and S.P. Konggaard. 1979. Effects of isolating first-lactation cows from older cows. Livest. Prod. Sci. 6: 137-146.

Leonardi, C., F. Giannico, and L.E. Armentano. 2005. Effect of water addition on selective consumption (sorting) of dry diets by dairy cattle. J. Dairy Sci. 88: 1043-1049.

Manson, F.J., and M.C. Appleby. 1990. Spacing of dairy cows at a food trough. Appl. Anim. Behav. Sci. 26: 69-81.

Mäntysaari, P., H. Khalili, and J. Sariola. 2006. Effect of feeding frequency of a total mixed ration on the performance of high-yielding dairy cows. J. Dairy Sci. 89: 4312-4320.

Mentink, R.L., and N.B. Cook. 2006. Short Communication: Feed bunk utilization in dairy cows housed in pens with either two or three rows of free stalls. J. Dairy Sci. 89: 134-138.

Metz, J.H.M. 1984. The reaction of cows to a short-term deprivation of lying. Appl. Anim. Behav. Sci. 13: 301-307.

Nocek, J.E., and D.G. Braund. 1985. Effect of feeding frequency on diurnal dry matter and water consumption, liquid dilution rate, and milk yield in first lactation. J. Dairy Sci. 68: 2238-2247.

Olofsson, J. 1999. Competition for total mixed diets fed for ad libitum intake using one or four cows per feeding station. J. Dairy Sci. 82: 69-79.

Phillips, C.J.C., and J.D. Leaver. 1986. The effect of forage supplementation on the behaviour of grazing dairy cows. Appl. Anim. Behav. Sci. 16: 233-247.

Phillips, C.J.C., and M.I. Rind. 2001a. The effects of frequency of feeding a total mixed ration on the production and behavior of dairy cows. J. Dairy Sci. 84: 1979-1987.

Phillips, C.J.C., and M.I. Rind. 2001b. The effects on production and behavior of mixing uniparous and multiparous cows. J. Dairy Sci. 84: 2424-2429.

Shabi, Z., I. Bruckental, S. Zamwell, H. Tagari, and A. Arieli. 1999. Effects of extrusion of grain and feeding frequency on rumen fermentation, nutrient digestibility, and milk yield and composition in dairy cows. J. Dairy Sci. 82: 1252-1260.

Shabi, Z., M.R. Murphy, and U. Moallem. 2005. Within-day feeding behavior of lactating dairy cowsmeasured using a real-time control system. J. Dairy Sci. 88: 1848-1854.
Shaver, R.D. 1997. Nutritional risk factors in the etiology of left displaced abomasum in dairy cows: A review. J. Dairy Sci. 80: 2449-2453.
Shaver, R.D. 2002. Rumen acidosis in dairy cattle: Bunk management considerations. In: Proceedings of the 12th International Symposium on Lameness in Ruminants, Orlando, Florida, pp 75-81.
Singh, S.S., W.R. Ward, K. Lautenbach, J.W. Hughes, and R.D. Murray. 1993. Behaviour of first lactation and adult dairy cows while housed and at pasture and its relationship with sole lesions. Vet. Rec. 133: 469-474.
Somers, J.G.C.J., K. Frankena, E.N. Noordhuizen-Stassen, and J.H.M. Metz. 2003. Prevalence of claw disorders in Dutch dairy cows exposed to several floor systems. J. Dairy Sci. 86: 2082-2093.
Tolkamp, B.J., D.P.N. Schweitzer, and I. Kyriazakis. 2000. The biologically relevant unit for the analysis of short-term feeding behavior of dairy cows. J. Dairy Sci. 83: 2057-2068.
Tucker, C.B., D.M. Weary, A.M. de Passille, B. Campbell, and J. Rushen. 2006. Flooring in front of the feed bunk affects feeding behavior and use of freestalls by dairy cows. J. Dairy Sci. 89: 2065-2071.
Tyler, J.W., L.K. Fox, S.M. Parish, J. Swain, D.L. Johnson, H.A. Grasseschi, and R. Gant. 1997. Effect of feed availability on post-milking standing time in dairy cows. J. Dairy Res. 64: 617-620.
Vanegas, J., M. Overton, S.L. Berry, and W.M. Sischo. 2006. Effect of rubber flooring on claw health in lactating dairy cows housed in free-stall barns. J. Dairy Sci. 89: 4251-4258.
Vokey, F.J., C.L. Guard, H.N. Erb, and D.M. Galton. 2001. Effects of alley and stall surfaces on indices of claw and leg health in dairy cattle housed in a free-stall barn. J. Dairy Sci. 84: 2686-2699.
Wierenga, H.K., and H. Hopster. 1990. The significance of cubicles for the behaviour of dairy cows. Appl. Anim. Behav. Sci. 26: 309-337.

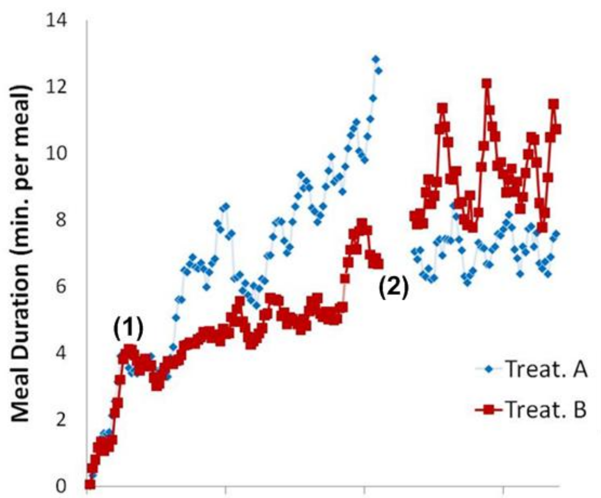

Figure 2. Meal duration during the experiment. At point (1) the troughs were allocated to individual calves in the computer. Treat A, dot-points, the calves that initially exposed to 6:1 and then, after 3-weeks familiarization (the missing data at point (2)) were allocated to 1:1 treatment. Treat B, square-points, the calves that initially exposed to 1:1 and then, after the familiarization time (the missing data) were shift to 6:1 treatment.

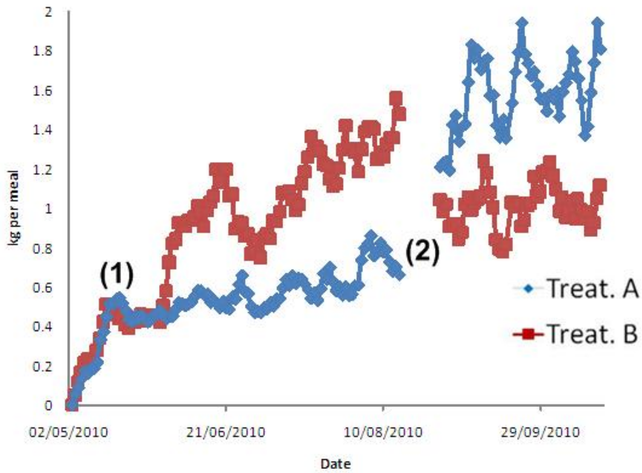

Figure 3. Meal size, kg per meal during the experiment. At point (1) the troughs were allocated to individual calves in the computer. Treat A, dot-points, the calves that initially exposed to 6:1 and then, after 3-weeks familiarization (point (2)) were allocated to 1:1 treatment. Treat B, square-points, the calves that initially exposed to 1:1 and then, after the familiarization time (point 2) were shift to 6:1 treatment.

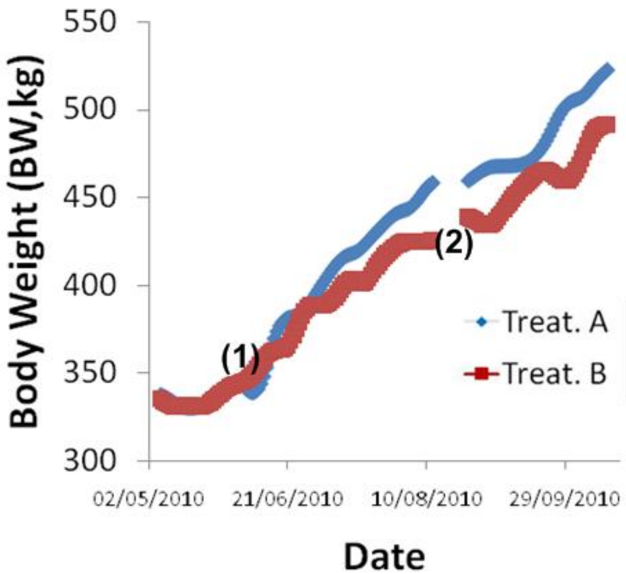

Figure 4. Body weight (BW) during the experiment. At point (1) the troughs were allocated to individual calves in the computer. Treat A, dot-points, is the calves that initially exposed to 6:1 and then, after 3-weeks familiarization (point (2)) were allocated to 1:1 treatment. Treat B, square-points, the calves that initially exposed to 1:1 and then, after the familiarization time (point 2) were shift to 6:1 treatment.

Automated behaviour monitoring in dairy cows

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Abstract

Acceleration sensors in a Wireless Sensor Network (WSN) were used to monitor the behaviour of dairy cows. The data processing from 3D acceleration into behaviour classification (lying, standing or walking) was based on a two-steps method: first the distinction between lying and standing/walking was based on the computed average values during standing and the calculated distance from the actual values and the standing average. Secondly the distinction between standing and walking was based on the variance in 10 successive measurements. With this method both on-node data processing and state-based triggering are possible. This classification was tested during one day with three cows were video recordings were available as reference data. The calculated behaviour corresponds highly with the observed behaviour, the distinction between lying and standing/walking is the same during 99.15% of the time. 99.5% Of the observed walking periods have a matching calculated walking period (if measurements are available).

Keywords: Wireless Sensor Networks, classification, dairy cows.

Introduction

Monitoring the behaviour of dairy cows is of importance for different purposes. Changes in daily activity are useful indicators of pain associated with lameness as lame cows are less active (O'Callaghan *et al*., 2003). Behaviour characteristics as total lying time and lying synchrony are possible indicators for the assessment of dairy cows welfare (Fregonesi & Leaver, 2001). Occurrences of a disease can influence the behaviour (Fourichon *et al*., 2000). Behaviour monitoring can also be important to meet quality requirements, e.g. to proof that milk originates from cows in pasture.

Behaviour monitoring may be done by visual observations but this method is not practical within the available time of the herdsman and the increasing herd sizes. The application of accelerometers in Wireless Sensor Networks (WSNs) makes it possible to automate the monitoring of behaviour. Behaviour is classified as lying, standing or walking. Nodes attached to legs of a cow can measure the acceleration and send the data to a base station (possibly via other cows). Important aspects for an efficient use of WSNs are:

- on-node data processing: it is more efficient to process data on the node and transmit only the aggregated data in the network as the data transfer in the network is most energy-consuming task;
- state-based triggering: process data only when this is relevant, e.g. reduce the measuring frequency when a cow is lying, as the energy use can be lowered when the frequency and contents of the data processing tasks depend on the current state.

The objective of this paper is to describe a method for behaviour classification in dairy cows that is suitable for on-node data processing and for state-based triggering in a WSN, and to describe the test results.
These results originate from the WASP project ('Wirelessly Accessible Sensor Populations', www.wasp-project.org), where possible applications of WSNs have been investigated. One of the two chosen scenarios in the WASP project was: 'Detection of health problems with focus on claw health and locomotion' (De Mol *et al.*, 2007, Lokhorst *et al.*, 2008).

Material and methods

The acceleration data were collected at the experimental farm "Waiboerhoeve" of Wageningen UR in Lelystad (The Netherlands). A part of the cubicles stall was fenced off and three Holstein-Friesian cows were kept in that part during one day (Figure 1). Each cow was equipped with two nodes: one at the right hind leg and one at the left hind leg (Table 1). The acceleration was measured with 50 Hz in three dimensions: X, Y and Z. Ten successive acceleration measurements comprise one message. The nodes could transmit their messages to four static nodes and one base node in an observation room on the first floor of the stable building. Video data were recorded with three cameras (with fixed position). The video recordings were analysed with dedicated software (Noldus Observer, www.noldus.com) to record the true behaviour of the cows. The observed behaviour was compared with the calculated behaviour based on the acceleration data.

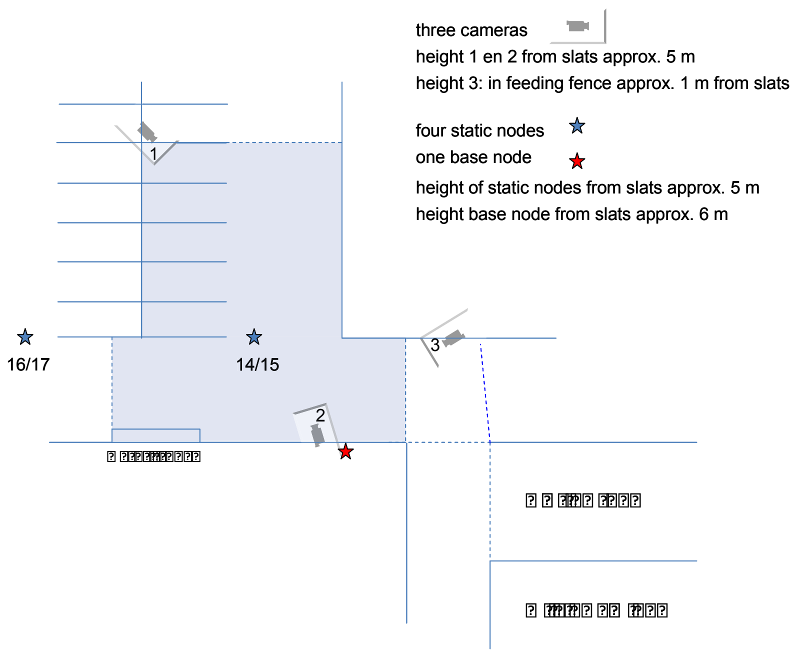

Figure 1. Overview of the situation in the barn during the experimental period.

Table 1. Cows and nodes involved in the experiment.

Nr	Cow ID	Characteristics	Node at left hind leg	Node at right hind leg
1	3246	Spotted cow marked with a X	105	106
3	3272	Black cow marked with a I	101	102
4	3830	Spotted cow marked with a O	103	104

The measured acceleration is used to calculate the behaviour, classified as lying, standing or walking. This is done with a two-steps method:

First a distinction is made between lying and standing/walking. Therefore the accelerometers were used as tilt sensors. If the cow is not accelerating, the only influence is the gravity. This influence will be zero when the sensor is perpendicular to the gravity; a changing value reflects the turning of the sensor in the gravity field. It is possible to calculate the angle when the acceleration sensors are calibrated (as in de Mol *et al.*, 2009a), but here a method is used that does not rely on calibration. The acceleration sensor has limited freedom when the cow is standing (or walking). The range of measurements is small when the leg is vertical. The sensor has a wider range when the cow is lying as the leg can point in any direction then. It is assumed that the variance of the acceleration values is small during standing and the actual values are close to the average values. For any measurement a distinction can then be made between lying and standing by calculating the Euclidian distance with the average values. The behaviour is classified as standing/walking when the distance is below a threshold; the behaviour is lying when the distance is above a threshold. The value of this lying/standing threshold depends on the measurement units and has to be set in practical circumstances.

Secondly, when a cow is standing/walking the distinction between standing and walking is based on the fact that the sensor hardly moves during standing. The behaviour is classified as walking when the variance of ten successive measurements in one or more dimensions is above a threshold and the behaviour is classified as standing otherwise. The value of the standing/walking threshold also has to be chosen.

Results

<u>Observed behaviour</u>

Observations were done on 20 May 2010, starting at 9.00 hr in the morning and ended around 16.00 hr after milking. A still of the video is shown in Figure 2.

Figure 2. Still of the video recording from Camera 1 at 9:01 hr: the three cows in the right part of the boxes are object of research: Cow 3272 is lying, Cow 3246 is standing in a cubicle and Cow 3820 is standing at the feeding fence.

The results of the analysis of the video recordings from 10:00 hr till 11:00 hr with the Noldus Observer software are depicted in Figure 3.

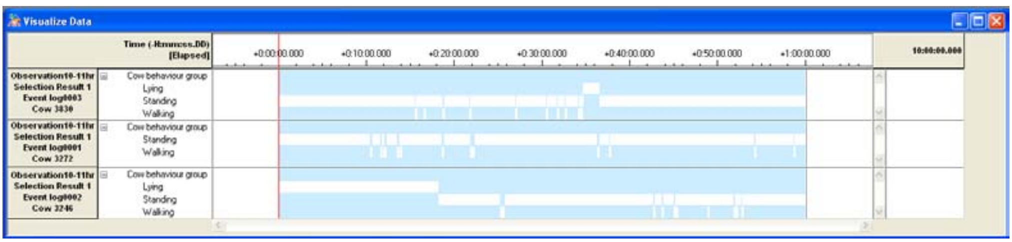

Figure 3. Visualization of the analysis of the video recordings between 10:00 and 11:00 hr of Cow 3830 (upper), 3272 (middle) and 2346 (lower); for each cow the white middle bar represents standing, the higher bar represents lying and the lower outliers represent walking.

<u>Calculated behaviour: lying and standing/walking</u>

The measurements of six nodes have been used to calculate the behaviour of the cows (Table 1). Acceleration was measured with a frequency of 50 Hz, the average value per second was used to calculate the behaviour. As an example the measured values in two dimensions of Node 103 are given in Figure 4. Node 106 stopped functioning after 10:10 hr. The system crashed around 13:15 hr, therefore there is a break in the measurements around that time.

The average value of the acceleration when the cow was observed standing was calculated for each node. For example right lower graph in Figure 4 shows the measured acceleration per second of Node 103 during standing, the average values during standing for the X, Y and Z values were 1818, 2199 and 2468 respectively.

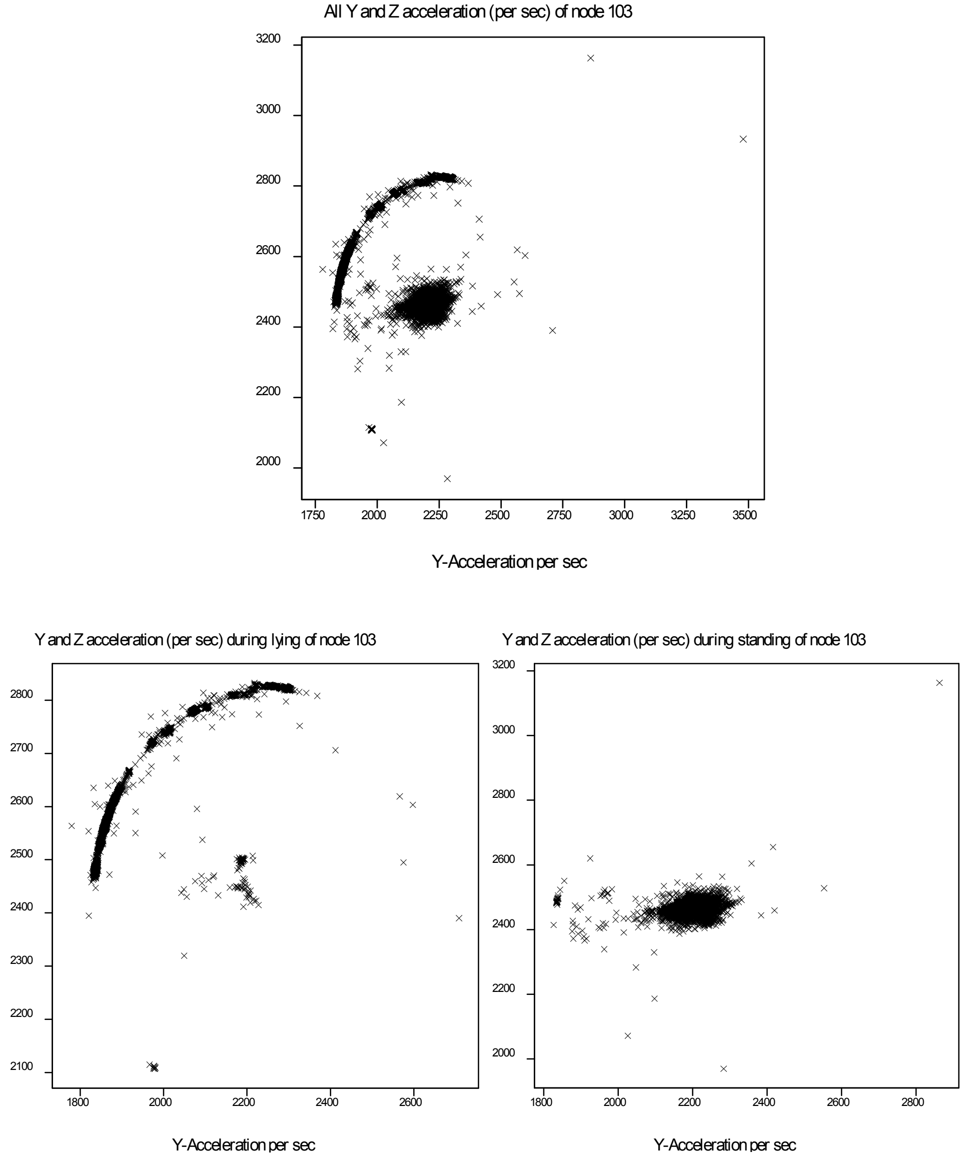

Figure 4. All measured acceleration values for the Y and Z dimension of Node 103 (upper graph); divided into measurements during lying (lower left graph) and during standing/walking (lower right graph).

The calculated behaviour is standing when the Euclidian distance with the average during standing is less than a threshold, otherwise lying. The value of this threshold that has been applied in this research is 300 (for all nodes).

Comparison of calculated and observed behaviour: lying and standing/walking

There is a great similarity between the observed and calculated behaviour, as can be seen in Figure 5, 6 and 7. Some small deviations occur when:

- there are outliers in the calculated behaviour where the behaviour is deviating during 1 second; these outliers could be filtered out easily;

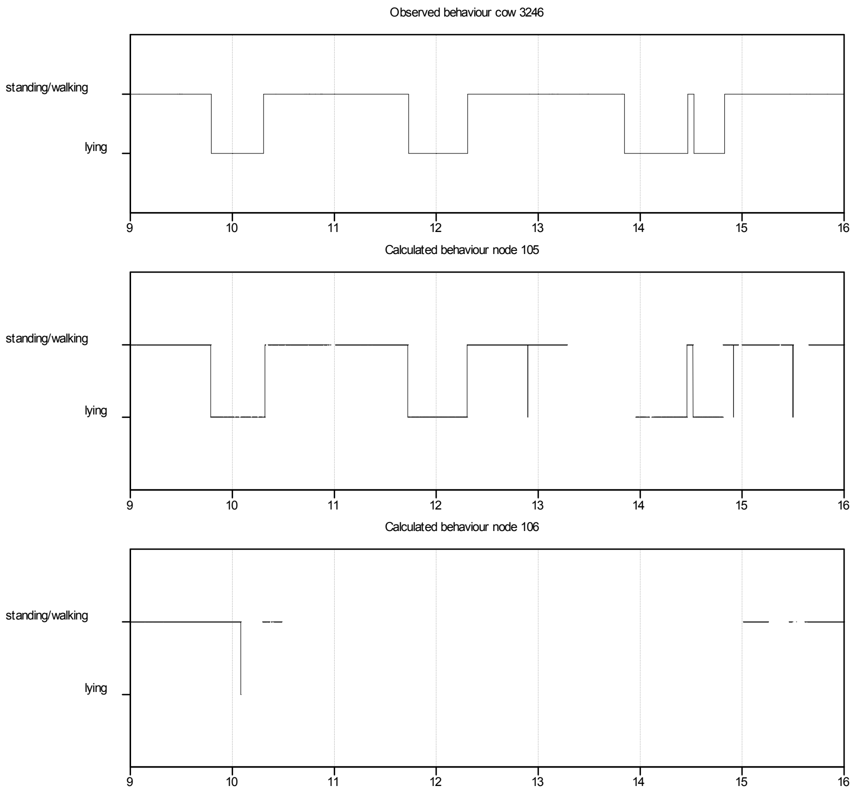

Figure 5. Comparison of observed behaviour of Cow 3246 (upper graph), calculated behaviour of Node 105 attached to the left hind leg of Cow 3246 (middle graph) and calculated behaviour of Node 106 attached to the right hind leg of Cow 3246 (lower graph).

- there are deviations around the moment of behaviour change, the observed moment of change is a few seconds earlier or later than the calculated moment;
- there are no accelerations measurements available on the moment of behaviour change (e.g. Cow 3830 around 10:40 hr).

Major deviations occur when the sensor is not working properly, e.g. the results of Node 106 after 10:10 hr are unreliable; this node did not function any more after 10:10 hr. The results of the comparison of the observed and calculated behaviour are given in Table 2. From these results, it can be concluded that the calculated behaviour is the same as the observed behaviour in 99.15% of the time. The results of Node 106 are not used in this overall result.

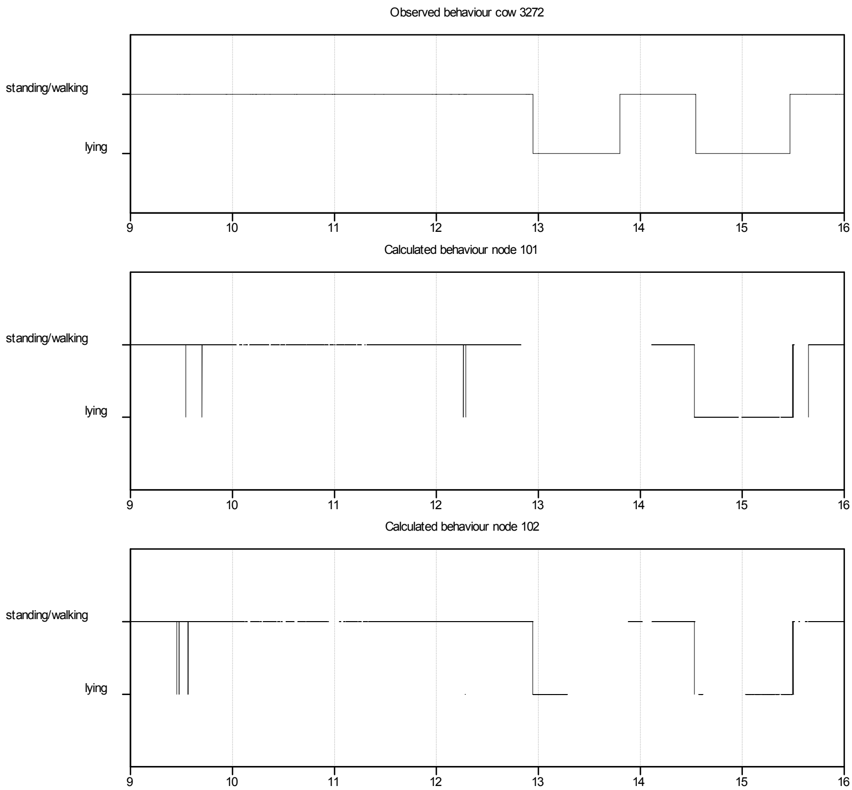

Figure 6. Comparison of observed behaviour of Cow 3272 (upper graph), calculated behaviour of Node 101 attached to the left hind leg of Cow 3272 (middle graph) and calculated behaviour of Node 102 attached to the right hind leg of Cow 3272 (lower graph).

Table 2. Comparison of observed and calculated lying and standing/walking behaviour (per second) per cow/node.

Cow	Node	measurements	calculated behaviours	calculated = observed	calculated ≠ observed	similarity
3246	105, left	22783	20121	19874	247	98.8%
	106, right	8900	6140	5178	962	84.3%
3272	101, left	23047	17968	17870	98	99.5%
	102, right	20578	17752	17620	132	99.3%
3830	103, left	20921	17550	17408	142	99.2%
	104, right	22797	16976	16829	147	99.1%

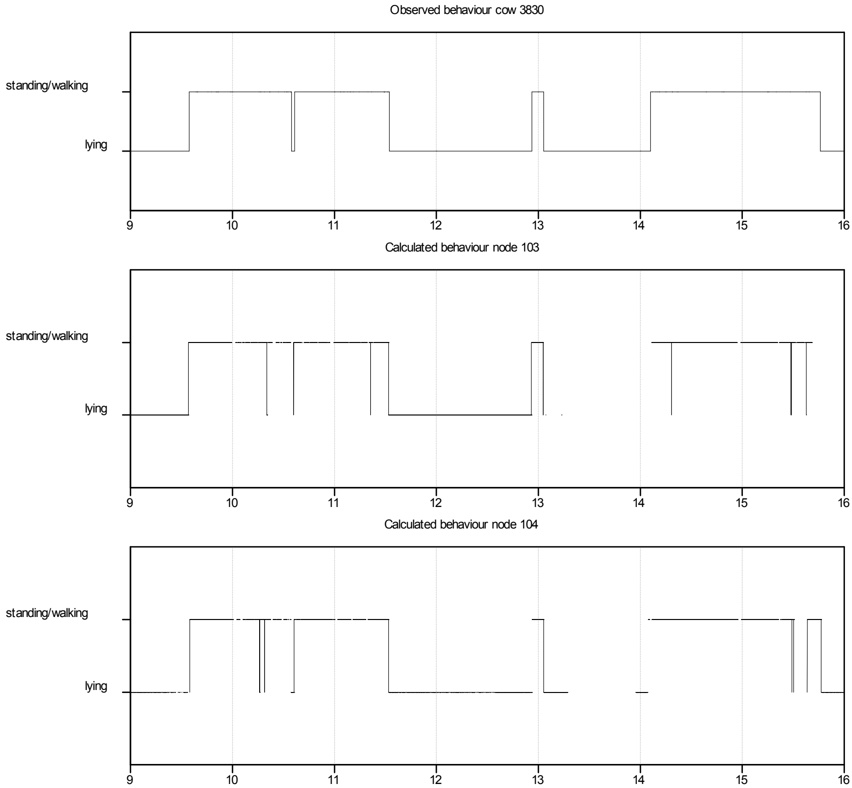

Figure 7. Comparison of observed behaviour of Cow 3830 (upper graph), calculated behaviour of Node 103 attached to the left hind leg of Cow 3830 (middle graph) and calculated behaviour of Node 104 attached to the right hind leg of Cow 3830 (lower graph).

Calculated behaviour: standing and walking

During standing/walking, the behaviour is subdivided in standing and walking based on the variance of ten successive measurements. The cow is walking when the variance is higher than a threshold (in one or more dimensions), otherwise standing. In this research the applied value for this threshold is 400. The values for standing and walking are averaged per second for the further analysis. An example of the results is given in Figure 8, where the observed and calculated standing and walking behaviour of Cow 3830 during 10 minutes is depicted. The walking values are only included in the analysis when the one-second average exceeds 0.5, that is when walking is detected during a major part of the time.

In general, the observed walking intervals do not overlap with the calculated walking intervals due to imperfect time synchronization. But it is quite easy to match observed walking intervals with calculated walking intervals by shifting the time line a bit.

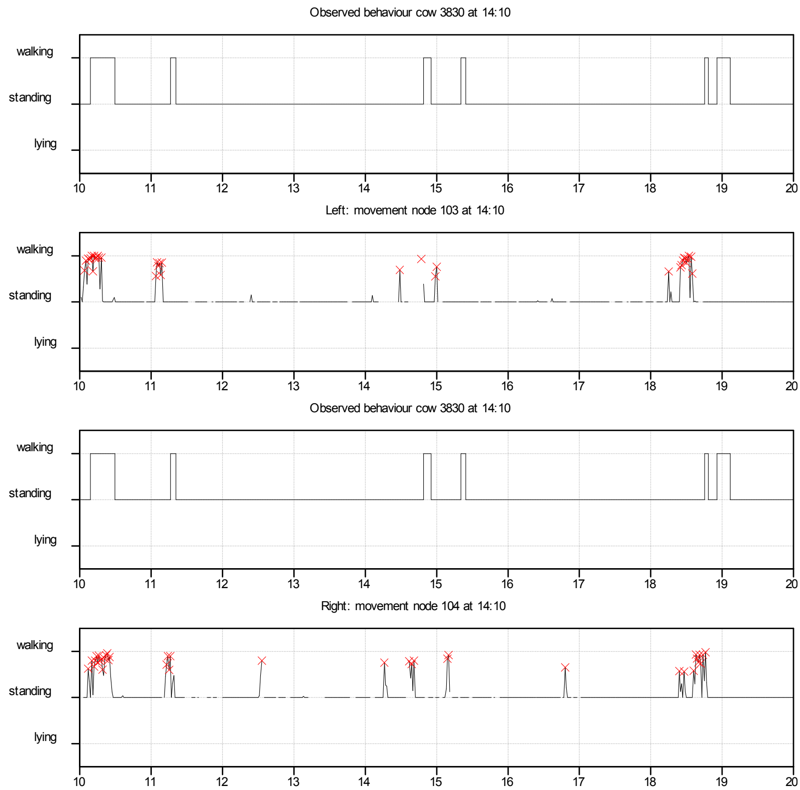

Figure 8. Comparison of observed standing and walking behaviour of Cow 3830 (first and third graph), calculated behaviour of Node 103 attached to the left hind leg of Cow 3830 (second graph) and calculated behaviour of Node 104 attached to the right hind leg of Cow 3830 (fourth graph), all during a 10 minutes interval from 14:10 till 14:20 hrs. The calculated walking values are averaged per second and a cross is added when the one-second average exceeds 0.5.

Comparison of calculated and observed behaviour: standing and walking

Results of the comparison of the observed and calculated standing and walking behaviour are included in Table 3.

In total 151 walking periods have been observed. With the left-side nodes all walking periods match with calculated moving periods if measurements available (there are no measurements available in 13 cases). With the right-side nodes all but one walking periods match (no measurements in 26 cases), there is one non-matching case for Node 104 attached to Cow 3830. So if measurements are available, 99.5% of the observed walking periods have a matching calculated moving period.

There are a lot of moving periods that do not match with an observed walking period. Mostly these are very short intervals. These probably correspond with leg movement during standing (or during the process of lying down or standing up). These non-matching periods may better be classified as 'moving legs' instead of 'walking'.

The method used is suitable for on-node processing as it needs only one message of ten successive measurements. The results make clear that the method can be used for state-based triggering as moving behaviour is (almost) always detected during walking (and also sometimes during standing).

Table 3. Comparison of observed and calculated standing and walking behaviour (per second) per cow/node.

Cow	Node	percentage of moving time during standing /walking	number of walking periods			number of calculated moving periods not walking
			total number	with matching calculated walking periods	without measure-ments	
3246	105, left	7.2%	26	19	7	349
	106, right	6.2%		8	18	138
3272	101, left	4.8%	44	40	4	230
	102, right	4.8%		41	3	248
3830	103, left	3.0%	51	49	2	35
	104, right	4.1%		45	5	66

Discussion

The calculated behaviour is the same as the observed behaviour during most of the time. Small differences can be filtered out (if they last only one second), have less influence (exact time of behaviour change) or were caused by the off-line calculation method. During this experiment the calculations were done off-line, the calculations will be done on node level during practical implementation to reduce the effects of packet loss during signal transmission and to reduce the radio traffic (Lokhorst *et al.*, 2010).

During this experiment the observed behaviour was known and has been used to calculate the average value during standing. This is not possible in practical circumstances. But the average value might as well be calculated during periods when the cow is known to be standing, e.g. during milking or in the waiting room before milking. Therefore this method is also applicable when the observed behaviour is not known.

The nodes were attached to outer side of the hind leg. In practical circumstances, the node might rotate around the leg (to the inner side). This did not happen in this experiment and the effects on behaviour classification are not known yet. This should be studied. The effects will be temporarily if the standing averages are updated regularly (e.g. during each milking).

Defect sensors will give bad behaviour classifications (e.g. Node 106). It will not always be clear when a sensor is defect. This might be solved by determining the trustworthiness of the sensor data (Gomez *et al.*, 2011).

When a cow is walking this can be recognized by the described method to distinguish standing from moving. This relation is one-way: moving is always detected during walking, but moving does not imply walking as there can be other similar leg movements. So this method is suitable for state-based triggering, moving detection can be the starting point of locomotion analysis (de Mol *et al.*, 2009b) as the cow may be walking then.

The time synchronization between the video recordings and the acceleration recordings was a practical problem in this research. Incorrect timing leads to false behaviour classifications around the moment of behaviour change. It also makes is necessary to include a time shift to match observed and calculated walking intervals. So imperfect time synchronization made it more difficult to show the evidence of the methods used, but it is no problem at all for the practical application: the interval lengths are correct and the exact moment of walking is irrelevant (but the number and length of walking periods can be relevant).

Conclusions

The proposed method for the behaviour classification, based on the distance between the actual value and the computed average during standing, gives good results, the similarity between observed and calculated behaviour is up to 100%. A clear distinction between lying and standing/walking can be made. When the cow is walking then moving is detected, but the other way round is not always true: moving can also be detected during standing (e.g. leg movements). Detection of moving is an effective method to initialize locomotion analysis. Bad results can occur when the sensor is defect. This method is suitable for use in practical applications of Wireless Sensor Networks as the method makes on-node processing possible as well as state-based triggering. For practical application there should be periods were the cow is known to be standing (e.g. during milking).

Acknowledgements

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References

de Mol, R.M., Bleumer, E.J.B., Hogewerf, P.H., Ipema, A.H., 2009a. Recording of dairy cow behaviour with wireless accelerometers. In: Lokhorst, C., Koerkamp, P.W.G.G. (Eds.), 4th European Conference on Precision Livestock Farming, Wageningen. Wageningen, pp. 349-356.

de Mol, R.M., Lammers, R.J.H., Pompe, J.C.A.M., Ipema, A.H., Hogewerf, P.H., 2009b. Recording and analysis of locomotion in dairy cows with 3D accelerometers. In: Lokhorst, C., Koerkamp, P.W.G.G. (Eds.), 4th European Conference on Precision Livestock Farming. Wageningen, pp. 333-341.

De Mol, R.M., van Eijk, O.N.M., Goense, D., Hogewerf, P.H., Ipema, A.H., Lokhorst, C., Frumento, E., Mazzu, M., Wells, H., Savio, W., Wrona, K., 2007. WASP, Scenario choice, Deliverable 6.1.

Fourichon, C., Seegers, H., Malher, X., 2000. Effect of disease on reproduction in the dairy cow: A meta-analysis. Theriogenology 53(9), 1729-1759.

Fregonesi, J.A., Leaver, J.D., 2001. Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems. Livestock Production Science 68(2-3), 205-216.

Gomez, L., De Mol, R.M., Hogewerf, P., Ipema, A.H., 2011. Trustworthiness assessment of cow behaviour data collected in wireless sensor networks. In: 5th European Conference on Precision Livestock Farming. Prague.

Lokhorst, C., de Mol, R.M., Wells, H., Mazzu, M., Frumento, E., Corongiu, A., Savio, W., Ipema, A.H., Sorniotti, A., Gomez, L., 2008. WASP, Specified application requirements and prototype selection, Deliverable D6.2.

O'Callaghan, K.A., Cripps, P.J., Downham, D.Y., Murray, R.D., 2003. Subjective and objective assessment of pain and discomfort due to lameness in dairy cattle. Animal Welfare 12(4), 605-610.

Predicting individual daily feed intake of Holstein, Danish Red, and Jersey cows in automatic milking systems

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Abstract

An individual feed intake model based on daily observed milk yield and body weight was tested on robotically milked cows of three different breeds. The average mean absolute errors were significantly ($p < 0.05$) lower than errors obtained with the NRC (2001) model – 2.10 vs. 2.43 kg; 2.24 vs. 2.49 kg; and 1.87 vs. 2.13 kg dry matter intake (DMI) – for the Danish Red, Holstein, and Jersey cows, respectively.

Keywords: milking robots, dairy cows, individual feed intake

Introduction

There is an increasing pressure on dairy production to develop strategies which are both sustainable and efficient. For the dairy cow total dry matter intake (DMI, roughage plus concentrate) is a very important parameter which links together nutrient efficiency, nutrient losses and health of the cow. However, DMI cannot be measured individually for group fed cows, therefore a model is needed. In a previous study (Halachmi *et al.*, 2004) a DMI model – the '2004 Model' – was developed for Israeli Holstein cows milked in a milking parlor. The present study aimed to apply the 2004 Model to cows of three different breeds: Danish Holstein, Danish Red, and Danish Jersey, different feedstuffs, different climatatic conditions, a different housing system and milked by an Automatic Milking System (AMS), which may influence both milk yield and feeding behavior.

Materials and methods

The 2004 Model predicts feed intake in relation to body weight based on data from the present day and the previous two days for milk yield (MY), daily changes in body weight (BW) and the MY/BW relationship, whereas milk fat content is from the latest recording. In the present study also milk composition was measured at each milking. The data were also processed by the US National Research Council (NRC) model which is based on MY, fat content, BW and week of lactation. The 2004 Model differs from the NRC model in its incorporation of continuously changing variables: 1) regression coefficients appropriate to each day in lactation; 2) daily values of and changes in BW; 3) values of MY normalized according to BW;

and (4) data from only the previous 2 days rather than constant coefficients based on data from the whole lactation. The models were tested on the basis of three data sets acquired from 2002 through 2005 at the Danish Cattle Research Centre, from a total of 206 lactations (62 Holsteins, 77 Danish Reds, and 67 Jerseys). Further details are given by Halachmi *et al.* (2011).

The cows were offered three mixed rations (MR) of high, medium and low energy concentration. High-energy MR at the beginning of lactation was gradually replaced by low-energy MR throughout the lactation; detailed feed tables were described by Bossen and Weisbjerg (2009) and Bossen *et al.* (2009). In the AMS, the concentrate allocation varied between 3 and 6 kg/d per cow according to stage of lactation, live weight changes, and according to which of the three MR the cows were allocated to. The MR were based on maize silage, grass/clover silage, rolled barley, rapeseed cake, and dried sugar beet pulp; the average energy concentrations in high-, medium- and low-energy MR were 7.65, 7.18 and 6.79 MJ NEl/kg DM, respectively; and the corresponding average NDF concentrations were 323, 353 and 375 g/kg DM, respectively. Mixed rations were offered ad libitum in feed troughs (Insentec RIC Systems, Netherlands) located along the feeding alley, and the feed intake at each visit was recorded. All cows had been familiarized with the feeding system, and there were less than 2.2 cows per feed trough.

For each of the two models (Table 1) 25% of the lactations within breed were used to calibrate the model and the remaining to test predicted values against measured values, whereas for the prediction across breeds also the calibration was done with 25 % of cows available from each of the three breeds. The cows were randomly selected to calibration or validation

Model equestion and coeficients

$$DMI_{0,i} = b_{0,i} + b_{1,i}\frac{MY_0}{BW_0} + b_{2,i}\frac{MY_{-1}}{BW_{-1}}$$

$$+ b_{3,i}\frac{MY_{-2}}{BW_{-2}} + b_{4,i}BW_0 + b_{5,i}\frac{BW_{-1}}{BW_0}$$

$$+ b_{6,i}fat + e,$$

where DMI is the predicted voluntary total DMI for the individual cow as percentage of BW_0, i.e., DMI_0 = 100 x feed intake in kg of DMI_0/BW_0. MY_0/BW_0 is the current day's (day 0) milk yield (kg) divided by the cow's BW (kg), MY_{-1}/BW_{-1} is the previous day's (day −1) milk yield (kg) divided by the cow's BW (kg), MY_{-2}/BW_{-2} is the milk yield that was measured 2 days earlier (day −2), divided by the cow's BW, BW_0 is the current BW (day 0), BW_{-1}/BW_0 is the daily BW change since yesterday, fat is the percentage of milk fat as measured in the last milk recording, b is the regression coefficients matrix that was calculated for each day, and e is the residual error.

Results

Results suggest that: (1) the average Mean Absolute Error (MAE) of DMI as calculated by the 2004 Model was significantly ($p < 0.05$) lower than that given by the NRC model. The MAE values from the 2004 Model were 16%, 11% and 14 % lower than for the NRC model for the Danish Red, Holstein and Jersey cows, respectively (Table 1).

There was a large difference between MAE- and SE-values. This regards the difference in precision between prediction of a new observation (MAE) and prediciton of the population mean (SE).

Table 1. Comparison between DMI (kg /d) predictions of 2004 Model and NRC model

	MAE (kg/cow per day)		SE (kg/cow per day)		Significance
	2004 Model	NRC (2001)	*2004 Model*	NRC (2001)	(t – test)
All cows (n=206)	2.14	2.35	0.010	0.012	$p< 0.05$
By breed					
Dan. Red (n=77)	2.10	2.43	0.017	0.020	$p< 0.05$
Holstein (n=62)	2.24	2.49	0.021	0.023	$p< 0.05$
Jersey (n=67)	1.87	2.13	0.015	0.018	$p< 0.05$

DMI = dry matter intake. MAE is the mean absolute error = abs (measured DMI – model DMI) for individual cows. SE = the standard errors for the individual cows.

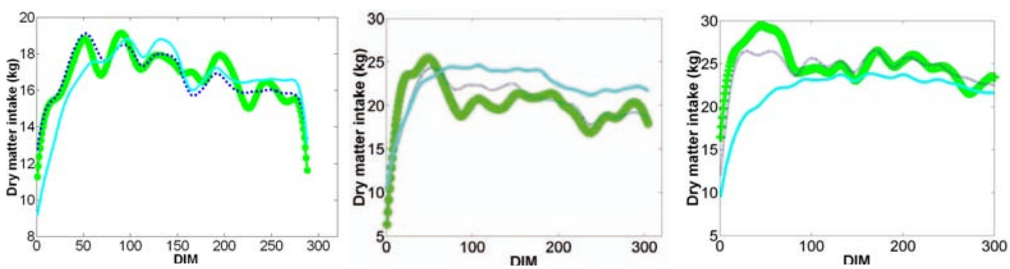

Figure 1. Examples of predicted values of 2004 Model *(dots ···) and* NRC (2001) model *(thin —) superimposed on the actual DMI (thick ▬▬) for 3 individual cows of 2nd parity of Jersey (left), Red (middle) and Holstein (right) breeds.*

Discussion

The graphs of Figure 1 infer that especially in early lactation the 2004 Model is superior to the NRC model because the latter underestimates DMI in the first 2 to 3 month after calving, which is not the case for the 2004 model. Because the 2004 model is based on the weight and yield over the latest three days it can capture short term fluctuations in feed intake as can be seen for all three cows in Figure 1.

One potential disadvantage of the 2004 Model is that it requires many coefficients. Indeed, the 2004 Model requires seven coefficients per day, i.e., ($b_{0,i}$; $b_{1,i}$; $b_{2,i}$; $b_{3,i}$; $b_{4,i}$; $b_{5,i}$; $b_{6,i}$)×330 d in milk=2310 coefficients per lactation period, whereas the NRC requires only four coefficients per lactation period. However, an AMS is highly computerized and therefor no human real-time involvement in the feed-allocation process is needed; thus, the "large number" of coefficients is not a problem with modern computers.

The precision of this cross validation may have a slight bias, since some af the data for the model calibration were collected under the same conditions as data for the model validation. However, the study tested the precision of both NRC and 2004 models under the same conditions. Therefore, the comparative advantage of the 2004 model is likely to be true also under other conditions. However, we would appreciate future studies including more cows of each breed and parity and kept under different farming conditions.

Although the error factor (MAE) in the 2004 Model equations is only 11-16% lower than that found in the NRC equations this improvement can be of economical value. Feed cost is the largest cost in a dairy enterprise, therfore, a saving of even only few precentages is significant for the economic failure or sucess of the enterprise.

Conclusions

Estimation of DMI is important for daily management, therefore the 2004 Model may be considered a potential on-line decision tool for daily adjustment of the amount of concentrate supplied by AMS and its concentrate feeders.

References

Bossen, D., Weisbjerg, M.R., 2009. Allocation of feed based on individual dairy cow live weight changes. II: Effect on milk production. Livestock Sci. 126, 273-285.

Bossen, D., Weisbjerg, M.R., Munksgaard, L., Højsgaard, S., 2009. Allocation of feed based on individual dairy cow live weight changes: I: Feed intake and live weight changes during lactation. Livestock Sci. 126, 252-272.

Halachmi, I., Edan, Y., Moalem, U., Maltz, E., 2004. Predicting feed intake of the individual dairy cow. J. Dairy Sci. 87, 2254–2267.

Halachmi, I., Børsting, C.F., Maltz, E., Edan, Y., Weisbjerg, M.R. 2011. Feed Intake in Holstein, Danish Red, and Jersey cows in automatic milking systems. Livestock Science. In Press.

National Research Council (NRC), 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. National Academy Press, Washington, DC.

Trustworthiness assessment of cow behaviour data collected in a wireless sensor network

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Abstract
Wireless sensor networks can be used for automated cow monitoring, e.g. for behaviour and locomotion monitoring. Sensor data should only be used when they can be trusted. The trustworthiness of sensor data can be assessed in a framework, from the acquisition at the node to their delivery to business applications, including any intermediary routing and processing. The trustworthiness assessment method has been evaluated with sensor data collected during one of the experiments within the WASP project. Sensor data are not trusted when the trustworthiness gets below a threshold. An alert is generated then and it is possible to find the cause by tracing back the trust of composing elements. The trustworthiness assessment method results in the detection of problems with nodes (e.g. detached node or exhausted battery). Most of these problems can be classified as true and most of them were not notified on the farm. Therefore trustworthiness assessment is worthwhile to improve automated cow status monitoring.

Keywords: Wireless Sensor Networks, behaviour, dairy cows.

Introduction

Application of wireless sensor networks (WSN) is a new method to collect data that can be used for automated cow monitoring (Wang *et al.*, 2006). The application of WSNs is especially useful for behaviour and locomotion monitoring. Sensor data should only be used when they can be trusted. Trustworthiness is defined as the probability that sensor data really corresponds to the measurement in the physical world. Sensor data may be erroneous due to intentional misbehaviour and unintentional errors. Intentional misbehaviour is expected to be less relevant in cow monitoring applications. Unintentional errors are caused by malfunction of the hardware (broken or obstructed sensors), mispositioning of the node (untied or incorrectly attached node) or exhausted battery (Gomez *et al.*, 2010).
The trustworthiness of sensor data can be assessed in a framework, from the acquisition at the node to their delivery to business applications, including any intermediary routing and processing (Gomez *et al.*, 2009).
Possible applications of WSNs have been investigated in the Wirelessly Accessible Sensor Populations (WASP) project (www.wasp-project.org). One of the applications was 'Detection of health problems with focus on claw health and locomotion' (De Mol *et al.*, 2007, Lokhorst *et al.*, 2008). The trustworthiness assessment using the framework has been evaluated with sensor data collected during one of the experiments within the WASP project.
In this paper the focus will be on the evaluation results. The framework will be described in short, as well as the experimental conditions.

Material and methods

The trust model

Three states are identified in the sensor data life cycle (for a more detailed description see (Gomez *et al.*, 2010): raw, routed and processed (Figure 1). A sensor produces raw data. The data is processed by data manipulation such as filtering, fusion or aggregation. The data is routed when it is sent to another node in the network (or delivered to the business application). There are specific trust assessment mechanisms for each state:

- for raw data it is based on the trustworthiness of several available attributes (e.g. node battery level and measurement accuracy);
- for routed data it is based on the trust relationship between the sender and the receiver;
- for processed data it depends on the information used for the processing mechanism, that is the type of processing services and the input sensor data used.

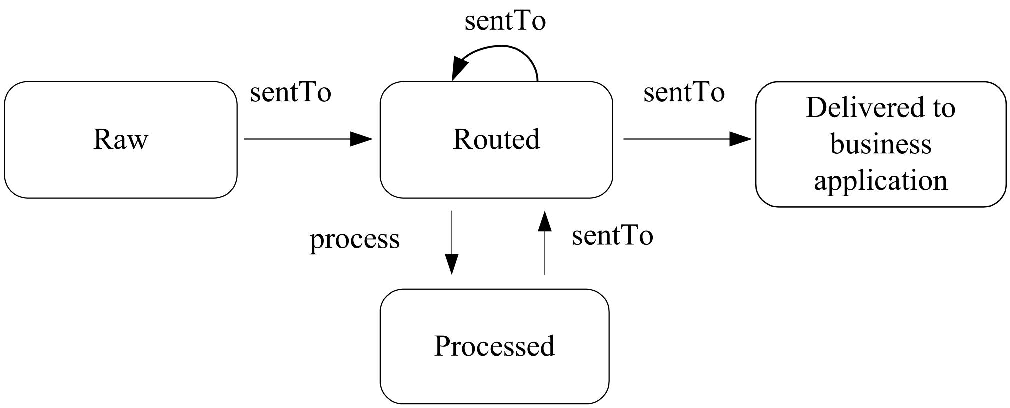

Figure 1. Sensor data life cycle, figure reproduced from Gomez et al. (2010).

In Gomez *et al.*, (2010), the trustworthiness is formalised as the opinion in the theoretical framework of subjective logic, based on Dempster-Schafer theory of evidence (Josang, 2001). An opinion is a 4-tuple (b, d, u, a) where b represent belief, d disbelief, u uncertainty and a the a priori probability. The range of all four values b, d, u, a is [0, 1] and b + d + u = 1. The subjective logic framework provides a set of operators for combining opinions. Gomez *et al.* define operators to evaluate the trust in sensor data attributes and a combine operator to determine the overall trustworthiness of sensor data.

Attributes of the raw data are battery and value. The battery operator is used to asses the trust in a battery given the current battery level. The trust decreases as the battery level decreases. The trust is always lower than the battery level and the difference depends on a parameter in the battery operator model.

The value operator is used to determine the trustworthiness of the sensor value. The trust decreases when an abnormal sensor data value is detected, based on the difference with the forecasted value found (e.g. with exponential smoothing). A sudden change in the measurement results in a decrease in the trust.

Gomez *et al.* (2010) also define a combine operator that fulfils the following requirements:

- a combination of close opinions is rewarded, it results in an increase of opinion;
- a combination of distant opinions is penalized.

The combine operator is based on formulas for combined belief and combined uncertainty of the underlying opinions. The same operator is used for raw and processed data.

<u>Experimental conditions</u>

In de Mol *et al.* (2009), the authors monitored daily behaviour of dairy cows during 50 days. The goal of this experiment was to evaluate in real-time the health and well-being status of cows, indoor and outdoor. The cows were indoor the first 36 days, and had access to pasture the last 14 days. Six cows were equipped with two tilt sensors to measure the acceleration in X and Y direction of their neck and right hind leg every half a minute (Figure 2). Each sensor device on the cow represents a mobile node in the network. Based on calibration measurements, raw acceleration from neck and leg were processed in order to determine cow behaviour (e.g. standing, lying). Applied to this scenario, our approach enables farmers to evaluate the trustworthiness of cow's acceleration and derived cow behaviour, which is the trustworthiness of the calculated lying and standing behaviour. Abnormal status should be detected at an early stage. In this scenario, erroneous acceleration is due to multiple factors (e.g. detached nodes, exhausted battery). During the experiment, few nodes have been detached from the cow, and found in the pasture. Farmers recorded in a logbook different events occurring to the nodes (see Table 1). The trustworthiness assessment should make it possible to detect in real-time such events. The value of trustworthiness assessment follows from the impact of erroneous data on the processing over cow activity.

Figure 2. Node attached to the leg (in circle in left picture) and node attached to the back of the neck (in ellipse in right picture).

Table 1. Description of events in the logbook during the first month of the experiment.

Date	Description of event
May 7, p.m.	Nodes allocated to cows
May 7, p.m.	Node 3 (Cow 428) replaced by Node 5
May 9, a.m.	Node 5 at the inner side of the leg of Cow 428, node turned back
May 9, a.m.	Node 15 detached and found by a farm worker, attached again to Cow 507
May 14, p.m.	Node 5 at the inner side of the leg of Cow 428, node turned back
May 14, p.m.	All nodes with transmission problems were restarted and attached again to the cows
May 14, p.m.	Node 7 detached and found in the feeding passage, attached again to Cow 74
May 20, p.m.	Node 4 replaced by node 1 on Cow 445

Results

Worked-out example of one event

The trustworthiness was calculated for the six cows during the experimental period. The data should not be trusted when the trustworthiness is below a threshold. The cause of such incidents can be tracked by following the trustworthiness assessment in the opposite direction:

- the trustworthiness per cow is a combination of the trustworthiness per node of that cow;
- the trustworthiness per node is a combination of the trustworthiness of acceleration X and acceleration Y;
- the trustworthiness in acceleration X (or Y) is a combination of the trustworthiness of value and battery.

For example a drop in the trust of a battery will give a trust decrease of the acceleration, and subsequently a trust decrease for the node and the cow.

Some results of Cow 507 are given in Figure 3 through 12 to illustrate this. The trust evaluation of Cow 507 during the first month in the experiment is shown in Figure 3. Drops in trust occur on May 9, May 11 and May 19. The first drop coincides with an event mentioned in Table 1. The trust in Cow 507 is based on the acceleration trustworthiness on Node 10 and 15; these are depicted in Figure 4 and 5.

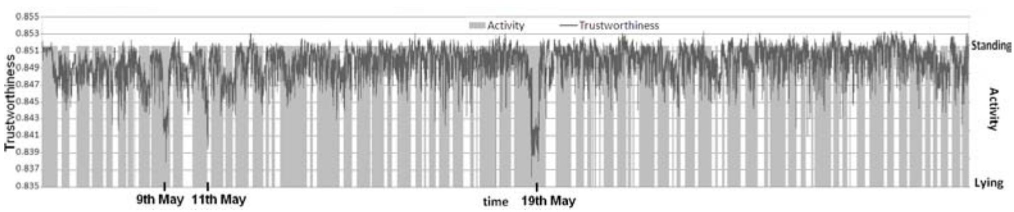

Figure 3. Trustworthiness evaluation and activity of Cow 507 during the month of May 2008.

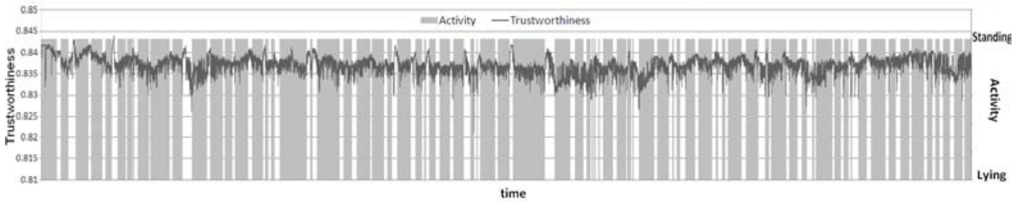

Figure 4. Trustworthiness evaluation and activity of Node 10 (attached to the right hind leg of Cow 507) during the month of May 2008.

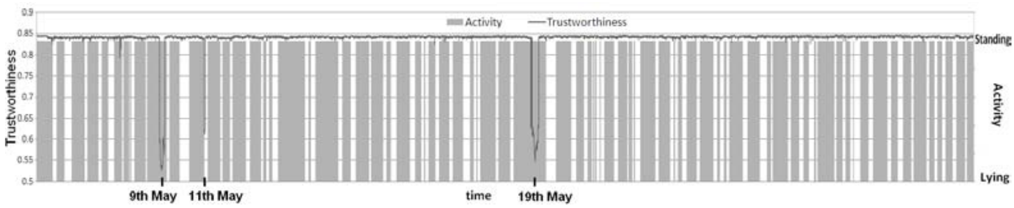

Figure 5. Trustworthiness evaluation and activity of Node 15 (attached to the neck collar of Cow 507) during the month of May 2008.

The trustworthiness around the third drop (May 19) is depicted in Figure 6 (trust of Cow 507), and the trust evaluation of Node 10 and Node 15 in the same period is shown in Figure 7 and 8. The trust in Node 10 remains at the same level, around 83%. Apparently the drop is caused by the drop in trust for 15 (below 55%, Figure 8). The trust in Node 15 is a combination of the trust in acceleration X and acceleration Y of Node 15. Therefore this is worked out further in Figure 9 and 10 where the trust evaluation around May 19 of acceleration X and Y of Node 15 are shown. The trust in Y (Figure 10) is decreasing which can be explained by a decrease in trust in the value of Y acceleration (Figure 11) while the trust in battery remains roughly at the same level (Figure 12). The trust in Y values gets below 20%; and the cause for this drop is unknown as there is no event given in the logbook on that date.

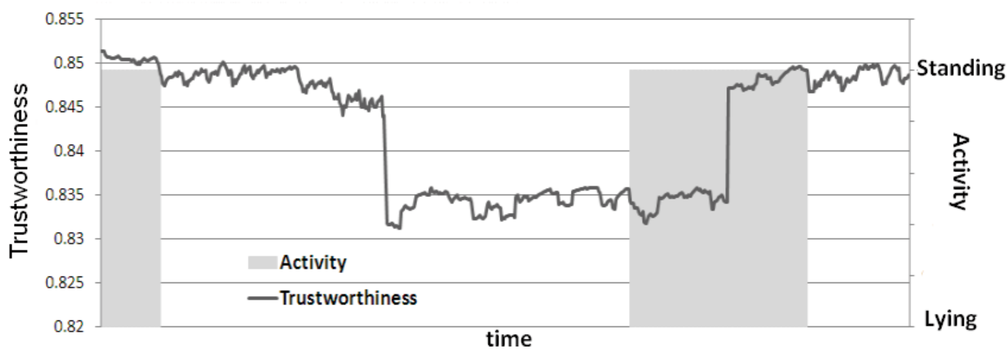

Figure 6. Trustworthiness evaluation and activity of Cow 507 around May 19.

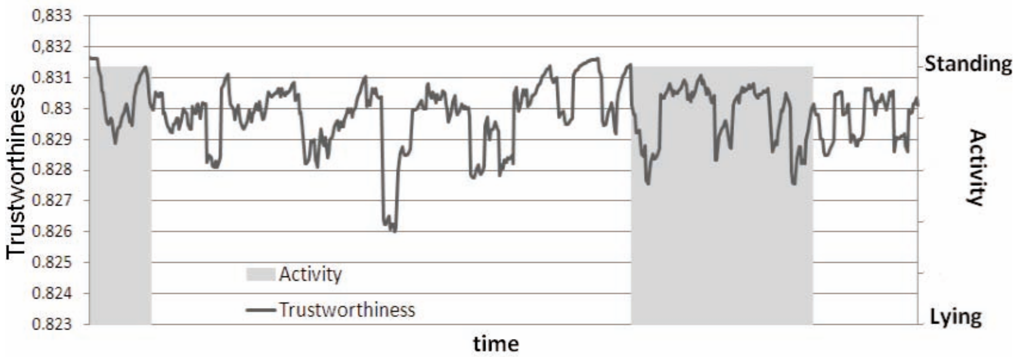

Figure 7. Trustworthiness evaluation and activity of Node 10 (attached to the right hind leg of Cow 507) around May 19.

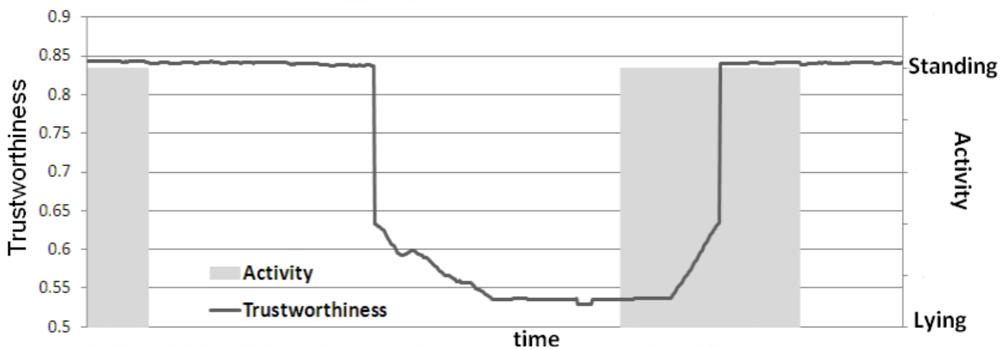

Figure 8. Trustworthiness evaluation and activity of Node 15 (attached to the neck collar of Cow 507) around May 19.

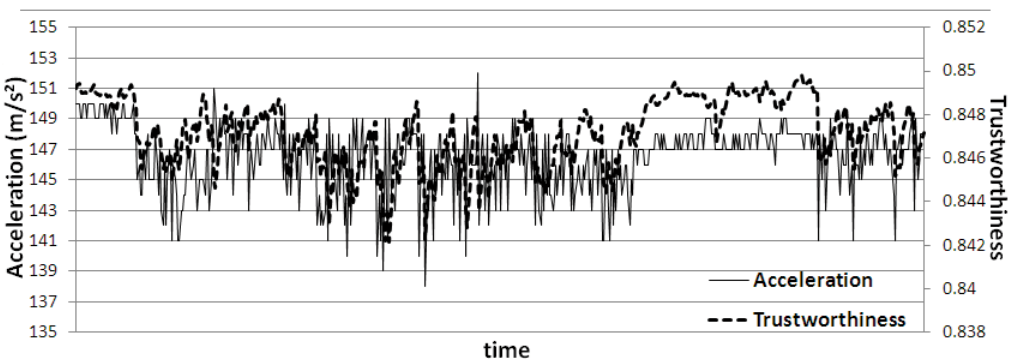

Figure 9. Acceleration and trustworthiness evaluation of acceleration X on Node 15 (attached to the neck collar of Cow 507) around May 19.

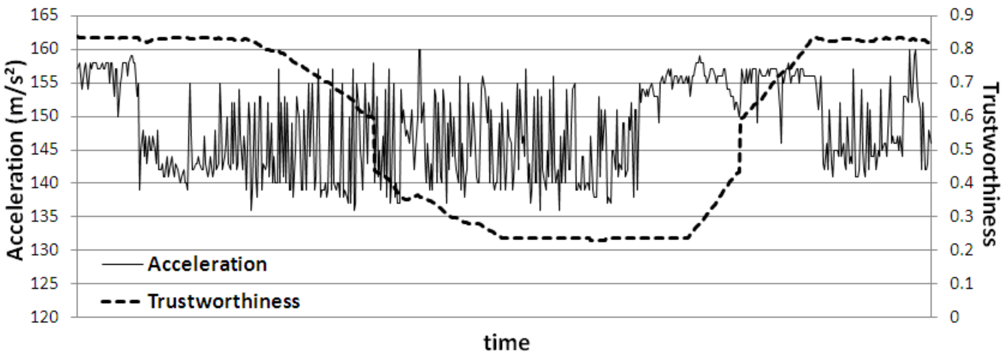

Figure 10. Acceleration and trustworthiness evaluation of acceleration Y on Node 15 (attached to the neck collar of Cow 507) around May 19.

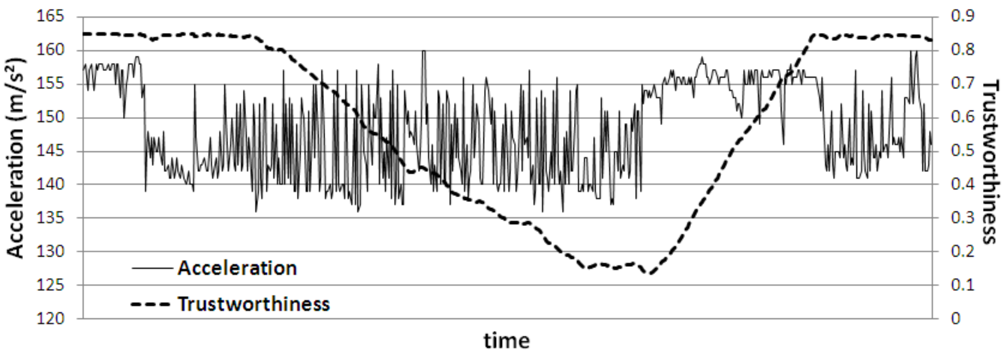

Figure 11. Acceleration and trustworthiness evaluation of acceleration Y value (left) and battery level (right) of Node 15 (attached to the neck collar of Cow 507) around May 19.

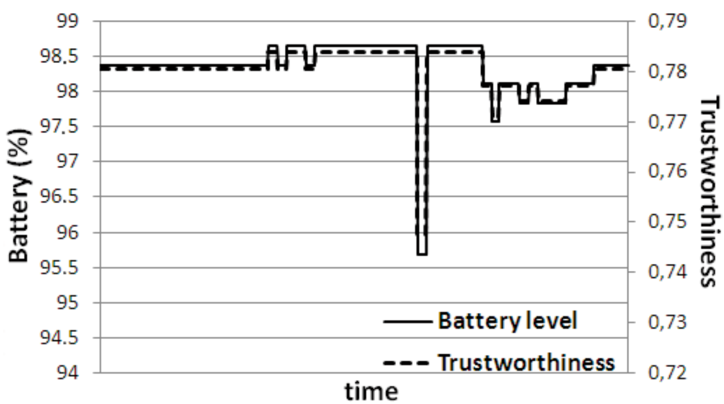

Figure 12. Battery level and trustworthiness evaluation of battery level of Node 15 (attached to the neck collar of Cow 507) around May 19.

In general, measured acceleration values and battery levels are used to calculate the trust in X or Y acceleration, both are combined for the trust in a node. The trust in both nodes is combined to get the trust per cow. This also works the other way round: when the trustworthiness is decreased for a cow, the cause can be detected by following the mechanism backwards.

Experimental results

Fifteen nodes have been used in the experiment to measure the behaviour of the six cows. Six nodes have been discarded for the trustworthiness analysis because they did not produce enough data. Three nodes did not produce any abnormal measurements. On the remaining six nodes, 73 events have been detected by the trust model (based on a threshold 83.5% for trustworthiness). On the farm only 19 events have been recorded in the logbook (Table 1), that is one out of four events was also detected by the farmer.
Whenever an incident occurs, (e.g. detached node, out of battery), it is important to consider three phases:

(i) the time when the problem occurs;
(ii) the time when the farmer detects the problem (reaction time);
(iii) the time when the farmer fixes the problem and everything goes back to normal (response time).

The trustworthiness model detects an event when the trust gets below a threshold. The higher the threshold, the more events will be detected. An event is classified as False Positive when the trustworthiness does not get below 40%. For the 85.5% threshold 73 events were detected, 10 of these 73 events were FP (14%). Results for other thresholds are included in Table 2. A higher threshold results in decreased reaction time as the alert will be generated earlier. But it is also more likely that the alert is FP (when the trust deceases but not far enough). Therefore a higher threshold is not attractive as the number of FP alert increases strongly.

Table 2. Event detection results for three threshold levels.

threshold	83.5%	84.0%	84.5%
average reaction time (min)	20.0	12.5	7.5
percentage of false positives	14%	40%	88%

Discussion

The results of the trustworthiness assessment depend on the threshold setting. It may be worthwhile to adapt this threshold automatically based on the generated results (true positives vs. false positives based on the minimum trust level reached per event).
It is assumed that intentional misbehaviour is not an issue in automated cow status monitoring. Otherwise the method should be adapted to detect such cases.
There might be some overlap in the results of trustworthiness assessment and the results of automated detection as both are looking for deviating measurement values. In trustworthiness assessment values are deviating when they cannot be trusted any longer. In automated detection values are deviating when the cow's behaviour is different because of a case of illness

or oestrus. Alerts from the detection model should be generated when the values are deviating (higher temperature, lower milk yield) but still trusted. Values are not trusted when they are outside the acceptable range. In practice these alerts might be combined because in both cases the farmer should inspect the cow or the cow's nodes.

Conclusions

Measurement values should only be used in business applications when they can be trusted. Therefore a method for trustworthiness assessment as described in this paper is worthwhile. Erroneous sensor data hamper automated cow status monitoring. Trustworthiness assessment is useful for data collection in WSN because erroneous data is detected and should not be used as input for the detection model. This will lead to a lower number of false positive alerts. It is possible to find the cause of the problem (e.g. defect sensor or flat battery) by analysing the drop in trustworthiness backwards in the trustworthiness assessment procedure.

Acknowledgements

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References

de Mol, R.M., Bleumer, E.J.B., Hogewerf, P.H., A.H.Ipema, 2009. Recording of dairy cow behaviour with wireless accelerometers. In: Lokhorst, C., Koerkamp, P.W.G.G. (Eds.), 4th European Conference on Precision Livestock Farming, Wageningen. Wageningen, pp. 349-356.

De Mol, R.M., van Eijk, O.N.M., Goense, D., Hogewerf, P.H., Ipema, A.H., Lokhorst, C., Frumento, E., Mazzu, M., Wells, H., Savio, W., Wrona, K., 2007. WASP, Scenario choice, Deliverable 6.1.

Gomez, L., Laube, A., Sorniotti, A., 2009. Trustworthiness assessment of wireless sensor data for business applications. In: Proceedings - International Conference on Advanced Information Networking and Applications, AINA. pp. 355-362.

Gomez, L., Gentile, X., Riveill, M., 2010. Trustworthiness assessment of sensor data: evaluation. In: IFIP NTMS'11

Josang, A., 2001. A logic for uncertain probabilities. International Journal of Uncertainty, Fuzziness and Knowlege-Based Systems 9, 279-311.

Lokhorst, C., de Mol, R.M., Wells, H., Mazzu, M., Frumento, E., Corongiu, A., Savio, W., Ipema, A.H., Sorniotti, A., Gomez, L., 2008. WASP, Specified application requirements and prototype selection, Deliverable D6.2.

Wang, N., Zhang, N., Wang, M., 2006. Wireless sensors in agriculture and food industry - Recent development and future perspective. Computers and Electronics in Agriculture 50, 1-14.

Section 3
Vision

Real-time monitoring tool for pig welfare

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Abstract

Recently, the support for improving animal welfare in livestock farming has been increased in the EU. The objective of this research is to develop an automatic camera-based system for continuously monitoring of the pigs' behaviour in a contactless way in order to understand the effect of environment on pigs. Therefore, a measure for the activity level calculated from camera images was proposed. The activity index was calculated for the group of pigs as the fraction of the floor space in the pen that contained motion in between two subsequent camera images. Finally, the effect of environment enrichment and its induced behaviour on the activity level of pigs is quantified. This suggests that in these experimental conditions, the increase in the activity level following the introduction of the environment enrichments accounted for 34.3% of the total activity level.

Keywords: image analysis, automatic monitoring, animal health and welfare

Introduction

In the past, livestock management decisions have been made entirely on the audio-visual observation, judgment and experience of the farmer (Frost et al. 2003). However, due to price competition the number of animals and the scales of animal farms have increased. This increasing scale of farms and the corresponding high number of animals has intensified the administrative, technical, organizational and logistic workload of the farmer who has, consequently, less possibility to monitor his animals by audio-visual scoring.
One of the objectives of Precision Livestock Farming (PLF) is to develop on-line tools for fully automatic and continuous monitoring of farm animals during their life (Berckmans 2008). PLF consists of measuring variables on the animals, modelling these data to select information and calculate specific parameters, and then using these parameters in real time for monitoring and the models for controlling purposes.
Image analysis is one of the tools used in PLF for monitoring. The advantage of this methodology is that nowadays it is relatively inexpensive, since it requires only some cameras and computers, and furthermore it doesn't interfere with the animals' environment.
The aim of these technical tools is not to replace but to support the farmer who always remains the crucial factor in a good animal management system.
Animals can be monitored as individuals or as a group. When single animals are observed,

automatic monitoring tool can be developed by, firstly, extracting features from the images in order to model the animal. The models of the animals can be simple or more complex depending on the application. A pregnant sheep, for example, can be represented as a line for predicting the time of birth, an ellipse is enough for real time detection of scratching behaviour in caged poultry (Leroy et al. 2006), and the contour and four points for describing altered gait in laboratory mice (Leroy et al. 2009). After the biological system is described in a simplified form by a real time model, the next step consists in developing a second dynamic model able to detect and predict specific behaviours.

This approach is not feasible anymore in the case of large number of animals observed both for complexity and computational reasons (for example, the case of monitoring each chicken out of more than a thousand in a poultry house). Therefore, another methodology has to be used. Instead of looking at each individual, the group is now taken into consideration. The activity index, the fraction of the floor space in the pen that contains motion in between two subsequent camera images, and the occupation index, the fraction of the floor space occupied by the animals, are good estimators for analysing the animals' behaviour and their welfare. These indexes have been implemented in a commercial product, namely Eyenamic, to evaluate in real time the thermal comfort in chickens (Cangar et al. 2008).

The same approach is proposed in this paper to quantify the effect of the enrichment of the environment in pig behaviour calculating continuously the activity and occupational indexes through an automatic camera-based system.

Material and Methods

Description of the monitored building

The study was conducted in a fattening room located in Zinasco, Italy. The barn was an open-space 4.6 m wide x 6.81 m long, mechanically ventilated and subdivided into 6 pens 2.27 m long and 1.9 m wide each, all equipped with fully slatted floor. The two selected pens were positioned at the end of the pig's barn and delimited by the wall 1 m high and 0.2 m thick (Figure 1). A corridor of 80 cm long divided the two pens monitored. Each pen contained 14 Dalland race piglets in post-weaning period with the mean weight around 6.4 kg and the mean age of 23 days at the beginning of the experiment.

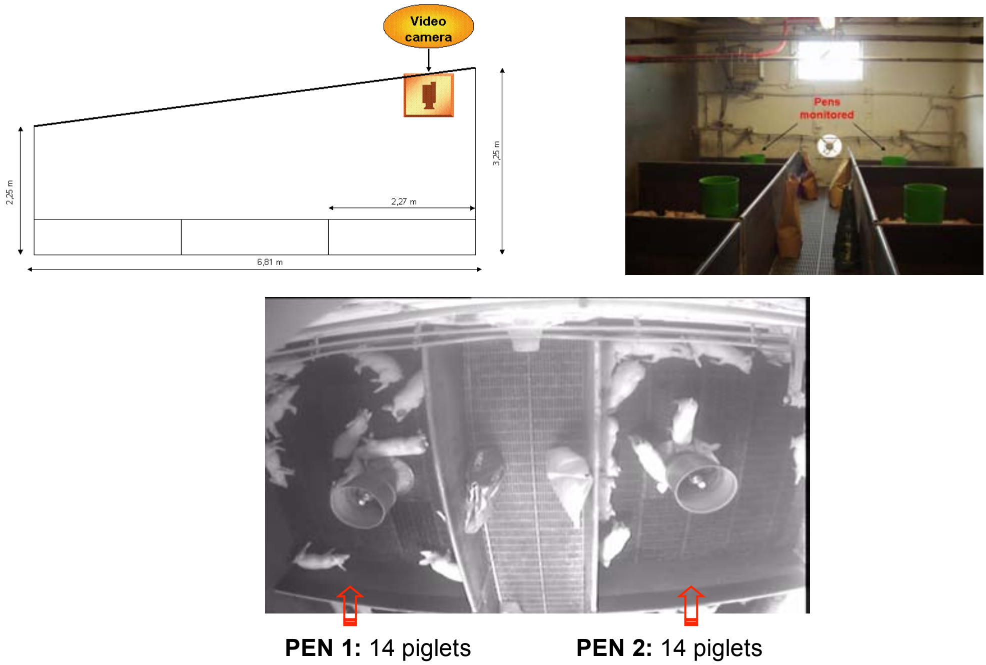

Figure 1. Camera system installed in a commercial pig house.

<u>Animal activity monitoring system</u>

An infrared CCD camera (Sanyo Analogue CCD) was mounted 3 m above the floor with its lens pointing downward directly above the corridor separating the two pens to get a top view of both pens in the camera image. The camera was connected to a PC with a built-in frame grabber (Data Translation DT 3210) using a coaxial cable. Images were captured continuously with a resolution of 786 x 586 pixels at a sample rate of one frame per second for a total of more than 5 days (From August 24 at 08:00 to August 29, 2009 at 10:00). During this period, the Eyenamic system (Leroy et al. 2008) was running in real-time and video images from the camera were recorded simultaneously.

<u>Activity measurements:</u>

The image-based system was developed to measure the activity and occupation indexes of the group of pigs in practical field conditions (Borgonovo et al. 2009).
The *activity index* (Costa et al. 2009) can quantify the activity of animals in a practical field condition such as a barn. The idea behind it is that the change in colour or grey value of the pixels in consecutive frames provides a good estimation of the activity of the animals. When the pigs are lying, for example, the number of pixels that changes between two consecutive frames is smaller than the one when pigs are playing or fighting.

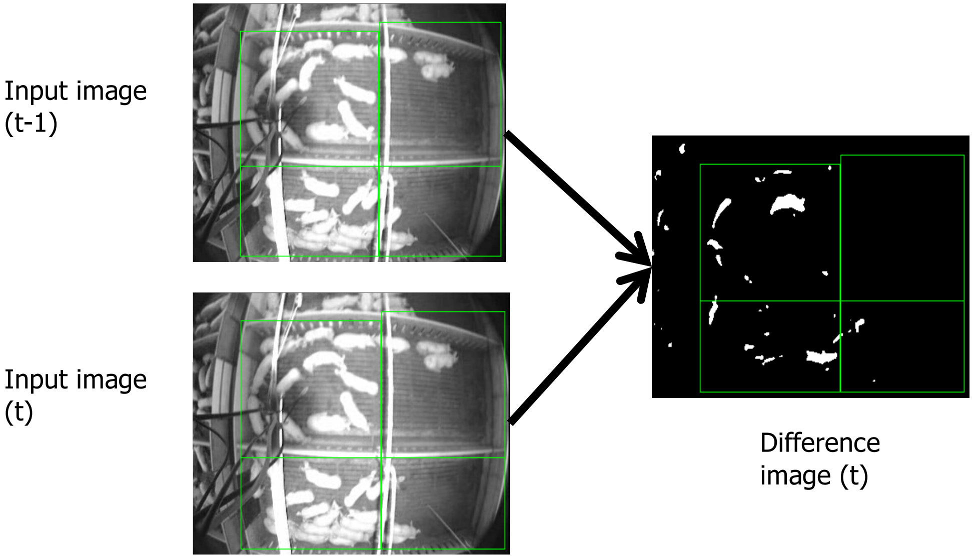

Figure 2. Difference in number of "pig-pixels" between images is a measure for movement.

Formally, the difference of pixel values $I_{diff}(x,y,t)$ between the binary image $I(x,y,t)$ extracted from the video at time t and the one $I(x,y,t-1)$ extracted one frame before at time t-1 was calculated (Figure 2):

$$I_{diff}(x,y,t) = I(x,y,t) - I(x,y,t-1) \tag{1}$$

In order to take into account the small changes of the pixels due to noise, e.g. small lighting variation, a threshold τ_1 was set to 10% of the maximal intensity variation observed in an empty region for 1 minutes of recording (60 frames). In order to compensate drastic changes in pixels' values, e.g. when lights were switched on and off a second threshold τ_2 was added and set to 50% of the maximal activity.

$$I_a(x,y,t) = \begin{cases} 1 & if \quad \tau_2 > I_{diff}(x,y,t) > \tau_1 \\ 0 & otherwise \end{cases} \tag{2}$$

The activity index $a_i(t)$ for the zone Z_i was calculated as the fraction of the 'activity image' $I_a(x,y,t)$ with respect of the total number of pixel of the zone:

$$a_i(t) = \frac{\sum_{(x,y)\in Z_i} I_a(x,y,t)}{\sum_{(x,y)\in Z_i} 1} \tag{3}$$

The *occupational index* calculates the fraction of the area occupied by the animals. In the images, the so-called "pig-pixels", representing the pigs, have different values than the one of the background. By applying a threshold value τ_0, obtained using Otsu algorithm (Otsu 1979), to the image I(x,y,t), it was calculated whether each pixel is considered foreground (pigs) or background.

$$I_o(x,y,t) = \begin{cases} 1 & if \quad I(x,y,t) > \tau_0 \\ 0 & otherwise \end{cases} \tag{4}$$

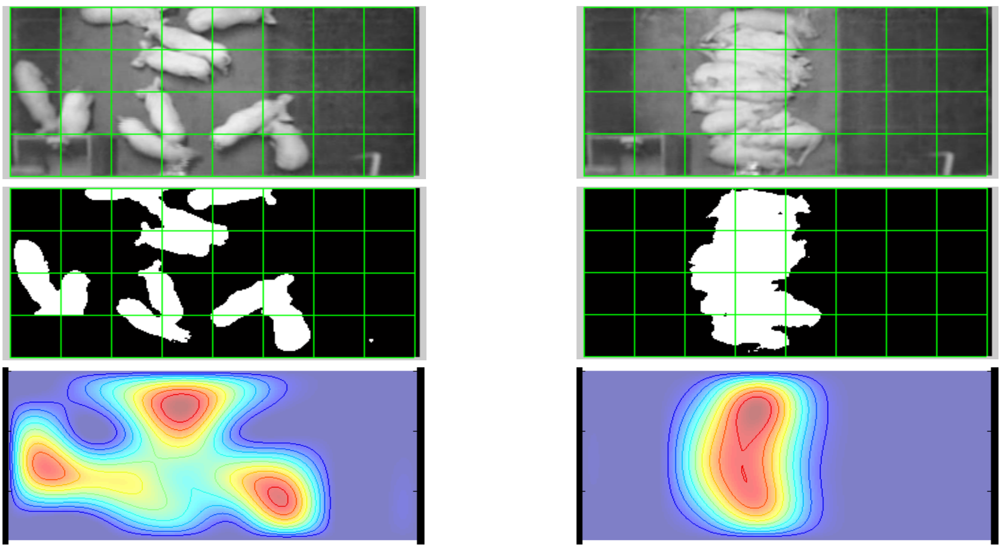

Figure 3. Example of the spatial occupation index for active pigs compared to resting pigs

From the occupational image $I_o(x,y,t)$ the occupation index $o_i(t)$ for the zone Z_i was calculated as the fraction of pixels corresponding to a region of the image occupied by pigs with respect to the total number of pixels within the zone Z_i:

$$o_i(t) = \frac{\sum_{(x,y)\in Z_i} I_o(x,y,t)}{\sum_{(x,y)\in Z_i} 1} \tag{5}$$

Labelling procedure

The behaviours of the animals were manually labelled during a 26-hour period, from 2 hours before the introduction of environmental enrichments in the form of two wooden logs and a chain (26th of August 2009 at 10.00).
The comportment of the animals in two pens was visually labelled in every recorded video image using a specially made user interface. The labelling was either of the behaviour types 'fighting', 'biting', 'nuzzling', 'suckling', 'belly nosing', 'feeding', 'playing' and 'none' (for any other type of behaviour). For 'biting' behaviour, a distinction was made for biting the ear, tail, hip or nose respectively. The 'playing' behaviour was also labelled separately as either playing with the wood logs or with the chain.
The labelling procedure took more than 2 months.

Results and discussion

In general, the environmental enrichments (wood logs and chain) introduced to the pens have led to increase of playing behaviour of piglets and reduction of demonstration of other types of behaviours labelled (Table 1).

Table 1. Effect of environmental enrichment on the frequency, number and duration of the behaviour. T0 is the time before introduction of the environmental enrichments; T1 is the time in presence of environmental enrichments; T2 is the time after the enrichments of the pens

Behaviour	**Observations frequency (%)**			**Mean duration of the behaviour (s)**			**Number of behaviour**		
	T0	**T1**	**T2**	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**
Nuzzling	9,43	7,43	2,22	23	88	39	15	3	2
Suckling	22,15	0,25	10,26	199	0	90	4	0	4
Belly nosing	3,85	8,19	0	89	39	0	8	7	0
Fighting	0,06	0,10	1,34	31	17	16	1	4	3
Biting ear	1,50	0,40	3,15	7	5	56	8	3	2
Biting tail	3,56	0,08	0	18	3	0	7	1	0
Biting hip	0	0	0	0	0	0	0	0	0
Biting leg	4,03	0	0	36	0	0	4	0	0
Playing		33,96	4,05		21	47		38	20
Playing		17,14	26,48		34	52		18	18

The introduction of environmental enrichments was accompanied by a reduction in the frequency and the number of nuzzling, suckling and biting behaviours. This decrease can be attributed to the enrichment since the piglets' attention was focused on playing with the wood

logs and the chain. The frequency of belly nosing and fight, on the contrary, increased while the duration of such comportment diminished.
The interest of piglets to the wood logs had decreased over time, but the duration had increased while the attention to the chain had slightly increased as frequency and duration.

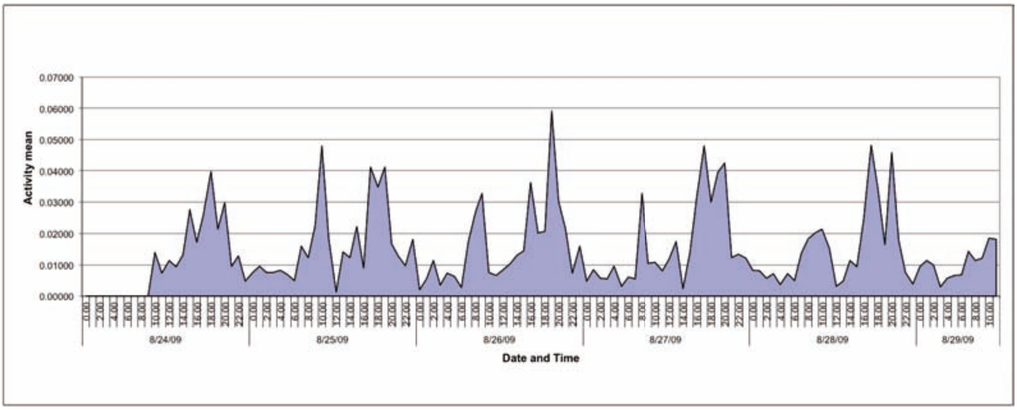

Figure 4. Activity mean of the piglets calculated continuously during the experiment.

The introduction of the environment enrichment affected considerably the dynamic daily activity pattern of the animals. During the day of environmental enrichments' introduction the piglets showed an increase of their activity index, which diminished during the next day and was back on average after 4 days (Figure 4).

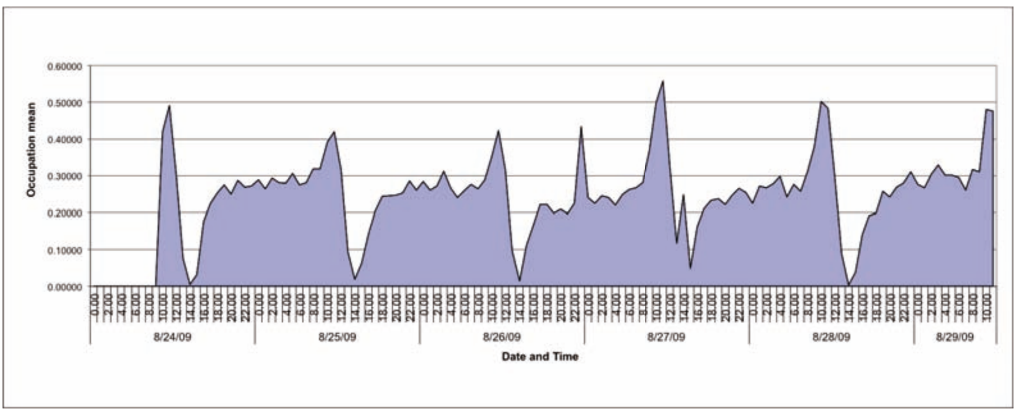

Figure 5. Occupation mean of the piglets calculated continuously during the experiment.

The occupation index, instead, slowly decreased on the day of the enrichment, since the pigs formed 4 different groups, one bigger around the chain and three smaller around each of the wooden stick. Also the occupation index returned to the average after 4 days (Figure 5).

Conclusion

This paper describes an automatic camera-based system for continuously monitoring in a contactless way the behaviour of a group of pigs.

The activity and occupational index were calculated and used for understanding the effect of environment enrichments in pigs' behaviours. The behaviour of the animals in the pen in every recorded video image was visually labelled using a specially made user interface. The results have shown that the pigs were really interested to the environmental enrichment, while the nuzzling, suckling and biting behaviours diminished. Their attention to the wood logs and the chain dropped considerably over time and everything went back to normal after four days.

The activity index followed this pattern showing an increase of the activity of the animals on the day of the enrichment and a decrease afterwards to return to average values in four days. Activity and occupation index showed to be useful for assessing behaviour in a group of animals. Moreover this might indicate that an automatic camera-based system can be used for increasing animals' welfare.

References

Berckmans, D. (2008). "Precision livestock farming (plf) - preface." Computers and Electronics in Agriculture 62(1): 1-1.

Borgonovo F., Costa A., Leroy, T., Aerts, J. M., Berckmans, D. and Guarino, M. (2009). "Real Time Monitoring of Pig's Feeding Behaviour and Pig's Activity Classification" Biosystems Engineering. *Submitted*.

Cangar, O., Aerts, J. M., Buyse, J. and Berckmans, D. (2008). "Quantification of the spatial distribution of surface temperatures of broilers." Poultry Science 87(12): 2493-2499.

Costa, A., Borgonovo, F., Leroy, T., Berckmans, D. and Guarino, M. (2009). "Dust concentration variation in relation to animal activity in a pig barn." Biosystems Engineering 104(1): 118-124.

Frost, A. R., Parsons, D. J., Stacey, K. F., Robertson, A. P., Welch, S. K., Filmer, D. and Fothergill, A. (2003). "Progress towards the development of an integrated management system for broiler chicken production." Computers and Electronics in Agriculture 39(3): 227-240.

Leroy, T., Borgonovo, F., Costa, A., Aerts, J.-M., Guarino, M. and Berckmans, D. (2008). Real-time measurament of pig activity in practical conditions. ASABE, American Society of Agricultural and Biological Engineers.

Leroy, T., Stroobants, S., Aerts, J. M., D'hooge, R. and Berckmans, D. (2009). "Automatic analysis of altered gait in arylsulphatase a-deficient mice in the open field." Behavior Research Methods 41(3): 787-794.

Leroy, T., Vranken, E., Van Brecht, A., Struelens, E., Sonck, B. and Berckmans, D. (2006). A computer vision method for on-line behavioral quantification of individually caged poultry, Amer soc agricultural & biological engineers.

Otsu, N. (1979). "Threshold selection method from gray-level histograms." Ieee Transactions on Systems Man and Cybernetics 9(1): 62-66.

Front-face fluorescence spectroscopy: a tool for differentiating sheep milk originating from different genotypes and feeding systems

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Abstract:
Fifty (*n = 50*) ewe's milk spectra were scanned after excitation set at 250, 290, 322 and 380 nm and emission set at 410 nm. Thirty (30) out of the 50 samples belonged to a trial composed of two different genotypes (i.e. Comisana *versus* Sicilo-Sarde); the second trial composed of 20 samples were obtained from the Sicilo-Sarde genotype with two different feeding systems in pens (soybean *versus* scotch bean). The five fluorescence spectra used jointly allowed a good classification of the four groups since 44 out of 50 samples were correctly classified. It was concluded that fluorescence spectroscopy could be considered as a powerful tool for differentiating between milk according to both genotype and feeding system.

Keywords: ewe's milk, feeding, fluorescence, chemometric

Introduction

Although intensification of livestock in Tunisia is increasing, its integration with crops is limited. Integration of forage into grain-fed farming has not really succeeded. The cultivated forage area has remained constant during the last decade and its contribution to animal feeding is limited. However, livestock numbers have significantly increased, especially, dairy ewes. Moreover, the contribution of natural pasture and range in the feed calendar was dramatically decreased due to frequent drought and overgrazing. To better cope with this problem and to meet animal requirements, increasing amounts of feedstuffs, namely soybean meal are imported from some western countries, which weigh down the national economy.
In the last few years, the economic situation in the world involved rising prices of soybean meal constituting the basic raw materials in concentrated food formulations for Tunisian livestock. Therefore, the research for better alternatives by partial or total replacement of soybean meal with local food resources is essential. Although soybean meal has been well established as the main protein source for animal nutrition, scotch bean is recently becoming available in Tunisia as a local and cost effective product. Consequently, it could be used as a substitute for soybean meal. As a protein supplement in rations of growing and fattening sheep, previous research studies have shown that scotch bean meal gave similar gain and feed efficiency as soybean meal did.
Recently, some research studies have assessed the potential of visible near infrared (Vis-NIR) spectroscopy to predict some chemical parameters of ewe's milk with pasture, soybean and scotch bean feeding and belonging to two genotypes (Comisana and Sicilo-Sarde). Among the investigated parameters, good prediction of protein, ash, lactose and freezing point were observed, while negative results (i.e. only discrimination between high and low values) were observed for pH and fat values suggesting Vis-NIR spectroscopy for the prediction of these

two parameters is not useful (Mouazen *et al*., 2009). To investigate the ability of Vis-NIR to discriminate milk samples according to the feeding system and genotype, the same research group (Mouazen *et al*., 2007) has applied factorial discriminant analysis (FDA) on the first five principal components (PCs) scores of the PCA performed on Vis-NIR and good results were obtained since correct classification amounting to 92.5% and 95% for respectively the calibration and validation data sets were observed. However, before using FDA, the authors have divided the spectral collection into two data sets: two-thirds were used for the calibration data sets and one-third for the validation data sets; this could induce some misclassification, taking into account: (i) that only one milk sample was scanned for each lactation period; and (ii) the limited number of milk samples in each group ($n = 10$ or $n = 15$).
Front face fluorescence spectroscopy (FFFS) has been used for discriminating between milk samples according to the feeding system (Hammami *et al*., 2010; Maâmouri *et al*., 2008; Rouissi *et al*., 2008) or genotype (Zaïdi *et al*., 2008). Although, some research studies were recently performed to determine the quality of ewe's raw milk following the use of Vis-NIR, there is no study, at our best knowledge, on using FFFS for differentiating simultaneously milk samples according to the feeding systems and genotypes. Thus, the objective of this study was to determine the feasibility of FFFS to discriminate between 50 ewe's milk samples according to the feeding system (pasture, soybean and scotch bean meal) and genotype (Sicilo-Sarde *versus* Comisana).

Materials and methods

The study corresponds to two experiments, each carried out separately: the objectives of the first and second studies were to determine respectively the effect of the: (i) feeding system and (ii) genotype on the quality of the milk.

Experiment 1

Twelve 5-year-old Sicilo-Sarde ewes, weighing 42.2 kg on average, at their third lambing were kept at 17 °C in individual boxes and in an environmentally controlled sheepfold. Zootechnical performances and energy intake were recorded individually. After 2 weeks of adaptation, ewes were divided into two homogenous weight matched groups ($n = 6$). The two experimental diets differed in terms of protein sources (soybean *versus* scotch bean, data not shown). Ewes remained on the experiment until 10 weeks post-partum. Diets were iso-energetic and were given in restricted amounts according to the feed intake of the two groups.

Experiment 2

Two genotypes, Comisana ewes ($n = 156$, weight = 45 kg) aged 4.3 years old and Sicilo-Sarde ewes ($n = 50$, weight = 50 kg) aged 5.2 years old were used. Animals were maintained on pasture feeding (yearly pasture of barely, oat, and clover or permanent pasture of ray grass) and supplemented with oat hay and concentrate (34 corn, 17 wheat, 19 soya, 25 barely, and 5 g 100 g^{-1} mineral and vitamin premix). They were inspected by a qualified shepherd on a daily basis, and routine animal care and vaccination procedures were conducted as prescribed by best practice protocols. Ewes remained on the experiment until 15 weeks post-partum.

All the analyses were determined at seven-day intervals during 10 (experiment 1) and 15 (experiment 2) weeks lactation period. For each group, the milk samples collected from the different ewes (n = 6 per group for experiment 1; and n = 156 and 50 for experiment 2) were mixed and an aliquot of 100 ml was taken and kept in freezer at -40 °C until analyses. Before each analysis, milk samples were thawed during the night at 4 °C in a refrigerator. Thus the number of the analysed samples was 50 samples (10 samples for each group of experiment 1 and 15 samples for each group of experiment 2).

<u>Physico-chemical parameter</u>
Milk samples were analysed for pH, density, dry matter, fat, protein, lactose, ash and freezing point by using LactoScan (Milkotronic LTD, Serial n° 4696, Hungary).

<u>Fluorescence measurements</u>
Fluorescence spectra were recorded using a Fluorolog-2 spectrofluorimeter (Spex-Jobin Yvon, Horiba, The Netherlands) mounted with a variable angle front-surface accessory. The incidence angle of the excitation radiation was set at 22.5° to ensure that reflected light, scattered radiation, and depolarisation phenomena were minimised. The emission spectra of aromatic amino acids and nucleic acids (AAA+NA) (280-450 nm; increment 1 nm), tryptophan residues (305-450 nm; increment 1 nm), vitamin A (330-540 nm; increment 1 nm) and riboflavin (400-640 nm; increment 1 nm) were recorded with the excitation wavelengths set at 250, 290, 322 and 380 nm, respectively. The excitation spectra of the vitamin A (280-350 nm; increment 1 nm) were acquired with the emission wavelength set at 410 nm. All spectra were corrected for instrumental distortions in excitation using a rhodamine cell as a reference channel.

<u>Statistical analyses</u>
In order to reduce scattering effects and to compare milk samples, fluorescence spectra were normalised by reducing the area under each spectrum to a value of 1. Mainly the shift of the peak maximum and the peak width changes in the spectra were considered following this normalisation.

The principal component analysis (PCA) was applied to the normalised spectra to investigate differences between the milk samples. The PCA transforms the original variables into new axes called principal components (PCs), which are orthogonal, so that the data set presented on these axes are uncorrelated with each other. This statistical multivariate treatment was earlier used to observe similarities among different milk samples (Karoui *et al.*, 2005), reducing the dimension to two or three PCs, while keeping most of the original information found in the data sets.

In a second step, FDA was performed, separately, on the first 10 PC scores of the PCA of each excitation and emission spectra, which contains the whole information found in raw data sets. The aim of this technique is to predict the membership of an individual to a qualitative group defined as a preliminary. A group was created for each type of milk, i.e. milk sample from Sicilo-Sarde ewes fed on scotch bean (Ssco), milk samples from Sicilo-Sarde ewes fed on soybean (Ssoy), milk samples from Sicilo-Sarde ewes with pasture feeding (Spas) and milk samples from Comisana ewes with pasture feeding (Cpas). The method cannot be applied in a straightforward way to continuous spectra because of the high correlations occurring between the wavelengths. Advantages were found in the preliminary transformation of the data into their PC scores. FDA assesses new synthetic variables called "discriminant factors", which are linear combinations of the selected PCs, and allows better separation of the centres

of gravity of the considered groups. The individual milk samples can be reallocated within one of the four groups (Ssco, Ssoy, Spas or Cpas) or the three groups when only the Sicilo-Sarde ewe's milk was considered (Ssco, Ssoy, Spas). For each milk sample, the distance from the various centres of gravity of the groups is calculated. The milk sample is assigned to the group where its distance between the centre of gravity is the shortest. Comparison of the assigned group to the real group is an indicator of the quality of the discrimination.
With leave one-out cross-validation, the same sample is used both for calibration and validation model. A sample is left out from the calibration data set and the model is calibrated on the remaining data points. Then the value for the left-out sample is predicted and the prediction residual is computed. The process is repeated with another sample of the calibration set, and so on until every sample has been left out once; then all prediction residuals are combined to compute the validation step.
Finally, the first 10 PC scores of the PCA performed on each of the fluorescence spectral data set were pooled into one matrix (concatenation) and this new table was analysed by FDA (Karoui *et al.*, 2004). The process consists of putting one beside the other in the same matrix using the first 10 PCs of the PCA resulting from each excitation and emission fluorescence spectra. The aim of the concatenation technique was to take into account the information contained in the fluorescence spectra recorded at different excitation and emission spectra allowing to improve the discrimination of the investigated milk samples according to the feeding system and genotype.
PCA was performed under DOS by using the "Saisir" package of D. Bertrand (INRA, Nantes) and the FDA was performed using StatBoxPro (Grimmer Logiciels, Paris, France).

Results and discussion

Physico-chemical analyses
A significant difference between the feeding systems (pasture feeding *versus* pen feeding) was observed regardless of the genotype (Comisana and Sicilo-Sarde). Considering milk samples belonging to Cpas and Spas groups, no significant difference between all the investigated physico-chemical parameters was observed indicating that ewe's genotype did not present a significant effect on the physico-chemical parameters ($P \geq 0.05$).
Similar results were obtained for milk samples originating from Ssco and Ssoy groups, except for the amount of fat; For the parameter fat, the highest values were observed for Ssoy group (7.85 g $100g^{-}1$), while the lowest one were found with Ssco group (6.75 g $100g^{-1}$).

Fluorescence measurements
The feeding system, genotype and lactation stage did not (seem to) have an impact on the emission spectra of AAA+NA and tryptophan fluorescence spectra. They showed similar trends with a maximum located around 347-348 nm (data not shown). Quite similar results were obtained on the emission spectra of vitamin A (data not shown) which presented a maximum around 408-409 nm.
Regarding the riboflavin spectra, we observed a clear discrimination between milk samples according to the feeding system and genotype, regardless the lactation stage. Indeed, Figure 1a shows a large difference between milk samples according to the feeding systems (pasture feeding *versus* pen feeding), regardless of the considered genotype. The investigated milk samples acquired after 1 week of lactation showed two maxima located around 440 and 520

nm. The peak at 520 nm has been attributed to riboflavin (Miquel Becker *et al.*, 2003), while the peak located around 440 nm has not been yet identified. Figure 1 seems to demonstrate that milk samples collected from Spas and Cpas groups were less oxidised than those belonging to the two other groups.

The vitamin A excitation spectra showed a maximum and a shoulder around 320 and 305 nm, respectively. From Figure 1b, milk samples originating from Spas and Cpas groups differed from those being fed in the pens (Ssco and Ssoy groups). This difference could be due to the variation in fat composition and/or protein-lipid interactions; indeed, at week 1, milk samples belonging to Spas and Cpas groups presented the highest level of fat (i.e. ~ 11 g 100 g^{-1}) while milk samples originating from the two other groups presented the lowest one (i.e. 7.1 and 7.93 g 100 g^{-1} respectively for groups Ssco and Ssoy).

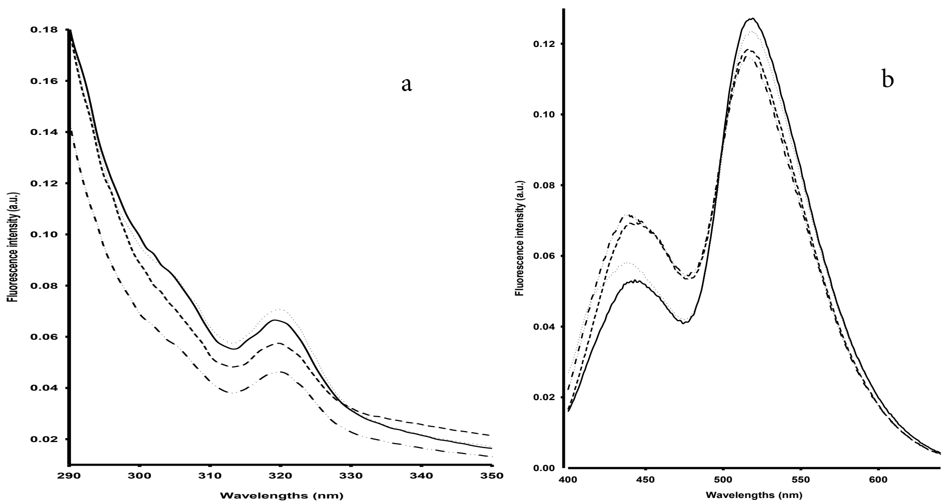

Figure 1. Normalised fluorescence spectra recorded following: (a) excitation at 380 nm and (b) emission at 410 nm on milk samples of 1 week for groups Cpas (—), Spas (…), Ssco (– – –) and Ssoy (—..—..).

<u>Milk discrimination based on aromatic amino acids and nucleic acids, tryptophan, riboflavin and vitamin A fluorescence spectra throughout the lactation stage</u>

The ability of each of the fluorescence spectra to differentiate milk samples according to the feeding system and genotype was investigated by applying the FDA on the first 10 PC scores of the PCA performed on each spectral data set. Before applying the FDA, four milk groups were created (Ssco, Ssoy, Spas and Cpas). The best result was obtained with vitamin A excitation spectra (data not shown). According to discriminant factor 1 accounting for 85% of the total variation, milk samples belonging to groups Spas and Cpas were separated from groups Ssco and Ssoy. A correct classification rate of 76% was observed. Indeed, Cpas, Ssco, Spas and Ssoy were predicted with correct classification rates amounting to respectively 80, 90, 66.7 and 70 %. The obtained result suggested the ability of the excitation vitamin A spectra to be a useful probe for the evaluation of milk samples according to the feeding system and genotype. This is in agreement with previous investigations reporting that excitation vitamin A spectra could be utilised for the differentiation between ewe milk samples (Hammami at al. 2010). The obtained result was confirmed following the application of the FDA to the Spas, Ssco and Ssoy groups since correct classification amounting to 88.6% was observed.

<u>Global analysis of milk samples based on excitation and emission fluorescence spectra throughout the lactation stage: concatenation</u>

Milk is a complex product, which contains many intrinsic molecules that could fluoresce at specific excitation-emission wavelengths. The five fluorescence spectra acquired on milk samples from Sicilo-Sarde and Comisana ewes could be complementary. Taking this into consideration, a better discrimination between the investigated milk samples according to both feeding system and genotype could be found by jointly analysing the five spectral data sets. This could be obtained by using the concatenation technique. The similarity map of the FDA applied to the four groups is shown in Figure 2a. The four groups were well separated. Indeed: (i) Ssco milk samples presented positive scores according to discriminant factors 1 and 2; (ii) Spas group exhibited negative values according to discriminant factors 1 and 2; (iii) Ssoy milk samples had positive scores according to discriminant factor 1 and negative values according to discriminant factor 2; and (iv) Cpas group presented negative values according to discriminant factor 1 and positive scores following discriminant factor 2.

Correct classification amounting to 88% was observed following the application of FDA with leave one-out cross-validation (Table 1a). No milk sample belonging to groups Spas and Cpas was classified as groups Ssco or Ssoy and *vice versa*. The concatenation technique allowed also a good discrimination of milk samples according to the genotype, which was not observed when fluorescence spectra was analysed separately. Regarding group Cpas, only 1 sample was classified as belonging to group Spas, while 3 samples belonging to group Spas were assigned to group Cpas. Nine out of 10 samples belonging to Ssoy and Ssco milk groups were correctly classified. The rate of correct classification was similar to those found with Vis-NIR by Mouazen *et al.* (2007), although the latter authors did not apply FDA with leave one-out cross-validation. In addition, FFFS gave a better separation of the investigated milk samples than the Vis-NIR (Mouazen *et al.*, 2009).

The FDA applied to milk samples of the three Sicilo-Sarde ewes allowed also a good separation (Figure 2b). A correct classification rate amounting to 88.6% was observed when the fluorescence data sets were analysed by the concatenation method (Table 1b). Again, better differentiation was obtained with the concatenated fluorescence spectra than with Vis-NIR spectra (Mouazen *et al.* 2009).

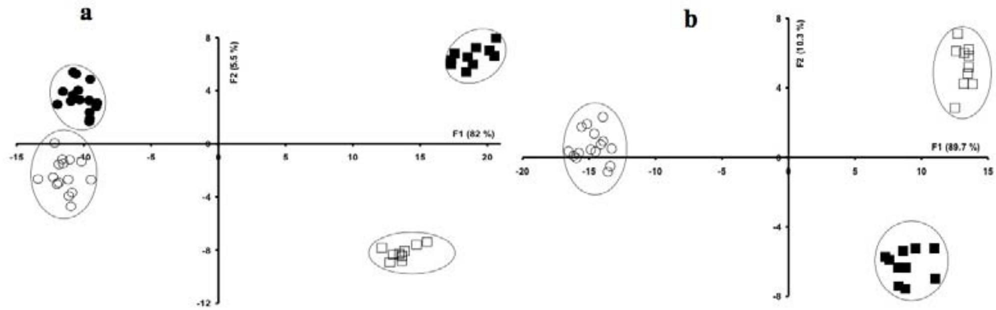

Figure 2. Discriminant analysis similarity map determined by discriminant factors 1 (F1) and 2 (F2). Factorial discriminant analysis (FDA) was performed on the concatenated PCs corresponding to the PCA performed on the aromatic amino acids and nucleic acids, tryptophan fluorescence spectra, riboflavin and vitamin A for groups: (a) Cpas (•), Spas (o), Ssco (■) and Ssoy (□) and (b) Spas (o), Ssco (■) and Ssoy (□).

Conclusion

The present investigation demonstrated the ability of front face fluorescence spectroscopy (FFFS) to monitor changes in ewe's milk according to both feeding system and genotype throughout the lactation period. Following the application of concatenation technique, 88% of correct classification was obtained from the FDA applied to the four groups. Although we found a relatively high level of correct classification, more samples should be analysed under the same conditions in order to test the robustness of the established model.

Table 1. Classification table of milk samples throughout the lactation period based on aromatic amino acids and nucleic acids (AAA+NA), tryptophan, riboflavin and vitamin A spectra and the concatenated fluorescence spectra for the four Spas, Cpas, Ssco and Ssoy groups (a) and three Spas, Ssco and Ssoy groups (b)

(a)

	Feeding system				
Observed[c] Predicted[d]	Cpas	Ssco	Spas	Ssoy	% Correct classification
	Concatenation: Fluorescence				
Cpas	**14**	-	1	-	**93.3**
Ssco	-	**9**	-	1	**90**
Spas	3	-	**12**	-	**80**
Ssoy	-	1	-	**9**	**90**
Total					**88**

(b)

	Feeding system			
Observed[c]	Ssco	Spas	Ssoy	% Correct
	Concatenation: Fluorescence			
Ssco	**7**	-	3	**70**
Spas	1	**14**	-	**93.3**
Ssoy	-	-	**10**	**100**
Total				**88.6**

[c] The number of measured milk samples; [d] The number of predicted milk samples

References

Hammami, M., Rouissi, H., Salah, N., Selmi, H., Al-Otaibi, M., Blecker, C. and Karoui, R. 2010. Fluorescence spectroscopy coupled with factorial discriminant analysis technique to identify sheep milk from different feeding systems. Food Chemistry **122** 1344-1350.

Karoui, R., Dufour, E., Pillonel, L., Picque, D., Cattenoz, T. and Bosset, J.O. 2004. Determining the geographic origin of Emmental cheeses produced during winter and summer using a technique based on the concatenation of MIR and fluorescence spectroscopic data. European Food Research and Technology **219** 184-189.

Karoui, R., Martin, B. and Dufour, E. 2005. Potentiality of front-face fluorescence spectroscopy to determine the geographic origin of milks from Haute-Loire department (France). Le Lait **85** 223-236.

Maâmouri, O., Rouissi, H., Dridi, S., Kammoun, M., De Baerdemaeker, J. and Karoui, R. 2008. Mid infrared attenuated total reflection spectroscopy as a rapid tool to assess the quality of Sicilo-Sarde ewe's milk during the lactation period after replacing soybean meal with scotch bean in the feed ration. Food Chemistry **106** 361-368.

Miquel Becker, E., Christensen, J., Frederiksen, C. S. and Haugaard, V. K. 2003. Front face fluorescence spectroscopy and chemometrics in analysis of yogurt: rapid analysis of riboflavin. Journal of Dairy Science **86** 2508-2515.

Mouazen, A.M., Dridi, S., Rouissi, H., De Baerdemaeker, J. and Ramon, H. 2007. Feasibility study on using VIS-NIR spectroscopy coupled with factorial discriminant analysis technique to identify sheep milk from different genotypes and feeding systems. Journal of Near Infrared Spectroscopy 15 359-369.

Mouazen, A.M., Dridi, S., Rouissi, H., De Baerdemaeker, J. and Ramon, H. 2007. Prediction of selected ewe's milk properties and differentiating between pasture and box feeding using visible and near infrared spectroscopy. Biosystems Engineering 104 353-361.

Rouissi H., Dridi S., Kammoun M., De Baerdemaeker J. and Karoui, R. 2008. Front face fluorescence spectroscopy: a rapid tool for determining the effect of replacing soybean meal with scotch bean in the ration on the quality of Sicilo-Sarde ewe's milk during lactation period. European Food Research and Technology **226** 1021-1030.

Zaïdi, F., Rouissi, H., Dridi, S., Kammoun, M., De Baerdemaeker, J. and Karoui, R. 2008. Front face fluorescence spectroscopy as a rapid and non destructive tool for differentiating between Sicilo-Sarde and Comisana ewe's milk during lactation period: a preliminary study. Food and Bioprocess Technology **1** 143-151.

Experimental setup for the study of a computer vision based automatic lameness detection system for dairy cows

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Abstract

The objective of this study is to develop an automatic detection system to quantify the severity of lameness for dairy cows, based on both analysis of video recordings of the cow's gait and with her associated behaviour. This paper describes the need for this type of research, and will discuss the experimental setup. During three recording sessions, 92.5% of the animals in the herd were recorded while walking through the video-corridor with at least two full gait cycles. This result indicates that the chosen setup, consisting of a corridor from the milking area, which the cows enter one by one through a separation gate, and two video cameras in two different angles, can be a useful tool for gait analysis.

Keywords: dairy cattle, gait, lameness, automatic detection, computer vision

Introduction

In modern European dairy farming, there is a trend for a decreasing number of dairy farmers, but on the same time the herd sizes become bigger (Eurostat, 2011). Bigger herds imply that the farmer spends less time to each individual cow to monitor its health and productive status. Automation and new technologies in the feeding and milking process help the farmer to solve this problem. A logical next step would be to automate the monitoring of the animals. As known, intensive farming systems sometimes have side effects, especially concerning the welfare of the animals. Lameness is such a side effect, and it is a major concern in modern dairy farming. It is rated as the second largest problem in intensive dairy farming, after mastitis (Kossaibati *et al*., 1997). The prevalence of lameness ranges from 5% to 70%, depending on several farm conditions (Clarkson *et al*., 1996; Barker *et al*., 2010; Tadich *et al*., 2010). This prevalence might even be an underestimation due to the low awareness, difficult recognition and the poor registration of lameness cases (Whay, 2002; Leach *et al*., 2010a). Under conditions of robotic milking, painful lameness impairs with visits to the milking station and reduces milking frequency (Borderas *et al*., 2008). Additionally, the issue is part of the intensified welfare societal discussions (Whay *et al*., 1998; Leach *et al*., 2010b). The economic impact of lameness is significant for the farmer, because losses increase with severity and the type of lameness (Kossaibati & Esslemont, 1997; Wilshire & Bell, 2009; Bruijnis *et al.*, 2010). These losses comprise the treatment costs, the indirect losses of decreased milk yield, reduced fertility, higher replacement rates and a lower selling price of the culled lame animal (Ettema & Ostergaard, 2006; Bruijnis *et al.*, 2010).

Lameness is often visually scored by a trained person in order to rate the lameness incidence on the farm (Clarkson *et al.*, 1996; Barker *et al.*, 2010; Borderas *et al.*, 2008). There are several scoring methods available (Sprecher *et al.*, 1997; Amory *et al.*, 2006; Tuyttens *et al.*, 2009). The most used method is the 5-point lameness scale developed by Sprecher *et al.* (1997). However, the assumption is that lameness scoring in practical situations is hardly done (Whay, 2002). When done, it is not frequently enough and uniformity in scoring methods will not be present (Brenninkmeyer *et al.*, 2007; Thomsen *et al.*, 2008; Van Nuffel *et al.*, 2009). This was the main reason for several researchers to start the development of automatic scoring methods.

Automation of lameness detection in dairy cattle is a hot topic in agricultural science. Many solutions are documented, and some of them even on the market. One method for automatically detecting lameness is based on strain gauges (Pastell *et al.*, 2006; Pastell *et al.*, 2008a) or force sensors (Kujala *et al.*, 2008; Pastell *et al.*, 2008b) to measure the weight load in each leg. This system can detect lameness very well, but the installation of the system is costly. Another disadvantage is the importance of the hoof placement on the scale. Misplaced hoofs lead to unsuccessful measurements.

Another promising technique to detect lameness is based on the lying behaviour of the animal (Chapinal *et al.*, 2009; Ito *et al.*, 2010). High lying times, long lying bouts and variability in the duration of the lying bouts could be associated with severely lame animals. This technique was only able to detect lameness in a later stage, when the cow was suffering from it (Whay *et al.*, 1998). Our research is about detecting lameness in any stage. Detecting lameness in an early stage is preferable, so that treatment can be started on time before the cow starts suffering, and as useful as being able to follow the course of lameness over time.

Previous studies that mimic the farmer‘s observations were the logical next step. These studies used vision techniques to detect lameness and showed some promising results (Song *et al.*, 2008; Pluk *et al.*, 2010; Poursaberi *et al.*, 2010). The results in the study of Song *et al.* (2008) showed a correlation coefficient of 94.8% between the human observed hoof locations and the image processed hoof locations in the frame.. This suggested the feasibility of vision analysis as a method to present the cows’ locomotion. Pluk *et al.* (2010) found a relation between the step overlap and the manual five-point gait scores of Sprecher *et al.* (1997). This indicates the possible use of the step overlap variable as an automatic lameness detection tool. However, Pluk *et al.* (2010) stress that this variable is not strong enough to use it as a single classifier for lameness. The study of Poursaberi *et al.* (2010) went a step further. They filtered the body of the cow out of the image, and used the curvature of the back arch as a lameness indicator. The results were very promising. The next step will be to combine the findings of these studies in a new experiment. Therefore, in this paper, the experimental setup for the next step in this process is made. The objective of this research will be to combine gait parameters that can be visually detected from the image, and incorporate them all together in a robust lameness detection tool. In this research we would like to elaborate on the practicability and robustness by also looking at different cows (genetics) held in different circumstances (climate, housing, feeding).

Some remarks should be considered when using vision technology to detect lameness. The domesticated dairy cattle are descendants from ranging wild cattle that were prone to predator

attack. In order to improve their chance on survival, they masked any signs of pain and its implied weakness (Phillips, 2002). This can imply that cows will only show their pain when their level of pain is high and their suffering unbearable. This might be a drawback in the early detection of lameness based on visual information as only a severely lame cow will show pain by an uneven or changed gait. It is also possible that cows hide their weakness from other herd mates in order not to lose their rank in the social hierarchy of the herd. A lower rank implies less eating, less lying and more standing, which in turn leads to an increased chance on lameness (Galindo & Broom, 2000; Galindo *et al.*, 2000; Galindo & Broom, 2002).
In order to develop an automatic detection system to quantify the severity of lameness for dairy cows, based on both the analysis of video recordings of the cow's gait and the behaviour of the animal, this paper will determine the feasibility of the experimental setup of this project.

Material and Methods

Animals and housing

The study comprised 70 lactating Holstein cows on a commercial dairy farm. The average milk production on the farm in 2009 was 12500 kg/year/cow. The cows were housed in a fully roofed free stall open cowshed without cubicles and dry manure floor. The cows were milked in an adjacent concrete-floor parlour equipped with two milking robots. The minimal time between two milking sessions was set at 4 hours, and if the cows did not come by themselves in 8 hours, they were fetched from the herd. The cows were fed concentrates according to their milk production in a concentrate feeding station, and in the milking parlour. The maximal amount of allocated concentrates was 10.0 kg/day. Twice a day, a TMR was supplied by a local cooperation.

Sensors

Cow gait was recorded from two perspectives: one in side view, and one in top view. The camera in side view was an AVT IEEE1394 Guppy F080C colour camera (Allied Vision Technologies GmbH, Stadtroda, Germany) with a resolution of 1024x768 pixels in RGB colour format, at a frame rate of 30 fps. The camera in top view was an AVT IEEE1394 Guppy F036C colour camera (Allied Vision Technologies GmbH, Stadtroda, Germany) with a resolution of 800x640 pixels in RGB colour format, at a frame rate of 30 fps. The images were taken in a concrete-floor corridor when the cows left the milking area. A separation gate made the cows enter the corridor one by one. The actual recording started after a time delay when the gate opened to let the animal pass, and stopped after a predefined time period of 15 seconds.
The cameras were connected to the operating computer by IEEE1394-FireWire cables. In order to cover the 30 meter distance between cameras and computer, 6 port FireWire Repeater Boxes were used. The hubs were connected to a 12 VDC power net in order to operate at the maximal transfer speed of 400 megabits per second (Mbps).
Visits to the milking station and feeding stations, and gate passes were recorded by the management software.

Scoring

The quality of the recorded videos was determined on the walking behaviour of the cow (Table 1). Each recording was manually labelled by one of the four categories in Table 1.

Table 1. Evaluation of video usability based on animal walking behaviour

Video score	Resulting Behaviour
Category 1	No video records available of the animal
Category 2	Cow stops walking, and keeps standing still. Less than 2 steps are taken before/after stop
Category 3	Cow stops walking or slows down. More than 2 steps are taken before/after stop
Category 4	Cow walks at steady pace the entire length of the path

Database building

Data included in this study was collected twice a week on the farm. Gate passing of the cow was registered by the management software by date, time and cowID. The recorded videos received a date- and time stamp, so the video file could be linked to a gate passing event in order to get the cow identification, and a video usability categorisation. All the data were stored on an 8Tb Western Digital ShareSpace storage unit (Western Digital, Lake Forest, USA).

Results

The experimental setup makes it possible to make video recordings of walking cows when they leave the milking area. The video in side view position is recorded with a resolution of 1024x768 pixels, and the top view videos have a resolution of 800x640 pixels. In order to reduce the file size and discard the recording of unnecessary data, a region of interest is selected. Only the region in the picture where the cow is walking is saved to the disk. This allows us to save up to 2/3rd of disk space. The quality of the picture was checked. A snapshot of such a video in side view position can be seen in Figure 8. A top view snapshot can be seen in Figure 9. In further research, gait characteristics will be calculated from these video-frames.

Figure 1. Side view snapshot from a recorded video

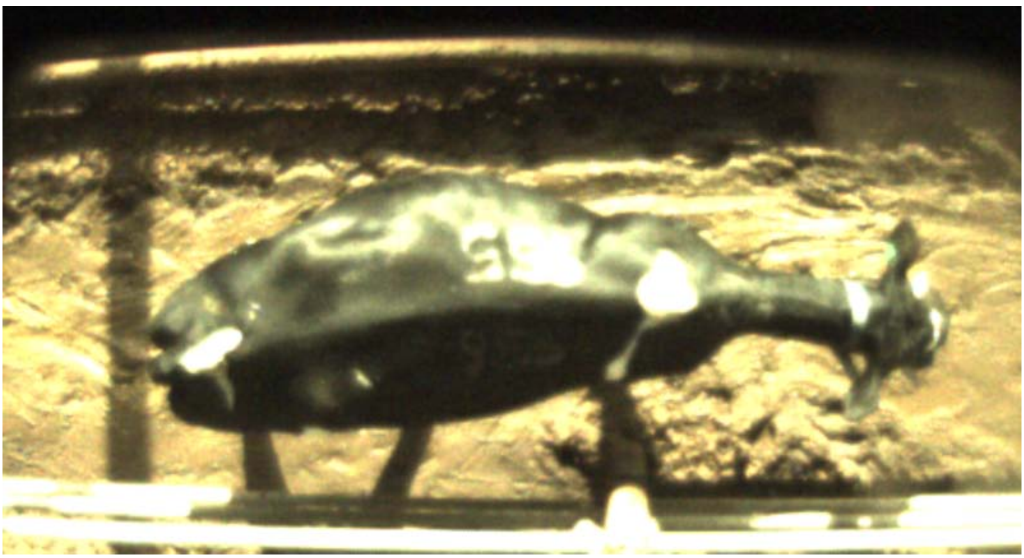

Figure 2. Top view snapshot from a recorded video

The objective of this study was to have at least 1 recording of each cow per session. In a two week period, three recording sessions were executed. The first was 6 hours and 15 minutes long, the second was 9 hours 30 minutes long and the last one was 6 hours and 45 minutes long. A total sum of 22 hours and 30 minutes was covered with recordings. The first two sessions started around 07.15 AM local time, and the third one around 09.00 AM.
The results are summarized in Table . The results of the sessions are expressed in absolute values (column 2, 4, 6 and 8) and in relative values (column 3, 5, 7 and 9). The 'Total' column is not a new session, but presents the animals that were in all three sessions. The session total

of the column 'Total' (67) is smaller than the session total of the other three sessions (70, 70 and 71, resp.) due to the exclusion of seven dried off animals and the inclusion of three calved animals in the time between the two last sessions. 67 animals attended all three sessions (last two columns), three cows attended two sessions, and four cows attended only one session. The column 'Total' shows that one cow was not recorded in either one of the three sessions. 50 cows (74.6%) were recorded in at least one of the three sessions in which they walked the full length of the path. Ten (14.9%) cows were categorised in category 4 in all three sessions. The recordings of 30 (42.9%) cows were labelled with category 4 in at least two sessions.

Table 2. Results of the video usability scoring for three sessions (#: number of animals)

	Session 1		Session 2		Session 3		Total	
	#	%	#	%	#	%	#	%
Category 1: standing	28	40.0	7	10.0	18	25.4	1	1.5
Category 2: walking <2 steps	7	10.0	11	15.7	11	15.5	4	6.0
Category 3: walking >2 steps	9	12.9	15	21.4	13	18.3	12	17.9
Category 4: walking full path	26	37.1	37	52.9	29	40.8	50	74.6
Session total	70	100	70	100	71	100	67	100

Discussion

The results in this study show that 74.6% of the cows were categorised in category 4. These recordings are the most interesting to analyse gait characteristics. The animals are walking at a steady pace along the path. Walking the path takes 4 or 5 gait cycles, so 4 to 5 subsequent strides can be analyzed. If the videos of Category 3 are included, a total sum of 62 cows (92.5%) can be reached. The cows in those videos do not walk at a steady pace, but more than 2 steps are recorded. Images of standing animals can be found in the videos of Category 2. Here, gait characteristics cannot be identified, but there may be some standing characteristics that can be linked to lameness. After three recording sessions, one out of 67 cows (1.5%) was not spotted in any of the recordings, meaning that she did not leave the milking area while the recordings took place, or that her recording was totally useless.

Useless recordings can have different underlying reasons. First of all, some cows kept standing when the selection gate opened. However the cow was not moving, the recording started after a short time delay. This caused the system to save files where no information could be found in. This could be resolved by including a light sensor that detects if the cow really passed the gate before starting the recording. Secondly, some cows walked through the selection gate, but stopped walking before they reached the part of the walking path that was filmed. Another event that made a recording useless was that some cows turned 90 degrees or more in the walking path when they saw something new in the feeding trough.

The behaviour of the animal is quite repetitive. In our recordings, we found out that ten cows on a total of 67 animals with three recordings (14.9%) were labelled in all three sessions with a recording of Category 4. The recordings of 30 cows on a total of 70 animals with at least two recordings (42.9%) were labelled in category 4. The walking behaviour of the animal is defined by the nature of the animal. Some cows just like to take their time before setting the next step. Especially lame animals or animals that suffer from walking will rather rest between their steps than walking at a steady pace, the so-called *willingness to walk* (Whay, 2002). This is a challenge in the current setup, because the animals are free (of will) to walk in the walking path. The chance that lame animals will walk the whole length of the path is rather low. On the other hand, the objective of the study is to detect lameness in an early stage, before the pain becomes unbearable.

The recording periods had to be interrupted because of the darkness. When darkness came up, there was not enough sunlight left to see the cows walking. This can be improved by installing some artificial lights. It will make it possible to make recordings at night, and therefore lengthening the recording period. Recording at night and including some artificial lighting might also improve the problem of the background (Poursaberi *et al.*, 2010). In the current side view setup, a moving background can be seen. When the recordings take place at night with artificial lighting in the foreground, the background will remain dark.

In this study, three recording periods were performed in a two week period. Increasing the number of recordings to three or four times a week, or daily recordings may increase the number and quality of the records.

The incidence of lameness on this farm is small. In the next experiments, a larger herd size is recommended in order to increase the number of lameness cases. More cases will improve the accuracy of the detection method.

The experimental setup is made in a robotic milking farm, and not in a farm with a conventional milking parlour. This is mainly due to practical reasons. This farm is located nearby and it is what we have. This paper is the first step in a larger project that will be conducted in this farm. Robotic milking farms have also some advantages. First of all, they are heavily computerized, so it is easy to install and plug your hardware to the electrical circuit or internet in the farm. Second, in a robotic milking farm, the cows leave the milking parlour one by one, and not in one group. One exception to this last point is a "Tandem" milking parlour, but no such milking parlour can be found in this region.

Lame cows show an irregular gait when they walk. This irregularity may be characterised by an asymmetric walking pattern that can be seen from a top view angle. Therefore a camera in top view position is installed to capture this gait characteristic.

Conclusions

The results in our study show that in three sessions, 92.5% of the animals could be recorded when walking at least two full gait cycles on a predefined path. This allows us to find in future research an algorithm that can detect lameness in an early stage, based on gait characteristics.

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References

Amory, J.R., Kloosterman, P., Barker, Z.E., Wright, J.L., Blowey, R.W. and Green, L.E. 2006. Risk factors for reduced locomotion in dairy cattle on nineteen farms in the Netherlands. Journal of Dairy Science 89(5) 1509-1515.

Barker, Z.E., Leach, K.A., Whay, H.R., Bell, N.J. and Main, D.C.J. 2010. Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. Journal of Dairy Science 93(3) 932-941.

Borderas, T.F., Fournier, A., Rushen, J. and De Passille, A.M.B. 2008. Effect of lameness on dairy cows‘ visits to automatic milking systems. Canadian Journal of Animal Science 88(1) 1-8.

Brenninkmeyer, C., Dippel, S., March, S., Brinkmann, J., Winckler, C. and Knierim, U. 2007. Reliability of a subjective lameness scoring system for dairy cows. Animal Welfare 16(2) 127-129.

Bruijnis, M.R.N., Hogeveen, H. and Stassen, E.N. 2010. Assessing economic consequences of foot disorders in dairy cattle using a dynamic stochastic simulation model. Journal of Dairy Science 93(6) 2419-2432.

Chapinal, N., de Passille, A.M., Weary, D.M., von Keyserlingk, M.A.G. and Rushen, J. 2009. Using gait score, walking speed, and lying behavior to detect hoof lesions in dairy cows. Journal of Dairy Science 92(9) 4365-4374.

Clarkson, M.J., Downham, D.Y., Faull, W.B., Hughes, J.W., Manson, F.J., Merritt, J.B., Murray, R.D., Russell, W.B., Sutherst, J.E. and Ward, W.R. 1996. Incidence and prevalence of lameness in dairy cattle. Veterinary Record 138(23) 563-567.

Ettema, J.F. and Ostergaard, S. 2006. Economic decision making on prevention and control of clinical lameness in Danish dairy herds. Livestock Science 102(1-2) 92-106.

Eurostat 2011. European Union Statistics. [online] Available at: <http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database> [Accessed 06 January 2011].

Galindo, F. and Broom, D.M. 2000. The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. Research in Veterinary Science 69(1) 75-79.

Galindo, F., Broom, D.M. and Jackson, P.G.G. 2000. A note on possible link between behaviour and the occurrence of lameness in dairy cows. Applied Animal Behaviour Science 67(4) 335-341.

Galindo, F. and Broom, D.M. 2002. The effects of lameness on social and individual behavior of dairy cows. Journal of Applied Animal Welfare Science 5(3) 193-201

Ito, K., von Keyserlingk, M.A.G., LeBlanc, S.J. and Weary, D.M. 2010. Lying behavior as an indicator of lameness in dairy cows. Journal of Dairy Science 93(8) 3553-3560

Kossaibati, M.A. and Esslemont, R.J. 1997. The costs of production diseases in dairy herds in England. Veterinary Journal 154(1) 41-51.

Kujala, M., Pastell, M. and Soveri, T. 2008. Use of force sensors to detect and analyse lameness in dairy cows. Veterinary Record 162(12) 365-368.

Leach, K.A., Whay, H.R., Maggs, C.M., Barker, Z.E., Paul, E.S., Bell, A.K. and Main, D.C.J. 2010a. Working towards a reduction in cattle lameness: 1. Understanding barriers to lameness control on dairy farms. Research in Veterinary Science 89(2) 311-317.

Leach, K.A., Whay, H.R., Maggs, C.M., Barker, Z.E., Paul, E.S., Bell, A.K. and Main, D.C.J. 2010b. Working towards a reduction in cattle lameness: 2. Understanding dairy farmers‘ motivations. Research in Veterinary Science 89(2) 318-323.

Pastell, M., Aisla, A.M., Hautala, M., Poikalainen, V., Praks, J., Veermae, I. and Ahokas, J. 2006. Contactless measurement of cow behaviour in a milking robot. Behavior Research Methods 38(3) 479-486.

Pastell, M., Hautala, M., Poikalainen, V., Praks, J., Veermae, I., Kujala, M. and Ahokas, J. 2008a. Automatic observation of cow leg health using load sensors. Computers and Electronics in Agriculture 62(1) 48-53.

Pastell, M., Kujala, M., Aisla, A.M., Hautala, M., Poikalainen, V., Praks, J., Veermae, I. and Ahokas, J. 2008b. Detecting cow's lameness using force sensors. Computers and Electronics in Agriculture 64(1) 34-38.

Phillips, C.J.C. 2002. In cattle behavior and welfare. Blackwell Science Ltd.

Pluk, A., Bahr, C., Leroy, T., Poursaberi, A., Song, X., Vranken, E., Maertens, W., Van Nuffel, A. and Berckmans, D. 2010. Evaluation of step overlap as an automatic measure in dairy cow locomotion. Transactions of the American Society of Agricultural and Biological Engineers 53(4) 1305-1312.

Poursaberi, A., Bahr, C., Pluk, A., Van Nuffel, A. and Berckmans, D. 2010. Real-time automatic lameness detection based on back posture extraction in dairy cattle: Shape analysis of cow with image processing techniques. Computers and Electronics in Agriculture 74(1) 110-119.

Song, X.Y., Leroy, T., Vranken, E., Maertens, W., Sonck, B. and Berckmans, D. 2008. Automatic detection of lameness in dairy cattle - Vision-based trackway analysis in cow's locomotion. Computers and Electronics in Agriculture 64(1) 39-44.

Sprecher, D.J., Hostetler, D.E. and Kaneene, J.B. 1997. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology 47(6) 1179-1187.

Tadich, N., Flor, E. and Green, L. 2010. Associations between hoof lesions and locomotion scores in 1098 unsound dairy cows. Veterinary Journal 184(1) 60-65.

Thomsen, P.T., Munksgaards, L. and Togersen, F.A. 2008. Evaluation of a lameness scoring system for dairy cows. Journal of Dairy Science 91(1) 119-126.

Tuyttens, F.A.M., Sprenger, M., Van Nuffel, A., Maertens, W. and Van Dongen, S. 2009. Reliability of categorical versus continuous scoring of welfare indicators: lameness in cows as a case study. Animal Welfare 18(4) 399-405.

Van Nuffel, A., Sprenger, M., Tuyttens, F.A.M. and Maertens, W. 2009. Cow gait scores and kinematic gait data: can people see gait irregularities? Animal Welfare 18(4) 433-439.

Whay, H.R., Waterman, A.E., Webster, A.J.F. and O'Brien, J.K. 1998. The influence of lesion type on the duration of hyperalgesia associated with hindlimb lameness in dairy cattle. Veterinary Journal 156(1) 23-29.

Whay, H. 2002. Locomotion scoring and lameness detection in dairy cattle. In Practice 24(8) 444-449.

Wilshire, J.A. and Bell, N.J. 2009. An economic review of cattle lameness. Cattle Practice 17 136-141.

Section 4
Dairy

Estimating the Development of Body Weight and Backfat Thickness of Heifers as a Foundation of Fertility Management

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Abstract

This paper describes the use of Akaike's information criterion (AICC) to design models for estimating the development of body weight and backfat thickness and then illustrates the subsequent selection of the model with the best fitting. The study was conducted with 310 Holstein-Friesian heifers from a production farm in central Germany. In monthly intervals, we measured these animals' body weight and backfat thickness. The goal of this study was to design a suitable model for the population- and animal-specific mapping of growth curves. For this purpose, we used the AICC value in order to compare non-linear and quasilinear models with further fixed and random effects. The best fitting was found for a Random Regression Model (RRM) with polynomials of the 1st or 2nd degree for the mapping of the population- and animal-specific growth curves of the body weight and backfat thickness in dependence on the age as well as with a fixed effect for the day of measurement. Our study found that the use of this modeling approach for the analyzed features is well-suited to map the growth curves per population and per animal, respectively. Additional experiments for a subset of the heifers are used to illustrate the relationship between growth curves and progesterone in order to elaborate further on a modeling approach for the animal-specific prediction of sexual and breeding maturity and their inclusion in a herd management program.

Keywords: Holstein heifers, body weight, backfat thickness, linear mixed model

Introduction

With improved process control for cattle rearing, we can significantly improve the efficiency of milk production. In this context, the monitoring and controlling of growth curves – and based on this, of the fertility – play a key role. While this fact has been known for quite a while now, the continuous measurement of the body weight in production scenarios has only become possible with the emergence of recent developments in the field of weighing technology. The same is true for ultrasound measurements of the backfat thickness. Only with the availability of more robust and mobile measurement devices has the continuous monitoring in production herds become feasible. The importance of these features for cattle health and fertility management has long been acknowledged (Berry *et al.*, 2003; Schröder and

Staufenbiel, 2006). Thus, the inclusion of these features into herd management for dairy cows is increasingly found in practical scenarios (Berry *et al.*, 2003; Schröder and Staufenbiel, 2006). In contrast, the scope of application with heifers is significantly lower.

On the one hand, this may be reasoned by the often extensive monitoring of the heifer production and the associated lack of herd management programs for heifers. On the other hand, we hardly find any simultaneous surveys of body weight and backfat thickness for heifers. Thus, we lack the required fundamentals for practical implementations. The study at hand shall help close this gap. Our analyses are based on measurements of body weight and backfat thickness that have been gathered for the growth curves of young female bovines during a period of eight months and under production conditions.

The goal of our study is to estimate the development with the help of quasilinear and non-linear functions. In this context, the use of polynomials allows the processing within the class of linear models and a very flexible modeling as a result thereof. We can also easily include additional fixed or random effects, such as the day of measurement or the individual animal. Special attention here is given to the quantification of animal-specific differences. For a limited number of animals, we establish the relationship between the animal-specific curve patterns and the sexual maturity based on additionally measured progesterone values.

Materials and methods

Subjects of our experiments were 310 Holstein-Friesian heifers in the age group of 100 to 600 days from a production farm in central Germany. From January to August 2010, we weighed the animals once per month and also measured the backfat thickness between the upper area of the ilium and the upper edge of the ischium (Schröder and Staufenbiel, 2006). Table 1 provides an overview of the gathered data.

Table 1. Data overview of the recorded body weights and backfat thickness according to the age.

	Body weight			Backfat thickness		
Age in days	**Number of measurements**	**Min (kg)**	**Max (kg)**	**Number of Measurements**	**Min (mm)**	**Max (mm)**
100 - 200	257	80	265	274	3.8	10.3
201 - 300	312	162	378	349	4.9	15.8
301 - 400	320	196	434	329	6.7	18.7
401 - 500	295	257	598	251	7.5	23.7
501 - 600	117	384	606	85	8.4	26.4

Our evaluation had 1301 weight data items and 1288 backfat thickness data items at hand.

Furthermore, from August 2010 on, we conducted weekly progesterone measurements over a period of 14 weeks in order to determine the beginning of sexual maturity (the onset of puberty). Here, we included all heifers with a body weight between 160 and 220 kg (n=28). The blood samples were taken from the jugular vein, then centrifuged with 4000 R/min for 15 minutes, and the acquired plasma was frozen at -112 °F (-80 °C) until its analysis. The progesterone analysis was performed with an enzyme immunoassay established for the ruminant system (Volkery *et al.*, 2010). Typically, sexual maturity is assumed to have appeared if there were two consecutive progesterone concentrations of more than 1 ng/ml or 2 ng/ml

(Day *et al.*, 1984; Rius *et al.*, 2005). In contrast to this approach, we use in our study the first oestrus and the first increase of the progesterone concentration to determine the onset of puberty.

Statistical Methods

In the available literature, we find the non-linear (Fitzhugh, 1976; Kratochvílová *et al.*, 2002; Forni *et al.*, 2009) and the quasilinear regression (Heinrichs and Hargrove, 1987; De Behr *et al.*, 2001) being used to describe growth curves. In our own experiments, we apply both model classes. The decision on the preferred model to use is made with the help of statistical model selection methods (Hurvich and Tsai, 1989; Burnham and Anderson, 2002; Mielenz *et al.*, 2006). Here the quality of a model's fitting is validated with Akaike's information criterion. This criterion takes into consideration model fit as well as model complexity. In our study we use the small sample version of Akaike's criterion, derived by Hurvich and Tsai (1989).
As our non-linear models, we chose the logistic function (1) and the Gompertz function (2):

$$y(t) = \frac{A}{(1+e^{-\frac{t-b}{c}})}, \tag{1}$$

$$y(t) = Ae^{-be^{-ct}}, \tag{2}$$

where in equation (1) the body weight $y(t)$ is the body weight at day t, A denotes the asymptotical final weight, b is the point in time when the animal has reached half of the asymptotical final weight, and c marks the point in time between reaching half of and approximately three quarters of the asymptotical final weight. The meaning of the variables in equation (2) only differs in b and c. Variable b denotes a time-scale parameter linked to the birth weight, and c is the relative growth rate (Kratochvíluvá *et al.*, 2002).
If we choose suitable covariates, however, we can also represent the non-linear growth curve with a linear model. The particular advantage of the linear model is found in its ability to include additional fixed and random effects.
The decision process for the linear model is based on the two levels outlined below.

1. Level: Optimization of the expectation structure
Here, we check the different modeling approaches with the help of AICC, based on the Maximum Likelihood method. The following models (M1 to M4) are selected steps for choosing a model with the help of quasilinear regression.

(M1) $y_i(t) = b_0 \cdot x_0(t) + b_1 \cdot x_1(t) + e_i$
(M2) $y_i(t) = b_0 \cdot x_0(t) + b_1 \cdot x_1(t) + b_2 \cdot x_2(t) + e_i$
(M3) $y_i(t) = b_0 \cdot x_0(t) + b_1 \cdot x_1(t) + b_2 \cdot x_2(t) + b_3 \cdot x_3(t) + e_i$
(M4) $y_{ij}(t) = b_0 \cdot x_0(t) + b_1 \cdot x_1(t) + b_2 \cdot x_2(t) + MT_j + e_{ij}$

with $x_0 = 1,\ x_1 = t,\ x_2 = t^2,\ x_3 = t^3$; with $t =$ day of life, where $y_i(t)$ is the body weight or backfat thickness, respectively, of animal i on the day of life t. Thus, $y_{ij}(t)$ is the body weight or backfat thickness of animal i on the measurement day MT_j for the day of life t; b_0 to b_3 are regression coefficients; x_0 to x_3 denote the covariates for the day of life (t); and e_i or e_{ij}, respectively, represents the random residual effect. Thus, such a model corresponds to a Fixed Regression Model. The problem of the above mentioned models is that repeated observations per animal cannot be included in the calculations. In order to analyze the importance of these random animal-specific effects, we need Level 2.

2. Level: Optimization of the covariance structure
In Level 2, we have to examine whether or not the addition of further random effects could improve the model's fitting. For this purpose, the expectation structure determined in Level 1 serves as the starting point. In the case at hand, we have to check whether or not the consideration of the repeated observations for an animal with the help of random effects and a variable covariance structure could improve the model's fitting. We introduce animal-specific random regression coefficients as deviations from the modeled growth curve of the population. Thereby, the model is extended to a Random Regression Model (RRM). In Level 2, the different modeling approaches are validated with the help of AICC and by using the Restricted Maximum Likelihood method.

(M5) $y_{ij}(t) = b_0 \cdot x_0(t) + b_1 \cdot x_1(t) + b_2 \cdot x_2(t) + MT_j + e_{ij}$

$y_{ij}(t) = b_0 \cdot x_0(t) + a_{0i} \cdot x_0(t) + b_1 \cdot x_1(t) + a_{1i} \cdot x_1(t) + b_2 \cdot x_2(t) + a_{2i} \cdot x_2(t) + MT_j + e_{ij}$ (M6) $\mathrm{y_{ij}(t) = b_0 \cdot x_0(t) + a_{0i} \cdot x_0(t) + b_1 \cdot x_1(t) + a_{1i} \cdot x_1(t) + b_2 \cdot x_2(t) + a_{2i} \cdot x_2(t) + MT_j + e_{ij}}$

with $x_0 = 1,\ x_1 = t,\ x_2 = t^2$; with $t =$ day of life.

The employed variables resemble those from Level 1. Variables a_{0i} to a_{2i} in (M6) represent a vector specific to the day of life for the random regression coefficients of animal i.
We conducted our estimation of the model parameters with the statistics program SAS 9.2 – for the non-linear models, we used procedure NLMIXED, and for the quasilinear models we used procedure MIXED.
The results from Level 1 simultaneously serve to compare the non-linear with the quasilinear models.

Results

The results of the model selection for the body weight curves are presented in Table 2.

Table 2. Results of the model selection for the body weight.

Model		AICC criterion
Non-linear models		
logistic function		13089
Gompertz function		13049
Quasilinear model		
Expectation structure:	(M1)	13152
	(M2)	13029
	(M3)	13029
	(M4)	13001
Covariance structure:	(M5)	12470
	(M6)	12349

For the scenario at hand, we find that the non-linear growth curve for the body weight can be mapped quite well when using a quasilinear model. We omit the illustration of the results of the model selection for the backfat thickness, since these do not differ substantially from the body weight results. For both features, we decided in favor of Model 6 (M6) for the subsequent steps, since it showed the best fitting according to the AICC criterion.
By using procedure IML and the estimations for the fixed effects and their covariance matrix from procedure MIXED, we can illustrate the curves for body weight and backfat thickness both for the whole population and for individual animals. First, Figure 1 shows a comparison between the non-linear and the quasilinear body weight curves. For clarity reasons, we omitted the interval bounds in this illustration.

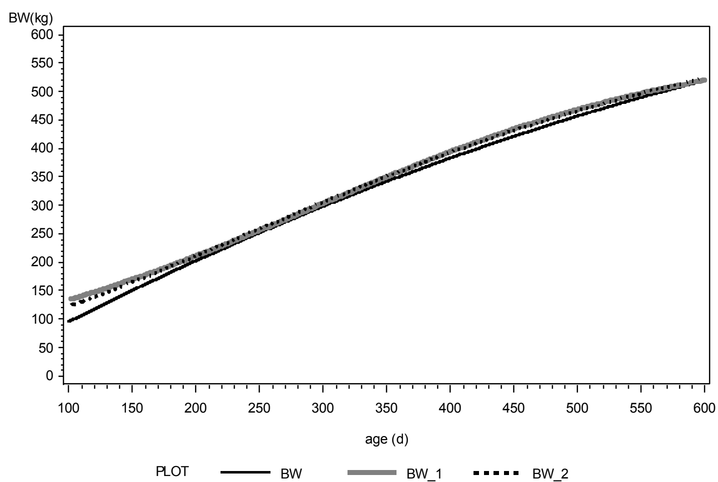

Figure 1. Comparison of quasilinear (BW) and non-linear body weight curves (BW_1=logistic function, BW_2=Gompertz function).

From the comparison of the different growth curves, we can see that the logistic function and the Gompertz function lie close to each another. The quasilinear curve is slightly below the two non-linear functions. In general, though, we can say that the three curves are very close to one another.
Figures 2 and 3 illustrate the measured body weight and backfat thickness values of the heifers over a period of eight months and in dependence on their age. Additionally, the estimated body weight curve for this population is shown to allow for comparisons.

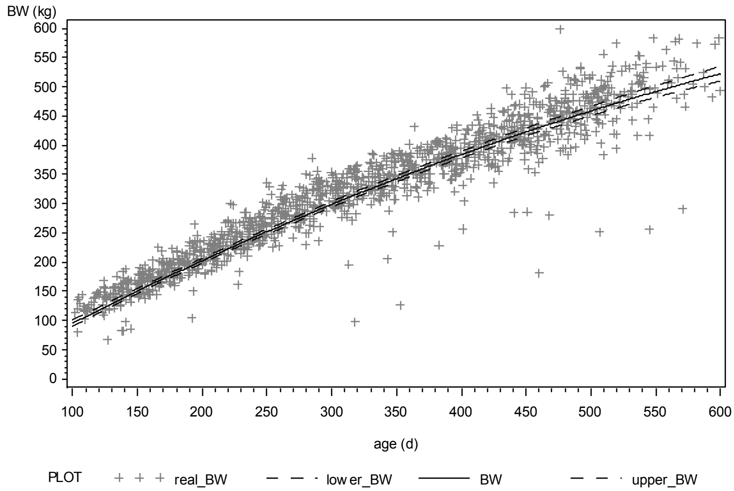

Figure 2. Measured body weight (real_BW) and the estimated curve (BW) as well as its confidence interval in dependence on the age (two-sided interval bounds, P=0.95).

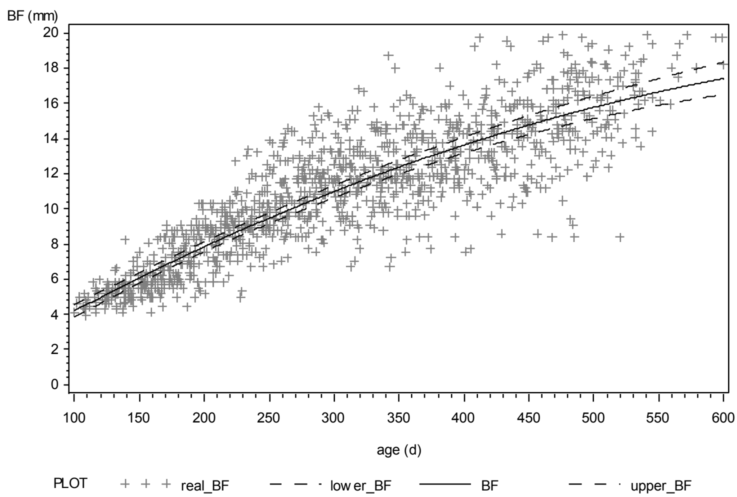

Figure 3. Measured backfat thickness (real_BF) and the estimated curve (BF) as well as its confidence interval in dependence on the age (two-sided interval bounds, P=0.95).

Since we can also map animal-specific curves by using the quasilinear models, including the fixed and random effects, Figures 4 and 5 show the population-specific curves for both features and the animal-specific curve for one example animal.

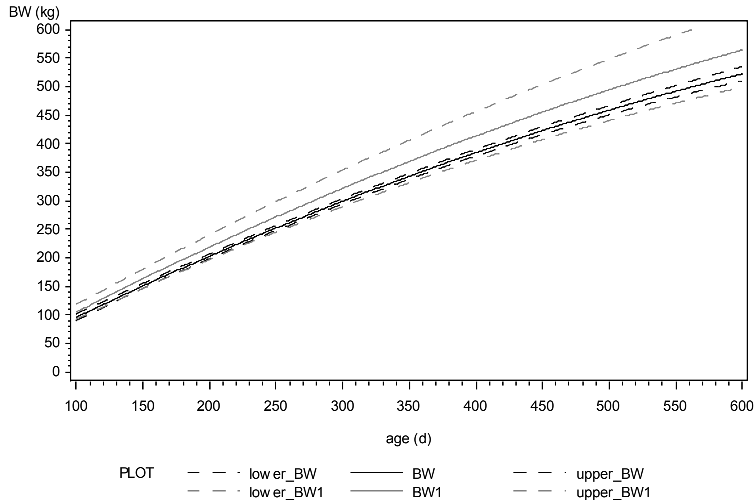

Figure 4. Curves for the body weight specific to the population (BW) and to animal 1 (BW_1) as well as their confidence intervals in dependence on the age (two-sided interval bounds, P=0.95).

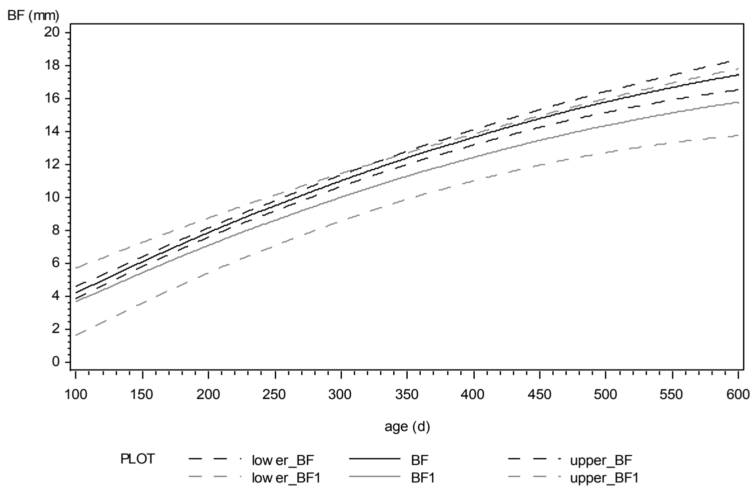

Figure 5. Curves for the backfat thickness specific to the population (BF) and to animal 1 (BF_1) in dependence on the age (two-sided interval bounds, P=0.95).

In both figures, we can see that the confidence interval of the population-specific growth curve is much narrower than for the animal-specific curve. Further, we note that the confidence interval increases with higher age, especially in case of backfat thickness. The use of the RRM allows illustrating and analyzing the animal-specific curves. Thereby, it becomes possible to quantify the animal-specific differences within a population. The animal-specific effects show a higher estimation error and consequently wider confidence intervals compared to the population-specific curves.

For the progesterone analysis, we found that for our given definition 19 from 28 animals had reached puberty at the end of the sampling period. Furthermore 7 from the 28 animals do not show any increase in the progesterone concentration till the end of the sampling period. For two further animals it was not possible to determine the onset of puberty with the help of the progesterone profiles and they didn't show any oestrus signs. Table 3 provides an overview about the onset of puberty in dependence of body weight, backfat thickness and days of life.

Table 3. Statistics for body weight, backfat thicknes and days of life depend on the onset of puberty

	Body weight (kg)	Backfat thickness (mm)	Days of life
Mean	251.2	10.2	248
Minimum	193	7.2	218
Maximum	283	11.4	300
Coefficient of variation	9.4 %	10.1 %	9.9 %

Discussion

The estimation of growth curves both for the body weight and the backfat thickness can prove highly useful for heifer management. Many studies have already shown that the beginning of sexual maturity strongly depends on the feeding (Kertz *et al.*, 1987; Murphy *et al.*, 1991). Over-intensive feeding may have a positive effect on the beginning of sexual maturity but negatively affects the milk production for the first lactation period (Kertz *et al.*, 1987; Van Amburgh *et al.*, 1998). Here, regular weighing and the estimation of growth curves for body weight and backfat thickness can serve as supportive tools for herd management. A particular advantage in this context is the use of the quasilinear function within a mixed linear model, which allows the inclusion of further important fixed and random effects in the model. Thus, not only can we map the population-specific development curve, but we can also illustrate animal-specific patterns, as shown in Figures 4 and 5. The animal-specific curve reveals whether the individual animal is marked by an above- or below-average development compared to the population, which then again is an important decision factor for feeding management. Due to the low number of observations per individual animal, the confidence intervals of the animal-specific curves are considerably wider than those of the population-specific curves. The fact that the distance between the interval bounds increases with higher age underlines the increasing variability with higher age. This is particularly visible for the backfat thickness feature.

As Figure 1 illustrated, the non-linear functions return good estimations of the body weight curves, too, and they lie close to the curve of the quasilinear function. However, difficulties arise with the selection of suitable starting values for the parameter estimation. Another disadvantage is the low degree of flexibility for the model formulation. For example, the consideration of additional fixed and random effects is quite problematic. While the resulting necessary formulation of mixed non-linear models is possible in principle, it often leads to problems during the convergence of the equation system as well as to long computation times

in practice. This is particularly true for scenarios in which more than one random effect in the model has to be considered, which is the case for the scenario at hand. As the model comparison has demonstrated, a polynomial of the second degree will already improve the model's fitting compared to the non-linear models for the examined growth range. Thus, the use of the quasilinear model for the scenarios at hand does not require any compromises regarding the model fitting.
Nineteen animals in our study had reached puberty at the end of our progesterone analysis. The average age, body weight and backfat thickness for those animals was 248 days, 251.2 kg and 10.2 mm, respectively. In a study of Del Vecchio *et al.* (1992), onset of puberty occurred at 247 ± 4.8 kg and an age of 304 ± 7.5 days. In a study of Macdonald *et al.* (2005), 259 Holstein heifers also reached puberty at a body weight of 251 ± 24.4 kg. The values found in the literature related to the body weight do not differ from our own findings. In contrast to the results given in the literature, our heifers reached puberty at a younger age. About the relationship of backfat thickness and the onset of puberty, we didn't found any results in the literature.

Conclusions

Currently, our concluding statement is that the selected RRM with fixed effects (day of life, measurement day) and random effects (animal) is suitable for mapping both the body weight curve and the backfat thickness curve for quasilinear mappings of the growth curves. Since the RRM may flexibly include fixed and random effects in the estimation, it is also possible to illustrate population-specific and, most importantly, animal-specific curves. Thus, we can develop a herd management program tailored to heifers that is capable of mapping such curves and thus may serve to support the feeding, fertility and health management. Otherwise, the important variation of body weight and backfat thickness show the restricted ability of these traits for puberty prediction.

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References

Berry, D.F., Buckley, F., Dillon, P., Evans, R.D., Rath, M. and Veerkamp, R.F. 2003. Genetic relationships among body condition score, body weight, milk yield, and fertility in dairy cows. Journal of Dairy Science **86** 2193-2204.

Burnham, K.P., Anderson, D.R. 2002. Model selection and multimodel inference. Springer, New York.

Day, M.L., Imakawa, K.,Garcia-Winder, M., Zalesky, D.D., Schanbacher, B.D., Kittok, R.J. and Kinder, J.E. 1984. Endocrine mechanisms of puberty: Estradiol negative feedback regulation of luteinizing hormone secretion. Biology of Reproduction **31** 332-341.

De Behr, V., Hornick, J.L., Cabaraux, J.F., Alvarez, A. and Istasse, L. 2001. Growth patterns of Belgian Blue replacement heifers and growing males in commercial farms. Livestock Production Science **71** 121-130.

Del Vecchio, R.P., Neuendorff, D.A., Stahringer, R.C. and Randel, R.D. 1992. Concentration of 13, 14-dihydro-15keto-prostaglandin $F_2\alpha$, estradiol-17β and progesterone during the peripubertal period in heifers. Theoriogenology **38** 419-429.

Fitzhugh, H.A. 1976. Analysis of growth curves and strategies for altering their shape. Journal of Animal Science **42** 1036-1051.

Forni, S., Piles, M., Blasco, A., Verona, L., Oliveira, H.N., Lôbo, R.B. and Albuquerque, L.G. 2009. Comparison of different nonlinear functions to describe Nelore cattle growth. Journal of Animal Science **87** 496-506.

Heinrichs, A.J. and Hargrove, G.L. 1987. Standards of weight and height for Holstein heifers. Journal of Dairy Science **70** 653-660.

Hurvich, C. M. and Tsai, C.L. 1989: Regression and time series model selection in small samples. Biometrika **76**, 297-397.

Kertz, A.F., Prewitt L.R. and Ballam, J.M. 1987. Increased weight gain and effects on growth parameters of Holstein heifer calves from 3 to 12 months of age. Journal of Dairy Science **70** 1612-1622.

Kratochvílová, M., Hyánová, L., Knížetová, H., Fiedler, J. and Urban, F. 2002. Growth curve analysis in cattle from early maturity and mature body size viewpoints. Czech Journal of Animal Science **47** 125-132.

Macdonald, M.A., Penno, J.W. Bryant, A.M. and Roche, J.R. 2005. Effect of feeding level pre-and post-puberty and body weight at first calving on growth, milk production, and fertility in grazing dairy cows. Journal of Dairy Science **88** 3363-3375.

Mielenz, N., Spilke, J., Krejcova, H., Schüler, N. 2006. Statistical analysis of test-day milk yields using random regression models for the comparison of feeding groups during the lactation period. Archives of Animal Nutrition **60:** 341-357.

Murphy, M.G., Rath, M., O'Callaghan, D., Augustin, F.H. and Roche, J:F. 1991. Effect of bovine somatotropin on production and reproduction in prepubertal Friesian heifers. Journal of Dairy Science **74** 2165-2171.

Rius, A.G., Connor, E.E., Capuco, A.V., Kendall, P.E., Auchtung-Montgomery, T.L. and Dahl, G.E. 2005. Long day photoperiod that enhances puberty does not limit body growth in Holstein heifers. Journal of Dairy Science **88** 4356-4365.

Schröder, U.J. and Staufenbiel, R. 2006. Invited review: Methods to determine body fat reserves in the dairy cow with special regard to ultrasonographic measurement of backfat thickness. Journal of Dairy Science **89** 1-14.

Van Amburgh, M.E., Galton, D.M., Bauman, D.E., Evertt, R.W., Fox, D.G., Chase, L.E. and Erb, H.N. 1998. Effects of three prepubertal body growth rates on performance of Holstein heifers during first lactation. Journal of Dairy Science **81** 527-538.

Volkery, J., Wittek, T., Sobiraj, A., Gottschalk, J., Einspanier, A. 2010. Trächtigkeitsdiagnostik beim Alpaka mittels Bestimmung von Progesteron und Pregnanediol-Glucuronid in Speichel, Milch und Urin. Berliner und Münchner Tierärztliche Wochenzeitschrift **123** 10-15.

Precision Dairy Farming - Effect of different milking-units on milk release parameters and udder health

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Abstract

In a joint project a standard cluster and a new innovative cluster were compared. The new cluster (AktivPuls, System Happel) is characterized by an innovative liner design. The vacuum shut off in the massage phase leads to a vacuum reduction at the teat under all milking conditions even with zero milk flow. In a 2 x 7 herringbone parlour the standard and the control group (137 animals in total) was investigated for 127 days.
The parameters of the milk removal as well as the udder health were all over the time of the trial reviewed with the analysis technology in the milking parlour and the livestock management program. For further investigations two LactoCorder recordings were implemented.

Keywords: Precision dairy farming, soft massage milking, milk release, livestock management software, udder health

Introduction

The invention of the two-chamber teat cup and pulsator around 1900 enabled gentle milking by machine. The working principle of the teat cup has hardly changed since then. But the parameters around the cow have changed. For instance, amount of milk produced, peak milk flow, quarter distribution, etc. These factors represent new challenges for milking equipment in ensuring rapid, gentle and complete milking-out (WORSTORFF, 1994). The number of cows per drove increases continuously. Without the use of precision dairy farming with its computer aided technology, the individual animal care concerning the milk removal hardly is possible. (ALBERS, KÜHBERGER, 2007). A central function is played here by the pulsation vacuum. On the one hand, vacuum is necessary for milk withdrawal. On the other, it stresses the tissue (WOLTER, 2008). Too high vacuum results in increased hyperkeratosis and tissue damage on the teats, e.g. reddening, hardening and ring marks, (MEIN, *ET AL.* 2001; NEIJENHUIS, *ET AL.*, 2001). This damage is not without effect on milk letdown parameters (GRAFF, 2005; KRÖMKER, 2007). A solution for the problem is offered by clusters that give optimum milking conditions, with at the same time, low stress on the teat. In a milking trial therefore the AktivPuls milking-unit was compared with a conventional milking-unit concerning the parameters of milk removal, milk amount, top milk flow and milking duration. The development of the teat condition and the udder healthiness was examined, in order to get data for the milk flow parameters.

Materials and methods

The milking trial took place in a 120-cubicle barn at Köllitsch training and research farm in Saxony with a 2 × 7 herringbone parlour. On one side the milking stalls were equipped with the AktivPuls milking-unit (System Happel) featuring an innovatively designed liner, which you see in the figures 1:

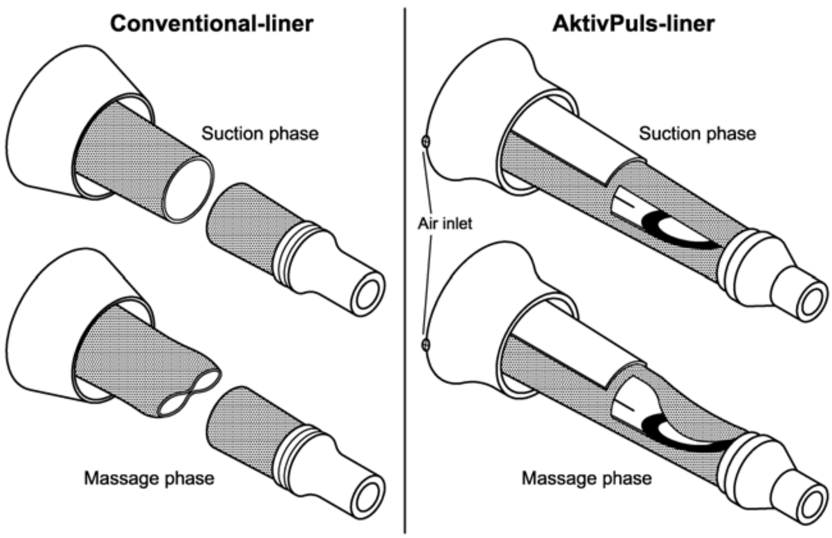

Figure 1. functional design of the conventional-liner and AktivPuls liner

The air-inlet has been designed to be always exposed during milking. The air-inlet is maintenance-free as it is circulated by fluid during every rinsing process.
The calibrated longitudinal ventilation duct on the inside of the stem is also clearly visible. This duct transports the atmospheric air bypassing the teat into the interior for the vacuum relief and the milk transport.
A determined oval forming of the barrel guarantees a safe function of the vacuum-relief. During the massage phase, absence of vacuum in the lower area of the liner leads to less vacuum stress on the teat under all milking conditions, suction phase and massage phase, especially where there's no milk flow.
On the other side of the parlour the control clusters with a circular liner were left in place. At trial start the clusters on both sides of the parlour were fitted with new liners. The milking equipment set-up in the parlour remained otherwise unaltered. Before trial begins, settings were tested to conform to DIN ISO 6690. The DIN ISO 6690 is a guideline for quality assurance about milking equipment. The milking vacuum was 42 kPA for both milking units

at pulsation ratio of 60:40 (suction phase to massage phase). The pulsation rates add up 60 pulses per minute.
The trial animals were Holstein-Friesian "Schwartzbunt". In the trial year the herd averaged 9338 kg milk with 4.03 % fat and 3.47 % protein. Following a habituation period of 21 days with free choice of milking point, the herd was divided into a trial and control group and monitored over 106 days (August – December) with twice daily milking and each group driven to its respective side of the parlour. Taking arrivals and departures into account, 137 animals were assessed altogether. In order to get the parameters of the milk removal the development of the parameters by the time, the data of the milking parlour was read daily with the use of the herd management software. Therefore the parameters of the daily milk amount, the peak milk flow, the average milk flow, the milking duration and electrical conductivity of the milk were collected.
Two LactoCorder examinations, respectively at begin and end of trial, were carried out to analyse milk flow. Hereby, total yield, flow increase, flow plateau and milking-out phases were measured with all milking cows. Because of the higher production and higher amount of milk at morning milking the tests were carried out then. To draw conclusions on teat conditions and on milk removal parameters, five evaluations on teat conditions were done, based on the udder rating guideline of the Teat Club International.
Recorded details were assessed and transferred into descriptive statistics. Information on teat condition and technical milk flow parameters was processed and subject to bifactorial variance analysis and covariance analysis. Factored in as model effect was lactation number and lactation day. Additionally, two evaluation variants were selected so that all collected data could be optimally evaluated. In the first variant 'A' were included animals that had taken part in the trial for at least three weeks, with arrival and departure dates taken account of. The second variant 'B' included only the animals in the trial during the entire period from august to december. This group therefore produced complete data. In the evaluation, 75 cows had complete records and these cows were distributed as evenly as possible between trial and control groups.

Results and Conclusion

The first data mining of the milk removal parameters of the daily enquiry and of the two LactoCorder examinations showed similar process during the attempt. Therefore the LactoCorder examinations will be shown.
Variant 'B' (animals with full data records) is presented in table 1 for demonstrating LactoCorder results. The milk flow curves were compared between the same animals.
Average values (MW) and standard variations (SD) for milk letdown parameter are presented for the characteristics recorded in the trial group (assay) and the control group (control).
The first analysis of milk flow parameters for animals present through the entire trial period timed, under total milk yield (MGG), milking period up to 0.5 kg/min milk (tS 500) up to plateau phase (tAN), time of plateau phase (tPL) and ending phase of milking (tMNG) with averages presented in table 1.
Total milk in the morning milking for both groups averaged at trial beginning 17.6 litres and at trial end 15.4 l per cow. Standard variation with the trial group was 3.3 l and with the control group 4.4 l. One can successfully identify the two separate groups because their respective milk yields are almost identical.

The phase from recording start to reaching the 0.5 kg/min threshold (tS 500) is the first parameter of a milk flow curve with the tS 500 phase and the increasing flow phase (tAN) presented in minutes. The tS 500 average for the trial group was 0.5 min at trial beginning and 0.34 at trial end. Respective averages for the control group were 0.33 and 0.56.

Table 1. Results of the LactoCorder-Analysis (n-assay = 44 cows ; n-control = 31 cows)

Parameters	**September**		**December**		**middle SD**	
	MW assay (n = 44)	**MW control (n = 31)**	**MW assay (n = 44)**	**MW control (n = 31)**	**SD assay**	**SD control**
MGG / total quantity of morning-milk (l)	17,5	17,7	15,3	15,5	3,30	4,40
tS500 / first milking parameter (min)	0,5	0,33	0,34	0,56	0,14	0,13
tAN / beginning phase of milking (min)	0,94	0,78	0,95	0,83	0,29	0,31
tPL / time of plateau phase (min)	2,74	3,36	2,74	2,94	1,6	1,75
tMNG / ending phase of milking (min)	0,37	0,39	0,39	0,33	0,29	0,32

The standard variations of both groups were comparable at 0.14. The trial variant reached the tS 500 threshold at trial end faster than the control although this difference could not be statistically secured.
The increase phase follows the tS 500 phase and begins with the first milk flow ≥ 0.5 kg/min. The change to the plateau phase is determined when flow drops below 0.8 kg/min[2]. Figure 2 graphically presents the increase flow phase.

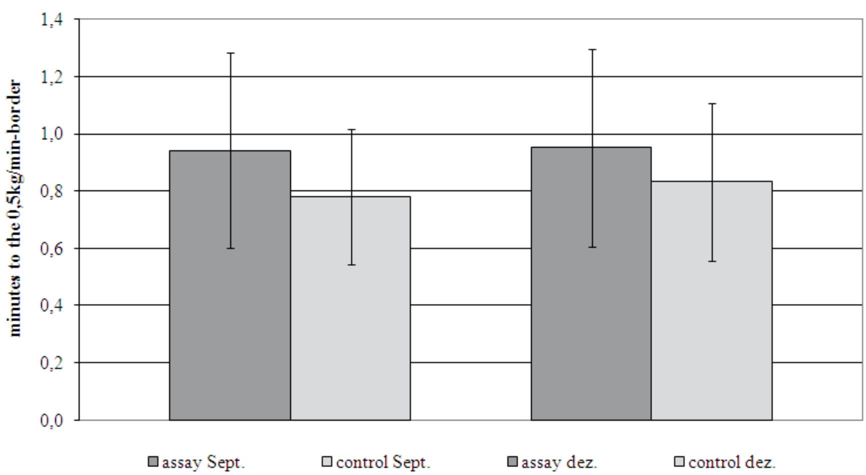

Figure 2. The beginning phase of milking

The trial group recorded 0.94 min at trial beginning and 0.95 min at trial end with average standard variation of 0.29. The respective figures for the control group were 0.78 min, 0.83 min with a standard variation 0.31 min. The trial group thus showed a longer increase flow phase. There was a significant difference ($p \leq 0.05$) between both groups.
The plateau phase average for the trial group was 2.74 min at september and 0.34 min at december. Respective averages for the control group were 2.74 and 2.94 min.
In the ending phase of milking the trial group is characterized by 0.37 min at trail beginning and ends with 0.39 min at december. The dates from the control group are comparable with this mentioned data.
The variables milking day and lactation are highly significant regarding parameters milk amount and flow increase phase ($p \leq 0.01$).
No clear difference in milk flow curves resulted between the milking equipment in this trial.

The 'A' variant was selected for presenting results on teat condition because development was comparable. Here, all observations were entered: for animals with incomplete data as well as those with complete data.
The descriptive statistic (table 2) gives an overview of herd teat condition. Average values (MW) and standard variations (SD) for teat scoring are presented for the characteristics recorded in the trial group (assay) and the control group (control)

Table 2. overview of teat condition

Parameters	**MW assay (n=67 animals)**	**MW control (n=70 animals)**	**SD assay**	**SD control**
teat skin (Note)	1,32	1,31	0,38	0,36
teat color (Note)	1,23	1,25	0,32	0,33
hardening (Note)	1,08	1,11	0,23	0,25
ring formation (Note)	1,26	1,66	0,37	0,41
hyperceratosis (Note)	1,71	1,91	0,65	0,79

Average values for teat skin and colour are comparable with both groups and lay around 1.3 with an average standard variation of 0.35. Hardening average for both groups was 1.1 which was a little better than the value of teat skin and colour.
Variance and covariance analyses gave no significant difference between both variants with parameters teat skin, teat colour and hardening. With ring forming, differences were indicated in averages with the trial group at 1.26 and the control group at 1.66 (Figure 3). The standard variations of both groups were similar at 0.37 and 0.41.
A significant difference in ring formation between the variants ($p \leq 0.05$) was evident. Ring formation was less marked with the trial group.

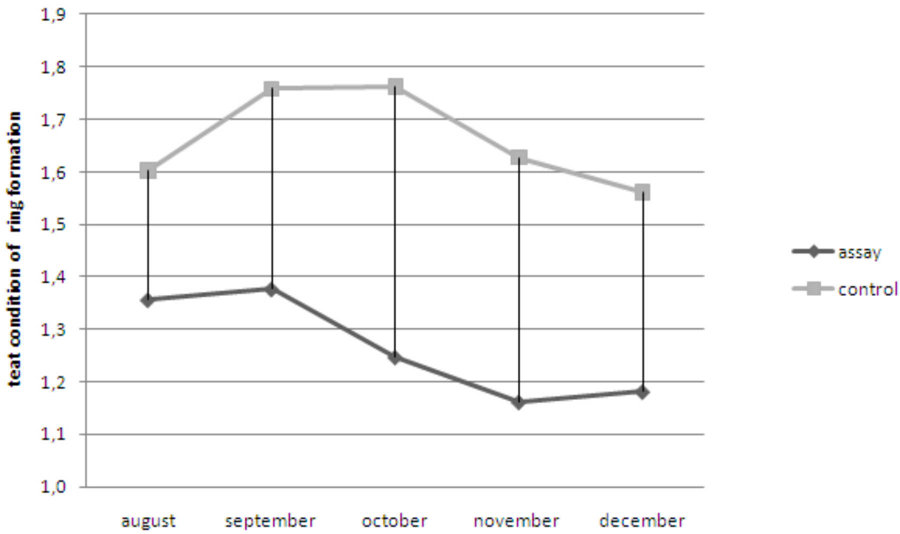

Figure 3. Development of ring formation

Milking method or type of milking equipment were the biggest influences on hyperkeratosis development. This was shown most markedly by the analysis of the hyperkeratosis averages in the trial group with 1.71 and control 1.91. Despite taking into account the variables milk day and lactation number, a highly significant difference in favour of the trial group was evident ($p \leq 0{,}01$)

In this examination the electrical conductivity of the milk had a high range of values. As a matter of this the milk only could be evaluated by the somatic cell count, although the cell count had a high range of values, too. There were no significant differences regarding the udder healthiness, which could have been lead to a certain milking equipment. It seems that the parameters of the udder healthiness depend a lot more on outward factors like e.g. feeding or the climate.

- First evaluation of milk flow curves showed the milk letdown parameter as being more strongly influenced by the variables milk day and lactation than from the milking equipment used.

- The AktivPuls- milking unit has a positive effect on the teat condition.

- The result of the udder healthiness factor is very oscillating and does not only depend on the milking equipment.

- The installed milking parlour technology, the measurement of the milk amount and the electrical conductivity of milk combined with the herd management software are important factors of the Precision Dairy Farming.

References

ALBERS, E, KÜHBERGER, M. (2007): „Precision Dairy Farming" Melken- Anlagenüberwachungen /„Precision Dairy Farming"- monitoring of milking process and milking systems, In: Precision Dairy Farming -Elektronikeinsatz in der Milchviehhaltung. Tagungband zur KTBL-Tagung vom 2. bis 3. Mai 2007 in Leipzig, KTBL, Darmstadt, S. 81-85

GRAFF, K. (2005): Untersuchungen von Zusammenhängen zwischen morphologischen Merkmalen des Euters, der Eutergesundheit und melktechnischen Parametern bei Tieren der Rasse Deutsches Holstein / „Investigation of relationship between udder anatomy, udder health and milking equipment at Holstein-Friesian" Dissertation, Martin-Luther-Universität Halle, Wittenberg ; Halle/Saale, S.57 ff.

KRÖMKER, K., BRUCKMAIER, R. FRISTER, H., KÜTZENMEIER, T., RUDZIK, L., SACH-HESSE-EDENFELD, T., ZANGERL, P. (2007): Kurzes Lehrbuch Milchkunde und Milchhygiene / „ Short course book of dairy products and hygiene" Hannover, Parey Verlag Stuttgart, S. 62

MEIN, G.A., NEIJENHUIS, F., MORGAN, W.F., REINEMANN, D.J., HILLERTON, J.E. BAINES, J.R., OHNSTADT, I., RASMUSSEN, M.D., TIMMES, L., BRITT, J.S. FARNSWORTH, R., COOK, N., HEMLING,T. (2001): Evaluation of bovine teat condition in commercial dairy herds: 1. Non infectious factors; Aus: 2nd International Symposium on Mastitis and Milk Quality, Vancouver 2001

NEIJENHUIS F., DE KONING, H., BARKEMA, H., HOGEVEEN, H., (2001): The effect of machine milking on the teat condition. ICAR Technical Series-No 7, Physiological and technical aspects of Machine Milking, Nitra 2001, S. 33 ff

WOLTER, W. (2008): Die Schutzbarriere Zitze intakt halten, Einfluss der Melktechnik auf die Bildung von Mastitis nicht unterschätzen / " Take care about teat cup condition, Influence from milking equipment about mastitis" Landwirtschaftliches Wochenblatt des Hessischen Bauernverbandes e.V. Landwirtschaftsverlag Hessen GmbH, Friedrichsdorf, Heft 18/2008, Seite 13 ff.

WORSTORFF, H. (1994): Melktechnik, der aktuelle Stand über Melken, Milch und Melkmaschinen / Milking technology, Current status of milking process, milk and milking machines, TopAgrar extra, Münster, Landwirtschaftsverlag Münster Hiltrup, S. 6 ff

Detection of clinical mastitis causal pathogens in automatic milking systems

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Abstract
The objective was to investigate whether sensor information or other readily available farm information can be used to predict the clinical mastitis causal pathogen or the Gram-status of the pathogen. Data from sensors of automatic milking systems as well as data available from clinical observations or from the management system were considered. We concluded that sensor information from the electrical conductivity, colour, and milk yield lacked discriminative power to predict the Gram-status or the causal pathogen itself. Variables referring to whether a cow was sick, indicating the somatic cell count, or the appearance of the milk, however, could be used for this purpose.

Keywords: automatic milking systems, clinical mastitis, detection, pathogen prediction

Introduction

Effective treatment of clinical mastitis (CM) in dairy cows is necessary to eliminate infections and prevent recurrence of disease. At the same time, it is important to use antimicrobial medicine (antibiotics) prudently (Hillerton and Kliem, 2002). Early detection and knowledge about the pathogen involved could help to select proper treatment and increase cure rate (Barkema *et al.,* 2006).

When milking fully automatically, CM is detected using two diagnostic tests: the first is the CM detection model on the automatic milking system (AMS) itself. This model uses sensor measurements as input and gives a CM alert as output. These CM alerts appear on a mastitis alert list to warn the dairy farmer for cows that need attention ("management by exception", Hogeveen and Ouweltjes, 2003). The second test involves the visual confirmation of CM and is conducted by the dairy farmer, who checks the alerts from the mastitis alert list he or she thinks necessary. If a CM case is visually confirmed, it is the responsibility of the dairy farmer to decide on antimicrobial treatment. Initially, the choice of antimicrobial treatment is based in absence of any knowledge about the CM causal pathogen, as the whole process from taking a milk sample, culturing it, and determining the pathogens usually takes three days.

Several sources of information are available on a dairy farm that could aid to some extent in indicating the causal pathogen of a CM case. For example, particular pathogens more frequently cause CM in some seasons of the year than in other seasons (Makovec and Ruegg, 2003; Olde Riekerink *et al.,* 2007). Also, cow-specific factors such as parity, days in milk (DIM), test-day somatic cell count (SCC) and CM history are a valuable source of information (Zadoks *et al.,* 2001; de Haas *et al.,* 2004). Finally, clinical signs such as the appearance of the milk and the demeanor of the cow can be used to aid indicating the causal pathogen (Jones

and Ward, 1990; Milne *et al.,* 2003). The clinical signs can be observed by the farmer when confirming the CM status of alerted cows, but possibly some of these signals can be indicated by sensors as well.
Objective of this paper was to investigate whether sensor information or other readily available farm information can be used to predict the CM causal pathogen or the Gram-status of the pathogen.

Materials and methods

Dataset 1

To explore whether sensor information from the AMS can be used for predicting the Gram-status or the CM causal pathogen itself, raw sensor data and observations of CM were collected at nine commercial Dutch dairy farms milking automatically (version A2 (n=10) or A3 (n=2); Lely Astronauts N.V., Maassluis, the Netherlands) from November 2006 until March 2009 (dataset 1). The collection of this dataset has been described in detail elsewhere (Kamphuis *et al.,* 2010b). In short, raw sensor data (values for each 100 mL of quarter milk) of the electrical conductivity and colour, and an estimation of quarter milk yield were collected by connecting a remote computer to each of the 12 AMS. From these raw sensor measurements 1,065 potentially descriptive variables were developed using a data flow diagram (Kamphuis *et al.,* 2008a; Kamphuis *et al.,* 2010a). These variables described characteristics (level, variability, and shape) of sensor measurement patterns from each quarter milking. Cows that raised suspicion of being affected by CM, according to the own criteria of the participating dairy farmer, were visually checked to confirm a CM case. By introducing a scoring protocol, the assessment of the actual CM status and the procedure to collect milk samples for bacteriological culturing was standardized: a scoring protocol instructed the dairy farmers to visually score the 5th and 6th squirts of milk. When visually normal, the milk was scored as 1. When abnormal, the milk was scored as 2) watery milk, 3) flakes, 4) clots, 5) serum-like milk, or 6) milk with blood. If a dairy farmer decided the CM infection was severe enough to start an antimicrobial treatment, they were asked to first take two milk samples for bacteriological culturing. Furthermore, they were instructed to record the cow's identification number, quarter, date and time, and the CM score assigned to the visually checked quarter. Milk samples were bacteriological cultured according to the standards of the National Mastitis Council (Harmon *et al.,* 1990). In order to combine visual observations of CM and sensor data, each visual quarter milk assessment was linked with sensor data from the most recent quarter milking, within a 24h time window prior to the assessment time, recorded for that same quarter by the remote computer (for a more detailed description, see Kamphuis *et al.,* 2010b).
In the end, 1,593 visually checked quarters could be combined with sensor measurements. Quarters that received a CM score from 2 through 5 were considered as quarters with CM (n=348), of which 243 quarters were sampled for bacteriological culturing. For those CM cases with only one milk sample (11.7% of 243 quarters), only this milk sample was evaluated for inclusion criteria for further analyses. For the remainder 89.3% of the quarters with two milk samples, both milk samples were evaluated. The inclusion criteria were: only CM caused by major CM causal pathogens (*Escherichia coli*, *Klebsiella spp. Staphylococcus aureus*, *Streptococcus dysgalactiae*, and *Streptococcus uberis*) were included for further analyses. If a culture within one milk sample or over milk samples of the same quarter showed

a combination of major CM causal pathogens, the quarter was excluded for further analyses. Culture results that were combinations of one major CM causal pathogen with a ‘mixed culture’, ‘no growth’, or ‘*Bacillus spp.*’ within one milk sample or over milk samples of the same quarter were included and were labeled according to the major CM causal pathogen cultured. This resulted in 26 quarters infected with *E. coli*, 4 with *Klebsiella spp*., 22 with *S. aureus*, 72 with *S. uberis*, and 16 with *S. dysgalactiae* (Table 1). Quarters infected with *E. coli* or *Klebsiella spp*. were classified as Gram-negative CM cases (n=30), and all others were classified as Gram-positive CM cases (n=110).

Table 1. Bacteriological culturing results of 140 clinical mastitis cases with at least one milk sample being bacteriological cultured, their Gram status, and their clinical mastitis score as recorded by the participating farmers

Main pathogen isolated	Gram status	Score assigned to quarter by farmer				Total (n)
		Watery (n)	Flakes (n)	Clots (n)	Serum-like (n)	
Escherichia coli	Negative	6	13	6	1	26
Klebsiella spp.	Negative	2	1	1	-	4
Staphylococcus aureus	Positive	2	19	1	-	22
Streptococcus dysgalactiae	Positive	-	14	2	-	16
Streptococcus uberis	Positive	5	40	22	5	72
Total		15	87	32	6	140

<u>Dataset 2</u>

In order to explore whether readily available cow information can be used to predict the Gram-status or the CM causal pathogen itself, data on CM were collected from 274 Dutch dairy herds entering the study between December 1992 and June 1994 (dataset 2). The collection of this dataset has been described in detail elsewhere (Barkema *et al.,* 1998). In short, all 274 herds were enrolled in the study for approximately 1.5 years. During the study, farmers were asked to collect milk samples for bacteriological culturing from cows with visible signs of CM. For each CM case, the farmer provided information on cow identification, date of occurrence, infected quarter, and whether the cow was sick at the moment of CM. Milk samples were bacteriological cultured according to the standards of the National Mastitis Council (Harmon *et al.,* 1990). Furthermore, the texture and colour of the milk were scored independently by two technicians after thawing and before bacteriological culturing (Barkema *et al.,* 1998). The Dutch national milk recording system (Nederlands Rundvee Syndicaat, Arnhem, The Netherlands) provided information from the 3- or 4-weekly milk production recording, including cow identification, date of milk recording, date of calving, date of drying off, test-day milk yields, and SCC for all cows in the study.

To ensure that no unrecorded previous cases of CM had occurred within the lactation, only CM cases from lactations that had been recorded from calving onward were eligible for inclusion. Furthermore, CM cases from lactations without any milk production information, or with a calving interval ≤ 320 days or ≥ 600 days were excluded. CM cases during dry-off were also excluded and intervals between pathogen-specific cases of CM in the same quarter had to be at least 14 days for a case to be included in the final dataset. All contaminated samples, culture-negative samples and CM cases where no sample was taken were excluded, resulting in a dataset of 3,833 CM cases of which the causal pathogens were known.

Cases were classified into STREP (n=962), containing all *Streptococci* (*Strep. dysgalactiae*, *Strep. agalactiae*, *Strep. uberis* and other streptococci), STAPH (n=746), containing *Staph. aureus,* and COLI (n=979, containing *E. coli* and *Klebsiella*). Mixed cultures containing pathogens from the same class were classified into this class. All CM cases that could not be classified into STREP, STAPH or COLI were excluded (n = 1,146). Regarding Gram-status, cases were classified as either Gram-positive (n=2,528; *STREP*, *STAPH and* coagulase-negative staphylococci) or Gram-negative (n=1,006; *COLI and Pseudomonas*). All CM cases that could not be classified according to their Gram-status were excluded (n = 299).

Table 2. Description of the independent variables with their abbreviation and different levels used for the construction of naive Bayesian networks.

Description	Abbrev.	# classes	Classifications
Parity	PAR	4	1, 2, 3, ≥4
Month in lactation	MONTH	8	1, 2, 3, 4, 5, 6, 7, ≥8
Season of the year	SEAS	4	January – March, April – June, July – September, October – December
Quarter position of the udder	QP	4	right front, left front, right rear, left rear
SCC 1-30 days before current CM	SCC1	2	<200,000 cells/mL, ≥200,000 cells/mL
SCC >30 days before current CM	SCC2	2	<200,000 cells/mL, ≥200,000 cells/mL
Geometric mean SCC in previous lactation	PrevSCC	2	<200,000 cells/mL, ≥200,000 cells/mL
CM history 1-30 days before current CM	CM1	2	no, yes
CM history > 30 days before current CM	CM2	2	no, yes
Gram history 1-30 days before current CM	GRAM1	3	no previous CM, Gram-positive, Gram-negative
Gram history > 30 days before current CM	GRAM2	3	no previous CM, Gram-positive, Gram-negative
Pathogen history 1-30 days before current CM	PATH1	4	no previous CM, STREP, STAPH, COLI
Pathogen history > 30 days before current CM	PATH2	4	no previous CM, STREP, STAPH, COLI
Colour of the milk of cow with CM	COLOUR	5	normal, yellowish, very yellow, watery, blood
Texture of the milk of cow with CM	TEXT	5	normal, small flakes, big flakes, serous, viscous
Cow sick at moment of CM	SICK	2	not sick, sick

Independent variables were defined using information from the literature and based on expert knowledge (Table 2). All SCC variables were classified as either < or ≥ 200,000 cells/mL (Dohoo and Leslie, 1991). Pathogen-specific CM history variables (Zadoks *et al.,* 2001) were defined covering the last 30 days before the case and for > 30 days history. Because hardly any CM information from previous lactations was available in the datasets, no such information was taken into account in our study. Furthermore, 3 variables were included with information on the clinical signs: colour of the milk, texture of the milk, and whether or not the cow was sick (Jones and Ward, 1990; Milne *et al.,* 2003).

<u>Model development</u>

Dataset 1 was analyzed with decision tree induction. Two thirds of all data were selected for training and the remaining third for testing, where quarters were randomly stratified according to the CM causal pathogen species. To prevent overfitting of the decision tree, first all independent variables that had an information gain ratio higher than 0.01 were selected. The information gain of an independent variable X is based on the change in information value (or entropy) of a dataset S with respect to the dependent variable Y, after partitioning S using the values of independent variable X (Witten and Frank, 2005). Sixteen out of 1.065 independent variables met this requirement and were used in further analyses on Gram-status prediction.

A decision tree is a graphic representation of a divide-and-conquer approach of a classification problem and consists of nodes at which a variable is tested. Based on its information gain ratio, an independent variable is selected to split a data set at the first node. For each possible outcome of the test involved at that node, a branch is made ending in a daughter node. Next, the process can be repeated for each branch, using only those records that actually reach that branch. If at any time all records at a node have the same classification, that part of the tree stops developing (Witten and Frank, 2005; Kamphuis *et al.,* 2010b). To develop a decision tree, the J48 algorithm as implemented in WEKA (Witten and Frank, 2005) with default settings was used. Because the number of Gram-negative CM cases in the training set was much lower than the number of Gram-positive CM cases (21 *vs.* 75, respectively), a cost matrix was applied to balance the data (Kamphuis *et al.,* 2010a).
Sixteen variables that met the 0.01 information gain ratio requirement were used to develop 16 univariate decision trees in order to prevent the selection of correlated variables in the development of a decision tree based on 96 CM cases in the training set. To select the best univariate decision tree (including the cost matrix), the kappa value (Dohoo *et al.,* 2009) was used. Next, a forward selection procedure started including all 16 independent variables added one by one. This procedure of forward selection was continued until the kappa value no longer improved. The developed decision tree was used to predict the Gram-status of the CM cases in the test set, where the output was a probability estimate for a quarter to have a CM infection caused by a Gram-positive or a Gram-negative pathogen. Kappa value and accuracy of this test set were used as evaluation measures.
Decision-tree induction was applied in the same way to develop a model that predicts the CM causal pathogen itself. However, as the number of CM cases caused by *Klebsiella spp*. was limited, these CM cases were excluded from the training set (n=3) and the test set (n=1). Only one independent variable had an information gain ratio higher than 0.01, which made a further forward selection procedure unnecessary. A final decision tree was trained with this

single independent variable and using a cost matrix that balanced the pathogen ratio in the training set. Also this decision tree was evaluated with data from the test set cases, with the kappa value and the accuracy as evaluation measures.

Dataset 2 was analyzed with naive Bayesian networks (NBN, Friedman *et al.,* 1997). An NBN consists of a single class variable that represents the possible classes for the dependent variable, and a set of feature variables modelling the relevant levels of the independent variables. The variable GRAM or PATH was the class variable, whereas all other variables were potential feature variables. In essence, all available feature variables can be included in an NBN. Methods exist, however, for selecting only those feature variables that best discriminate between the different classes of a dependent variable, thereby preventing overfitting of the data (Langley and Sage, 1994). For this study, a wrapper method with forward selection was used for selecting appropriate feature variables (e.g., Blanco *et al.*, 2005; Geenen *et al.,* 2005). With this method, feature variables were selected to optimize the accuracy of the NBN under construction. The method started with an NBN including just the class variable and no feature variables. In each subsequent step, it computed the accuracy of the NBN with a single feature variable added, for each such variable separately. It then included the feature variable that increased the accuracy the most, if any. The inclusion of feature variables was continued until the accuracy of the NBN no longer improved.

Two thirds of the herds were selected randomly for training and the remaining third for testing. Selecting herds rather than separate CM cases was aimed at applicability of the resulting models on farms. The selection process apparently did not result in a bias, as the prevalence of pathogens was approximately equal in the training and validation datasets. Construction of the NBNs was done with 10-fold cross validation on the training dataset. The NBN which performed best on the training set during the cross validation was selected for further evaluation on the test dataset.

From the posterior probability distribution computed for the class variable for a CM case, the predicted class was established. For the GRAM variable, which had 2 possible classes, the predicted class was the Gram-positive class if its posterior probability was > 0.71; otherwise, the predicted class was Gram-negative. This threshold was chosen to reflect the prevalence of Gram-positive CM cases in the dataset. For the PATH class variable, having 3 possible classes, the predicted class was the one with highest posterior probability. If 2 or more classes had equal posterior probabilities, ties were broken at random.

In practice on a farm, only CM cases with a very high (posterior) probability for a single pathogen or group of pathogens will be eligible for pathogen-specific treatment; CM cases which resulted in more or less equal posterior probabilities will be more eligible for broad spectrum use of antibiotics. By providing probability distributions for the causal pathogens or Gram-status of the pathogen, the farmer can readily distinguish between such cases. To establish the accuracy of the models for CM cases with a high posterior probability (for instance > 0.80) for a single class, all other cases were left unclassified. These accuracies are called stratified accuracies, since they are based upon different strata of the dataset under study.

The data mining software WEKA (Witten and Frank, 2005) was used to select variables based on their information gain ratio, to perform the forward selection of independent variables, and to develop the final decision tree (dataset 1). Constructing the different NBNs, which includes estimating the prior and conditional probabilities, was done by using the Bayesian-network editing package Dazzle (Schrage *et al.*, 2005) (dataset 2). All (stratified) accuracies and kappa values were calculated using SAS, version 9.1 (SAS Institute Inc., Cary, NC) (dataset 1 and 2).

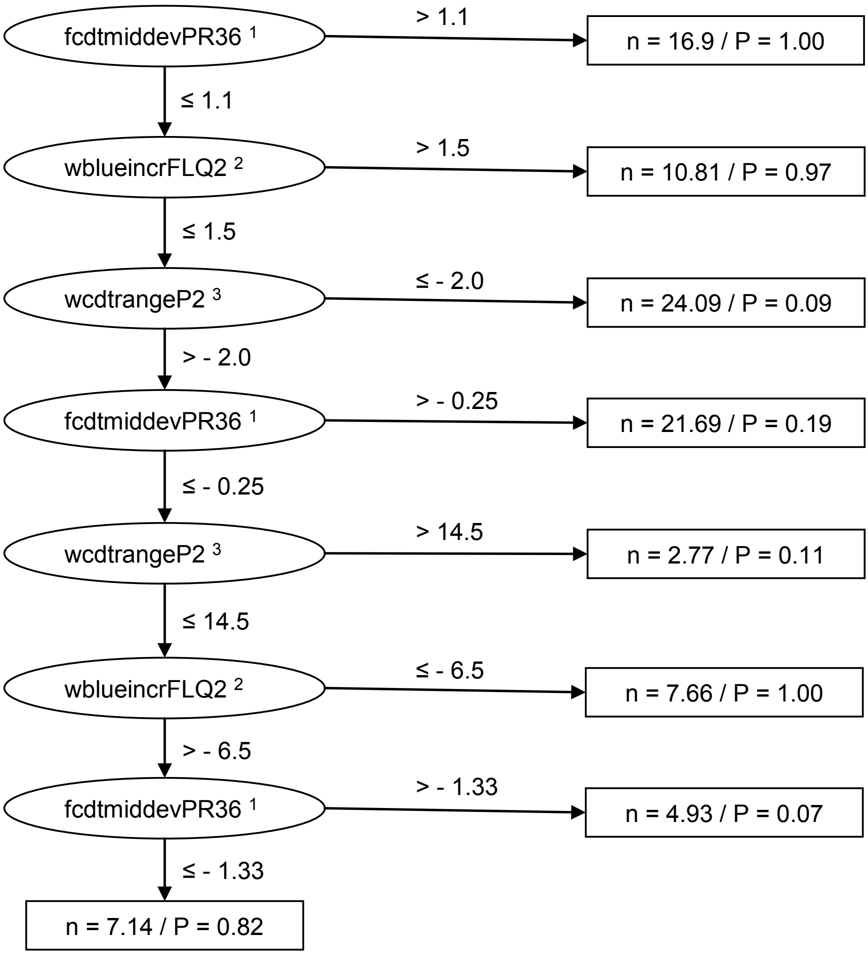

Figure 1. Final decision tree using three different independent variables (variables with gain ratio >0.01) to classify 96 quarters in the training set for their Gram-status. The ovals represent test nodes at which a variable is tested. The rectangles represent end-nodes containing information on the total number of records reaching this rectangle (n), and the probability (P) of being a Gram-positive CM case.

[1] deviation of electrical conductivity between actual midpoint observation and expected midpoint observation from first 500 mL of quarter milk produced compared with mean value for this variable of all milkings within previous 36h for that same quarter;

[2] increase from first to last sensor measurement of whole quarter milking of blue compared with mean value of increase of two quarters within the same milking that showed highest values for this increase;
[3] range of electrical conductivity of whole quarter milking compared with mean value for range of two previous milkings for that same quarter

Results

Dataset 1
There were 16 independent variables selected for Gram-status prediction based on their information gain ratio being > 0.01. The information gain ratios ranged from 0.0260 to 0.2923. Most of these selected variables were based on electrical conductivity, but some were based on the colours red and blue. Selected variables were based not only on absolute values, but also on comparisons with previous milkings from the same cow or on other quarters within the same cow milking.
The accuracy of the final decision tree (with the highest kappa value) for Gram-status prediction (Figure 1) based on data from the training set was 90.6%, and the kappa value was 0.76. The stratified accuracy for the 87.5% of the cases that received a probability estimate > 0.80 was similar, 92.9%. The tree used seven tests (ovals in Figure 1) to classify the 96 records in the training set based on three independent variables; two were based on electrical conductivity measurements, and one was based on the colour sensor blue. The rectangles in Figure 1 represent end nodes where records are classified as being caused by a Gram-positive causal pathogen with a certain probability. The numbers of cases in the rectangles show decimals due to the way the J48 algorithm deals with records with missing values for the variables on which a test at a node applies (Witten and Frank, 2005).
The accuracy of the decision tree dropped to 54.5% when applied to the test set and the kappa value decreased to -0.20.The stratified accuracy was marginally higher; 57.9% for 86% of the cases.
There was only one independent variable that fulfilled the requirement of having an information gain ratio higher than 0.01 for predicting the actual CM causal pathogen. However, the application of the cost matrix made the final decision tree such that it did not use this variable at all. Instead, the model simply predicted all CM cases to be caused by the majority class (*S. uberis*).
More detailed results are presented in Kamphuis *et al* (2011).

Dataset 2
The NBN for Gram-status prediction (NBN_{GRAM}) contained five feature variables (SICK, GRAM1, COLOUR, GRAM2 and SCC1; in order of addition), whereas the NBN for pathogen prediction (NBN_{PATH}) contained eight feature variables (SCC1, PATH1, SICK PATH2, SCC2, TEXT, SEAS and COLOUR). Information on Gram-status or pathogen of previous cases appeared to be important variables in the models, but also information on whether the cow was sick, the level of SCC and colour of the milk were important.
For each CM case from the test datasets, posterior probability distributions were established using the constructed NBNs. Using a threshold probability of 0.71, NBN_{GRAM} resulted in an accuracy of 73%. The stratified accuracy for the 50% of the CM cases that received a posterior probability estimate > 0.80 was 90.0%. Using the most likely pathogen as the predicted value,

NBN_{PATH} resulted in an accuracy of 52%. The stratified accuracy for the 17% of the CM cases that received a posterior probability estimate > 0.80 was 76%.
More detailed results are presented in Steeneveld *et al* (2009).

Discussion

From the results of the decision tree, developed and tested on different parts of dataset 1, we could conclude that sensor information from the electrical conductivity, colour, and milk yield lacked discriminative power to predict the Gram-status or the CM causal pathogen itself. This conclusion rejects the suggestion of Espada and Vijverberg (2002) that colour patterns could help discriminating between different pathogens, but, on the other hand, both studies confirm each others results. The high accuracy and kappa values of the decision tree developed and tested on the training data led to the same promising suggestion as Espada and Vijverberg (2002)drew from their study based on six cases of abnormal milk. The current study, however, showed that when the developed model was applied on the test set, this resulted in a very poor performance. So, although a forward selection procedure was used to prevent selection of correlated independent variables and a cost matrix was applied to balance the data in the training set, it has to be concluded that the developed decision tree was overfit to the training data. This result has been confirmed with two other iterations of different training and test sets (results not shown). As the results of the pathogen-specific decision tree were even worse, they are not discussed anymore.
For a minority of the cases, clinical symptoms and management information can be used to give Gram-status predictions with acceptable confidence, but still (too) many CM cases remain non-predictable. As the feature variables on SICK, SCC1, COLOUR, TEXT and pathogen-specific CM history were selected first in the NBN, especially these variables can be used to predict the Gram-status for the minority of CM cases. Also in previous studies the importance of these variables was reported for pathogen diagnosis of CM cases (e.g., Jones and Ward, 1990; Zadoks *et al.,* 2001; de Haas *et al.,* 2004).

Stratified accuracies were established to gain insight in the reliability of high (posterior) probabilities for a single pathogen or group of pathogens. Results, especially of NBN models, showed that the stratified accuracies of the Gram-predicting models increased with higher threshold probabilities. For 50% of the CM cases, for instance, a stratified accuracy of 90% for prediction of Gram-status was reached and for 15% of the cases a stratified accuracy as high as 100% was reached. These high stratified accuracies indicate that the greater a posterior probability computed for either a positive or a negative Gram-status of the causal pathogen, the more the farmer can rely on the classification result.

As SCC, SICK and variables on appearance of the milk (COLOUR, TEXT) appeared to be important in the NBNs, we would expect that, with the development of new sensors (e.g., on SCC, temperature and colour), automatic prediction of Gram-status or causal pathogen would be feasible in the near future. Sensors assessing SCC on-line are already available (Whyte *et al.,* 2004) and are known to improve detection performance of CM (Kamphuis *et al.,* 2008b; Mollenhorst *et al.,* 2010). This may contribute even more to the Gram-status prediction than the SCC information used in the NBNs, which came from the 3- to 4-weekly Dutch national milk recording system. Having fever is a strong indication whether a cows is sick or not, and

sensors are available that measure the temperature of milk, which may serve as indicator for a cow to have fever (e.g., Bitman, 1984; Berry *et al.,* 2003; Polat *et al.,* 2010). In addition, a new colour sensor is available that measures LED light transmittance. First results with this sensor indicate an expected improvement of the detection of CM (Song *et al.,* 2010). This sensor may as well improve the prediction of the Gram-status or CM causal pathogen, compared to the colour sensor used in this study which measures LED light reflection.
Developing pathogen specific algorithms with additional or improved sensor data, may be one way to improve mastitis detection and treatment selection. As long as sensors are used that do not need any additional reagent (like conductivity, colour, milk yield, temperature), this will by far be the cheapest solution. The main disadvantage of, for example, an on-line SCC sensor is that the costs per milking are quite high due to the need of reagent and disposal of milk. When more expensive sensors are needed to reach an acceptable performance, also other possibilities need to be considered, as pathogen specific sensors are developed nowadays. One example is a DNA detection method that can directly detect DNA in e.g. milk, which has been tested for the detection of *S. aureus* (Spain *et al.,* 2011). As this kind of sensors can become much more specific, costs and performances of different types of sensors need to be weighted when they become available for practical on-farm use.

Conclusions

Predicting the Gram-status of the causal pathogen of CM cases or the pathogen itself is still not feasible with data available on farms. With a combination of clinical symptoms and management information processed in an NBN model it is possible to give predictions with acceptable confidence for a minority of the cases, however, still many cases will be non-decisive. Data from electrical conductivity, colour, and milk yield sensors are not informative enough for this goal. In automatic milking systems, however, progress can be made by incorporating sensors that can better assess clinical signs (e.g. temperature) or other milk constituents and, furthermore, there are interesting developments with respect to pathogen specific sensors that may become available.

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References

Barkema, H. W., Schukken, Y. H., Lam, T. J. G. M., Beiboer, M. L., Wilmink, H., Benedictus, G. and Brand, A. 1998. Incidence of clinical mastitis in dairy herds grouped in three categories by bulk milk somatic cell counts. Journal of Dairy Science **81** 411-419.

Barkema, H. W., Schukken, Y. H. and Zadoks, R. N. 2006. Invited review: The role of cow, pathogen, and treatment regimen in the therapeutic success of bovine staphylococcus aureus mastitis. Journal of Dairy Science **89** 1877-1895.

Berry, R. J., Kennedy, A. D., Scott, S. L., Kyle, B. L., Schaefer, A. L. 2003. Daily variation in the udder surface temperature of dairy cows measured by infrared thermography: potential for mastitis detection. Canadian Journal of Animal Science **83** 687-693.

Bitman, J., Lefcourt, A., Wood, D. L. and Stroud, B. 1984. Circadian and ultradian temperature rhythms of lactating dairy cows. Journal of Dairy Science **67** 1014-1023.

Blanco, R., Inza, M., Merino, M., Quiroga, J. and Larranaga, P. 2005. Feature selection in bayesian classifiers for the prognosis of survival of cirrhotic patients treated with TIPS. Journal of Biomedical Informatics **38** 376-388.

De Haas, Y., Veerkamp, R. F., Barkema, H. W., Grohn, Y. T. and Schukken, Y. H. 2004. Associations between pathogen-specific cases of clinical mastitis and somatic cell count patterns. Journal of Dairy Science **87** 95-105.

Dohoo, I., Martin, W. and Stryhn, H. 2009. Veterinary Epidemiologic Research, 2nd edition. S. M. McPike (ed.) VER Inc., Charlottetown, Prince Edward Island, Canada.

Dohoo, I. R. and Leslie, K. E. 1991. Evaluation of changes in somatic-cell counts as indicators of new intramammary infections. Preventive Veterinary Medicine. **10** 225-237.

Espada, E. and Vijverberg, H. 2002. Milk colour analysis as a tool for the detection of abnormal milk. In: First North American Conference on Robotic Milking. Wageningen Pers, Wageningen, The Netherlands, pp. 28-38.

Friedman, N., Geiger, D. and Goldszmidt, M. 1997. Bayesian network classifiers. Machine Learning. **29** 131-163.

Geenen, P. L., Van der Gaag, L. C., Loeffen, W. L. A. and Elbers, A. R. W. 2005. Naive bayesian classifiers for the clinical diagnosis of classical swine fever. In: Proceedings of 2005 meeting of Society for Veterinary Epidemiology and Preventive Medicine, Nairn, Inverness, Scotland. pp. 169-176.

Harmon, R. J., Eberhart, R. J., Jasper, D. E., Langlois, B. E. and Wilson, R. A. 1990. Microbiological Procedures for the Diagnosis of Bovine Udder Infection. National Mastitis Council Inc., Arlington, VA.

Hillerton, J. E. and Kliem, K. E. 2002. Effective treatment of streptococcus uberis clinical mastitis to minimize the use of antibiotics. Journal of Dairy Science **85** 1009-1014.

Hogeveen, H. and Ouweltjes, W. 2003. Sensors and management support in high-technology milking. Journal of Animal Science **81** 1-10.

Jones, G. F. and Ward, G. E. 1990. Evaluation of A scheme for predicting the gram-staining reaction of organisms causing bovine mastitis. Journal of the American Veterinary Medical Association **196** 597-599.

Kamphuis, C., Mollenhorst, H., Feelders, A. J., Pietersma, D. and Hogeveen, H. 2010a. Decision-tree induction to detect clinical mastitis with automatic milking. Computers and Electronics in Agriculture **70** 60-68.

Kamphuis, C., Mollenhorst, H., Heesterbeek, J. A. P. and Hogeveen, H. 2010b. Detection of clinical mastitis with sensor data from automatic milking systems is improved by using decision-tree induction. Journal of Dairy Science **93** 3616-3627.

Kamphuis, C., Mollenhorst, H. and Hogeveen, H. 2011. Sensor measurement patterns revealed: Predicting the Gram-status of clinical mastitis causal pathogens. Computers and Electronics in Agriculture. doi: 10.1016/j.compag.2011.03.012

Kamphuis, C., Pietersma, D., Van der Tol, R., Wiedemann, M., and Hogeveen, H. 2008a. Using sensor data patterns from an automatic milking system to develop predictive variables for classifying clinical mastitis and abnormal milk. Computers and Electronics in Agriculture **62** 169-181.

Kamphuis, C., Sherlock, R., Jago, J., Mein, G. and Hogeveen, H. 2008b. Automatic detection of clinical mastitis is improved by in-line monitoring of somatic cell count. Journal of Dairy Science **91** 4560-4570.

Langley, P. and Sage, S. 1994. Induction of selective bayesian classifiers. In: Proceedings of the Tenth Conference on Uncertainty in Artificial Intelligence. Morgan Kaufmann Publishers, San Francisco, CA, pp. 399-406.

Makovec, J. A. and Ruegg, P. L. 2003. Results of milk samples submitted for microbiological examination in Wisconsin from 1994 to 2001. Journal of Dairy Science **86** 3466-3472.

Milne, M. H., Biggs, A. M., Fitzpatrick, J. L., Innocent, G. T. and Barrett, D. C. 2003. Use of clinical information to predict the characteristics of bacteria isolated from clinical cases of bovine mastitis. Veterinary Record. **152** 615-617.

Mollenhorst, H., Van der Tol, P. P. J. and Hogeveen, H. 2010. Somatic cell count assessment at the quarter or cow milking level. Journal of Dairy Science **93** 3358-3364.

Olde Riekerink, R. G. M., Barkema, H. W. and Stryhn, H. 2007. The effect of season on somatic cell count and the incidence of clinical mastitis. Journal of Dairy Science **90** 1704-1715.

Polat, B., Colak, A., Cengiz., M., Yanmaz, L. E., Oral, H., Bastan, A., Kaya, S. and Hayirli, A. 2010. Sensitivity and specificity of infrared thermography in detection of subclinical mastitis in dairy cows. Journal of Dairy Science **93** 3525-3532.

Schrage, M. M., van IJzendoorn, A. and Van der Gaag, L. C. 2005. Haskell ready to dazzle the real world. In: Proceedings of the 2005 conference of ACM Special Interest Group on Programming Languages, pp. 17-26.

Song, X., Zhuang, S., and Van der Tol, R. 2010. New model to detect clinical mastitis in Astronaut A3 Next^{tm} milking robot. In: Mastitis research in practice: Proceedings of the 5th IDF mastitis conference, edited by J.E. Hillerton, VetLearn, New Zealand, pp. 474-480.

Spain, E., Kojima, R., Kaner, R. B., Wallace, G. G., O'Grady, J., Lacey, K., Barry, T., Keyes, T. E. and Forster, R. J. 2011. High sensitivity DNA detection using gold nanoparticle functionalised polyaniline nanofibres. Biosensors and Bioelectronics **26** 2613-2618.

Steeneveld, W., van der Gaag, L. C., Barkema, H. W. and Hogeveen, H.. 2009. Providing probability distributions for the causal pathogen of clinical mastitis using naive bayesian networks. Journal of Dairy Science **92** 2598-2609.

Whyte, D. S., Orchard, R. G., Cross, P. S., Frietsch, T., Claycomb, R. W. and Mein, G. A. 2004. An on-line somatic cell count sensor. In: Automatic Milking: A Better Understanding, edited by A. Meijering, H. Hogeveen and C.J.A.M. de Koning, Wageningen Academic Publishers, Wageningen, the Netherlands, pp. 235-240

Witten, I. H. and Frank, E. 2005. Data Mining; Practical Machine Learning Tools and Techniques. Morgan Kaufmann Publishers, San Fransisco.

Zadoks, R. N., Allore, H. G., Barkema, H. W., Sampimon, O. C., Wellenberg, G. J., Grohn, Y. T. and Schukken, Y. H. 2001. Cow- and quarter-level risk factors for streptococcus uberis and staphylococcus aureus mastitis. Journal of Dairy Science **84** 2649-2663.

Comparison of results using *smardwatch*® to detect oestrus in dairy cattle parallel to progesterone test and visual oestrus detection

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Abstract

According to Balzer *et al.* (2009), where we introduce a new method of fertility monitoring in cattle herds based on telemetric data recording with the sensor system *smardwatch*® and chronobiological analysis of permanent measured psycho-physiological data, we are now will present our results in comparison to classical oestrus detection methods like visual observation or progesterone test. Using distinct chronobiological parameters we reach from 65 up to 94 percent agreement.

Keywords: oestrus/heat detection, cattle/cow, telemetric sensor, chronobiology, *smardwatch*®.

Introduction

Besides keeping animal health in raising cattle herds, oestrus detection is one of the most important factors affecting the economic success of milk production. Different studies show, that with increasing time for visual oestrus detection it is possible to involve higher identification rates of cows in oestrus followed by better results of insemination (Kanitz *et al.*, 2005). Another possibility is measuring activity e.g. by pedometers (Wangler *et al.*, 2005), often used in combination with information about milking parameters. But one problem, especially in high performance breeds, are cows which have only a short oestrus with low level symptoms or cows with silent oestrus. For these animals in practice it is possible to use hormone tests based on progesterone levels in milk - with the disadvantage of relatively high costs (Förster Technik - FT Multilyzer, DeLaval - Herd Navigator, Frim Tec - eProCheck and others)
Solving the problem will be possible by using sensor based technology with permanent measuring of psycho-physiological data (see below) of each animal and the use of methods from the science of chronobiology - that means data analysis of time series with the specially focus on the changes of measured parameters (Hecht *et al.*, 2001).

Materials and methods

Measuring eight psycho-physiological and behavioural parameters constant on animal skin we examined 21 dairy cattle. 17 of them where clearly identified by visual oestrus detection and/or progesterone test Hormonost® being in oestrus. Data where analysed by chronobiological data analysis to observe changes in synchronization between distinct parameters and to identify changes in so called regulation states (Balzer and Hecht, 2000; Balzer *et al.*, 2009).

Instrumentation

smardwatch®-system consists of a sensor which was implemented in a neckband, sending measured parameters wireless to a receiver – so called base station – connected with a PC using special software. Psycho-physiological parameters, each measured 10 times per second are: skin resistance (SR) showing vegetative-emotional reactions, skin potential (SP) as sign of vegetative-nervous reactions, electromyogram (EMG) for muscular reactions of an organism, skin temperature (TE) – usually runs contrariwise to the core temperature of the body – and 3D-accelleration. The connection between the parameter SR and vegetative-emotional reactions or SP and vegetative-nervous reactions are described by Bureš *et al.* (1960) and Boucsein (1988).

Progesterone test Hormonost®

Sobiraj *et al.* (1995) found a concordance of 91 per cent over all days of oestrus for progesterone milk test Hormonost® comparing with results of a laboratory test. Tree other stable tests show only concordance between 73.5 and 81 per cent. So we use Hormonost® farmers test for milk (Jumbo-Test) to get time series of the changing progesterone concentration to find the days of oestrus. The test gives the information "oestrus" by showing blue colour in the test result (by changing the colour in the run of time from: clear = high progesterone level = no oestrus, over light and middle blue to dark blue = low progesterone level = oestrus, and back) (Arnstadt, 2006). While the first investigations we took assays two times per day, in the last investigations we took an assay only once a day, because the separation effect of the test was not high enough to see low differences/changes.

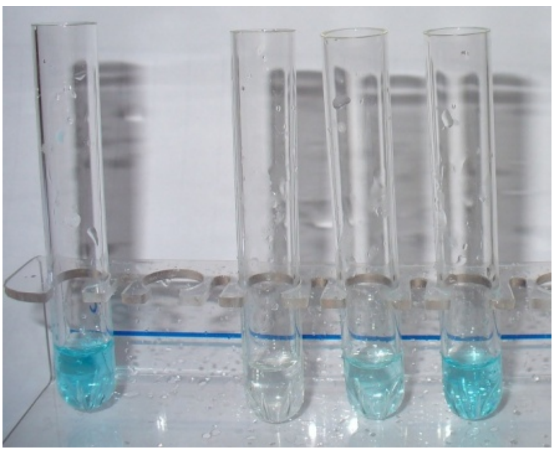

Figure 1. Result of Hormonost® test: chemical standard „oestrus“ (left) and a run from clear – no oestrus, and next two days in the beginning of oestrus

Visual oestrus detection

The farmer use only visual oestrus detection. It was a tie-stall with only 20 cows, observation was done while feeding and milking and when the cows walks to/from the meadow. Not every oestrus will be used for mating – the aim is constantly having milk and meet all over the year for their farm shop.

Analysis of *smardwatch*® data

We use two distinct approaches for data analysis with chronobiological methods (Balzer, 2009, Balzer and Hecht, 2000): First are significant differences in regulation states between normal day and days in oestrus; second changing's in correlations between measured parameters that means in synchronization of the regulatory process.

First step was a plausibility check of measured data, because the measuring system including the neckband was under construction during the project.

Second step is removing the trend and do distinct spectral analysis to find the distinct rhythms of regulation - so called regulation periods - in the time series of parameters (Balzer, 2009, Balzer *et al.*, 2009). For a defined time window of 20 data we so get a state of regulation (a picture which shows the given regulatory rhythms in this time) for each parameter, which changes over the time. By classifying these pictures Balzer and Hecht (2000) get the periodic system of regulation states (P.S.R) (Figure 2.) which was enlarged over the time (Fritz, 2005).

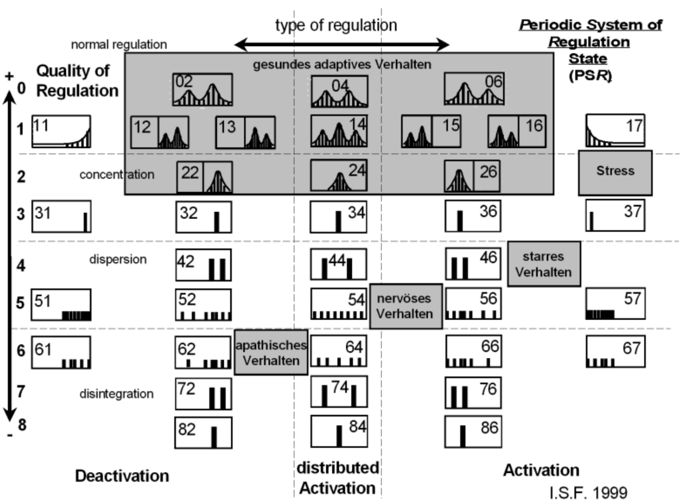

Figure 2. Periodic system of regulation states (Balzer und Hecht, 2000)

The frequency of distinct regulation states we compare between every night to every other night and every day to every other day by Kolgomoroff-Smirnoff-test (p = 0,05) to check the following thesis:

1. Between one day (night) and another day (night) exist significant differences in frequency of the distinct regulation states in one animal
2. Between days (nights) of oestrus an normal days (nights) exist the highest differences considered over all parameters.

Third was to calculate synchronization clouds (Balzer, 2009) to find the balance point (where are the most data of the cloud are located) of excitation and relaxation. Within a defined time period the x-axis of the cloud-chart shows regulation periods found in the time series of EMG, SP, SR and TE standardized between -1 and 1, y-axis shows the averaged correlation between these data. More information's about chronobiology (history, explanations and publications) you can find on http://www.smardwatch.com.

Results

We get measured data of 170 days from 32 cows (some we measured more than once). The monitoring time was between 2 and 16 days, that means no complete oestrus cycle. 21 cows came in oestrus and from this 4 show problems.
There are distinct patterns of the frequency of regulation states in comparable periods. After analysing the frequency of regulation states per day/night for every cow and every parameter we are looking for significant differences in these patterns. Table 1 show an example for EMG.

Table 1. „Lyra" measured from 09.04. – 15.04.2009: triangulation of significance between regulation states of EMG from distinct days (p = 0,05)

		day	day	day	day	day	day	day		
EMG		9	10	11	12	13	14	15	significance	
day	9	0	0,09	0,27	0,14	0,32	0,31	0,15	Yes all	Maximum change at day 13 to day 15 with 0,41 (bold)
day	10		0,00	0,32	0,18	0,36	0,35	0,06	Yes all	
day	11			0,00	0,15	0,04	0,03	0,36	Yes all	
day	12				0,00	0,19	0,17	0,23	Yes all	
day	13					0,00	0,02	**0,41**	Yes all	
day	14						0,00	0,40	Yes all	
day	15							0,00	Yes all	

In analogy to the EMG triangulation was made for all other parameters and after this we are looking for the highest differences (Table 2).

Table 2. „Lyra" measured from 09.04. – 15.04.2009: Maxima of differences of frequencies of regulation states from EMG from all days and nights (p = 0.05)

day	max. difference	from day to day
EMG	0,41	"**13/15**"
SP	0,39	"10/**13**"
SR	0,07	"9/10"
TE	0,39	"14/**15**"
nigth	max. difference	from nigth to nigth
EMG	0,43	"10/11" / "**15**/16"
SP	0,39	"12/**13**" / "**15**/16"
SR	0,05	"9/10" / "12/**13**"
TE	0,30	"**13**/14" / "14/**15**"

In this example highest differences over all parameters were found between day 13 and 15 (bold - 5 times 13 from 8 possible and 5 times 15 from 8 possible).
By visual control the 13.4.2009 was found as the day of oestrus. Progesterone test was dark blue from 13. to 15.4.2009.
Especially if cows show problems in oestrus we observed in progesterone test results that don't show dark blue colour (only middle blue) or they show changes in the intensity of blue.

Synchronization is a characteristic attribute for the "playing together" of body functions. Highest performance only can be reached by high synchronization because in this situation the body not needs so much energy for regulation of all other functions. Distinct factors are able to change the location of the cloud (Figure 3), that means that they are able to influence the regulation of body functions and their synchronization. But the organism tries to eliminate a disturbance as soon as possible if he can, so the changing will usually stay only for a relatively short time.

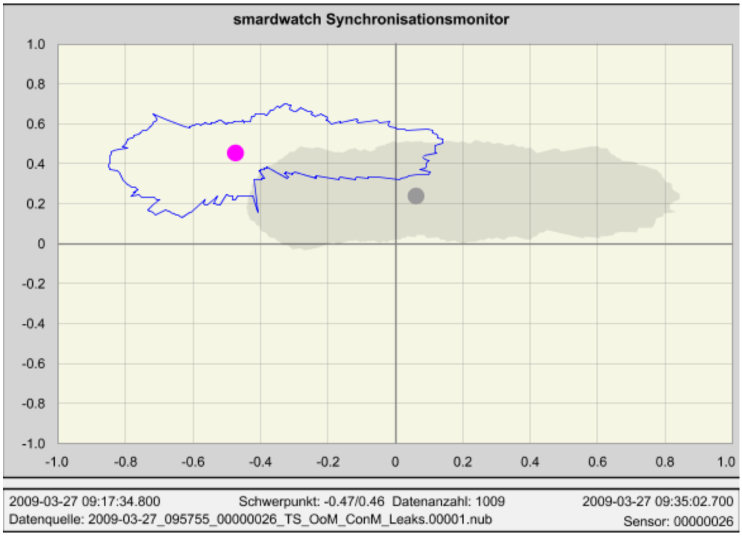

Figure 3. Change of the synchronization cloud of „Narzisse“ at the 27.3.2009 while she was on the meadow (grey – normal location of the cloud with dark grey point as normal balance point i.e. where the most data in the cloud are located)

Looking only at the change of balance point (in horizontal direction of Figure 3), we get the kind of pictures like shown in figure 4.

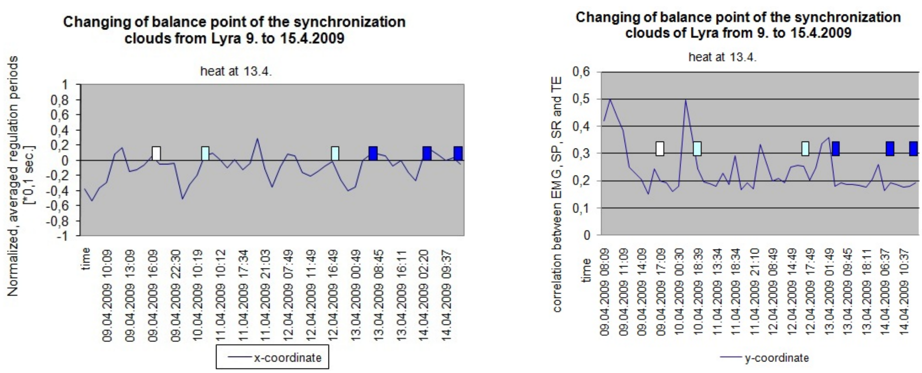

Figure 4. Moving of the balance point (right – x-coordinate, left – y-coordinate) of the synchronisation cloud from „Lyra“ measured from 9. – 15.04.2009 with oestrus at 13.04.2009 in comparison to progesterone test (blue boxes)

The most important changes we found in the changings of x-axis of the balance point.
With a blue progesterone test (that means cow with oestrus, blue boxes in Figure 4 and Figure 5) we found changes in the synchronisation cloud – specially shown by moving of the balance point (x-axis) of the cloud. One day before progesterone test show blue colour, we see a bigger decrease in the graph than on other time points in the measured time followed by an increase

for nearly one day (Figure 5). But in the run of oestrus (that means with blue probes of progesterone test) we found these characteristic distribution more than once and we also found it, when the progesterone test show only middle blue colour and never became dark blue.

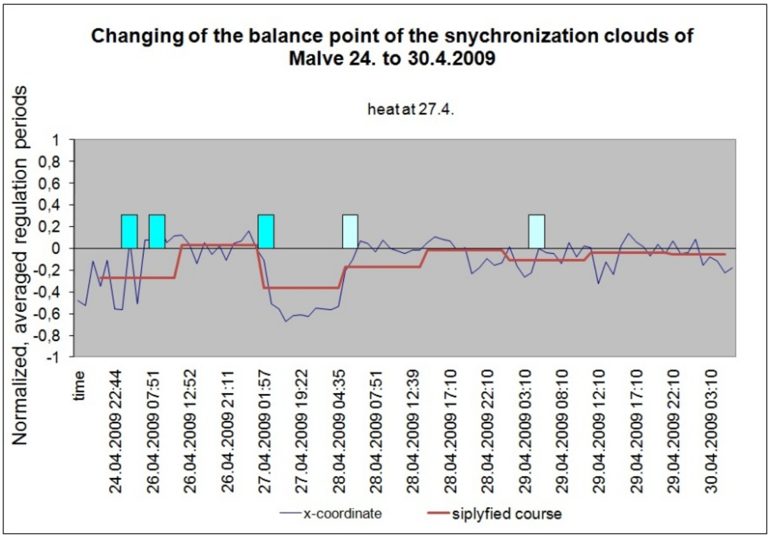

Figure 5. Moving of the balance point (x-axis) of the synchronisation cloud from „Malve“ measured from 24. – 30.04.2009 with oestrus at 27.04.2009 in comparison to progesterone test (blue boxes), the brown line shows a simplified course of the x-coordinate from the balance point

Finally we compare the distinct results: visual detected oestrus with progesterone test, visual detected oestrus with changes of the balance point (x-axis), progesterone test with changes of the balance point (x-axis), progesterone test with significant changes in the frequency of regulation states in physiological parameters and visual detected oestrus with significant changes in the frequency of regulation states in physiological parameters. Agreement was set when the time point of oestrus from one to the other method was ± 1 day (Table 3) and if the day of oestrus ascertains visually falls in the time of blue progesterone test. Where we had no clear information from visual oestrus detection we use the day, given by oestrus calendar as the day of oestrus.

Comparing the method of visual oestrus detection with results of progesterone test we reach 61 per cent of conformity. Visual detection in accordance to changes in regulation states gives 65 per cent of conformity while visual detection to changes in synchronization between parameters results in 71 per cent conformity.

Examine consensus between progesterone test and changes in regulation states we found 88 per cent agreement, even 94 per cent by monitoring changes in synchronization in comparison to the result of progesterone test.

Table 3. Comparison of distinct methods of oestrus control

Animal	Agreement				
	visual oestrus proges-terone	visual oestrus balance point	progesteron e balance point	progesterone frequency	visual oestrus frequency
Heide_28.8.	yes	no	yes	yes	yes
Hera_21.2.	no	*	*	yes	no
Hera_24.8.	no [C]	no [C]	yes	yes	yes [C]
Hera_25.7.	yes[A]	no	no	*	*
Ida_24.3.	no	yes	yes	no	no
Ida_10.4.	no [C]	no [C]	yes	no	no [C]
Indira_18.8.	yes [C]	yes [C]	yes	yes	yes [C]
Indira_8.9.	no	yes	yes	yes	no
Laila_21.7.	yes	yes	yes	yes	yes
Laila_1.9.	yes [C]	yes [C]	yes	yes	yes [C]
Lyra_9.4.	yes	yes	yes	yes	yes
Malve_25.3.	yes	yes	yes	yes	no
Malve_24.4.	no	yes	yes	yes	yes
Minze_6.9.	no	no	yes	yes	no
Narzisse_27.3.	yes	yes	yes	yes	yes
Narzisse_24.4.	yes [C]	yes [C]	yes	yes	yes [C]
Nelly_19_22.7.	yes	yes	yes	yes	yes
Nette_26.8.	yes	yes	yes	yes	yes
Agreement (%)	**61**	**71**	**94**	**88**	**65**

* no statement, [C] day of oestrus of oestrus calendar, [A] no oestrus

Conclusions

The agreement of the new methods based on permanent monitoring with the *smardwatch*® system used for oestrus detection in cows and classic methods lies between 65 and 94 per cent. The comparison of the both classical methods visual oestrus detection and progesterone test in our project was only 61 per cent. So - only by use of differences in the frequency of regulation states between days/nights and the change of synchronization of body functions - we found a new possibility to detect oestrus without need of human resources. Further the method should integrate detailed information about activity we get by the use of measured 3D-data which we don't use up to now. Besides validating the results on more animals (240 cows in a new project) it becomes necessary to develop software which can convert data automatically and identify distinct changes in every individual using a neuronal network.
At the moment another deficit is that we are not able to give good information about non oestrus days, because we monitored these days only by the way. Even it is necessary to get

information's about the influence of environment/management on the regulation of body functions; therefore we now investigate 200 cattle. In future all information's should be implemented in a herd management system. Therefore a first step is done by a common project between IASP and a system developer for management software.
At all: there are a lot of open questions which should be investigated by chronobiological methods to get an better understanding of agricultural animals to improve their health, welfare and last but not least the economic success of animal production.

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References

Arnstadt, K-I., 2006: Zur Fruchtbarkeitsverbesserung in der Milchviehhaltung. Höhere Bundeslehr– und Forschungsanstalt für Landwirtschaft Raumberg–Gumpenstein: 33. Viehwirtschaftliche Fachtagung, 26.–27. April 2006, 5–10.

Balzer, H.-U., 2009: Chronobiology – as a foundation for and an approach to a new understanding of the influence of music, in: Haas / Brandes (ed.) Music that works, p. 1-76, Springer Wien, ISBN 978-3-211-75120-6

Balzer, H.-U., Hecht. K, 2000: Chrono-Psycho-Physiologische Regulationsdiagnostik (CRD): Ein neuer Weg zur objektiven Bestimmung von Gesundheit und Krankheit, in: Hecht, K., Balzer, H.-U. (Hrsg): Stressmanagement Katastrophenmedizin Regulationsmedizin Prävention, 1. Berliner Stress-Forschung-Tage 1999 Pabst Science Publisher, 2000, S. 134-155

Balzer, H-U., Kultus, K., Köhler, S., 2009. A new generation of fertility monitoring in cattle herds. Joint International Agricultural Conference 6.-9.7.2009 Wageningen, Abstract-book p. 236

Bureš, J., Petráň, M., Zachar, J., 1960: Electrophysiological methods in biological research. Publishing House of the Czechoslovak Academy of Sciences, Prague 1960

Boucsein, W. (1988): Elektrodermale Aktivität: Grundlagen, Methoden und Anwendungen. Springer-Verlag Berlin, Heidelberg New York 1988, ISBN 3-540-18586-0

Fritz, F. M., 2005. Eine Methode zu Klassifizierung von Regelvorgängen biologischer und musikalischer Prozesse mit Hilfe eines künstlichen neuronalen Netzwerkes. Dissertation. Universität Mozarteum Salzburg, 2005

Hecht, K., König, O., Scherf, H-P., 2001: Emotioneller Stress durch Überforderung und Unterforderung. Schibri-Verlag, ISBN 978-3933978479

Kanitz, W., Becker, F., Sanftleben, P., 2005. Brunstfeststellung und Optimierung des Besamungszeitpunktes: Schlüsselmaßnahmen im Reproduktionsmanagement von Rindern. Vortrag Iden/Bernburg 13./14.3.2005

Sobiraj, A., Seyrek-Intas, K., Wollgarten, B., Taday, B., 1995: Die Anwendungseignung aktueller Milchprogesteron-Schnelltests für Rinder im Vergleich zu einer laborgebundenen Routinemethode. Tierärztliche Praxis 1995, 23, S. 32-36

Wangler, A., Meyer, A., Rehbock, F., Sanftleben, P., 2005. Wie effizient ist die Aktivitätsmessung als ein Hilfsmittel in der Brunsterkennung bei Milchrindern? Züchtungskunde, 77, (2/3) S. 110 – 127

Section 5
Sound

Vocalization as a tool for identifying the level of stress in piglets

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Abstract

Amongst the challenges in pig production under today's competitive market the issue of meeting the standards of animal welfare is enhanced. Animal vocalization can be a useful tool to identify the level of stress in piglets. This research aimed to evaluate the vocalization of piglets during a surgical procedure with and without anesthesia, and assess their level of stress by analyzing their vocal expressions. Two level of stress were assessed: moderate stress and acute stress. No difference was found the level of pain in both treatments.

Keywords: vocal expression, level of pain, signal analysis.

Introduction

In global economy the competitivity is reached when price, quality and bio safety are met. International meat market has become more demanding for ehical solutions in animal husbandry, and welfare standards are getting more difficult to be assessed. The use of swine vocalization as assessment of animal well being has been presented in current literature (Weary & Fraser, 1997; Marx *et al.*, 2003; Manteuffel & Schon, 2004). Vocalization with low tone such as grunts are used to maintain social contact with other members of the group, while high tone vocalization is similar to screams, and are often used during high degree of excitement (Schrader & Todt, 1998).
Most studies in swine bio acoustics search for findings specific calls' characteristics associated to specific events such as: weaning, castration an social conflicts. According to (Weary & Fraser, 1997) vocalization is a useful tool for assessing stages of well being or distress in commercial reared animal. As castration surgery is indicated to male swine reared for meat production, researchers are trying to find a way to manage the demand and assess piglets' welfare under this painful procedure. According to (White *et al.*, 1995) local anesthesia may reduce the stress caused by the pain of castration; however there are discrepancies related to this issue in literature (Leidg *et al.*, 2009).
This research aimed to evaluate the effect of local shot of anesthesia in the reduction of the stress during piglet castration by assessing its vocalization during the process.

Methodology

<u>Animals and experimental procedure</u>
Two groups of 10 animals each of 3-4 days old piglets were used during the castration procedure. In the first group (G1) castration was done without anesthesia and in the second group local anesthesia was used (G2). The castration procedure used was after containing the piglet in a box (10 cm high and 30 cm long) and the animal was held in the position of lying on

its back and the area was disinfected and cleaned. For the second group (G2) the anesthesia used was commercial lidocaine 20%, 10 min prior to the surgical procedure. The sounds emitted by the piglets were recorded during the whole process in distinct phases of the management (Table 1).

Table 1. Description of the conditions the piglet were and the sounds recorded in distinct stress managements the piglets were involved.

Procedure	Description
A (handling)	To hold the piglet by their limbs
B (first weight)	To weight the piglet prior to castration
C (contention)	To hold the piglet in the proper box used for castration
D (anesthesia)	To apply the anesthesia with the meddle in the testicles
E (castration)	Castration surgery
F (castration after the anesthesia shot)	Surgery of the animals that were under the effect of anesthesia
G (second weight)	To weight the piglet after castration
H (second weight after anesthesia)	To weight the piglet that had anesthesia after castration
I (release)	Return of the animals to their original rooms

For recording the acoustic signals a unidirectional microphone Yoga® was used positioned at approximately 15 cm from the piglet's mouth. This microphone was connected to a digital recorder Marantz® PMD 660, and the signals were digitalized to a frequency of 44.100 Hz.

Signal analysis

The sounds recorded were edited and analyzed using the software Praat®, and the following attributes of the signals were obtained: duration (s), energy (Pa^2 s), maximum amplitude (Pa), minimum amplitude (Pa), mean amplitude (Pa), and amplitude interval (Pa). ANOVA was initially applied to the signal values and Tukey test was used for comparing the mean values using the statistical software Minitab®. The results were considered significant for $\alpha \leq 0.05$.

The experiment was approved by the Ethic Commission of UNICAMP with the protocol number 2224-1.

Results and Discussion

Table 2 presents the average values of the following parameters: duration, energy, maximum amplitude, minimum amplitude of the signal, and the interval of the amplitude for each of the procedures used in the experiment and showed in Table 1 (A, B, C, D, F, G, H and I).

The signal duration was larger in the moment of castration without anesthesia (63.875 s) than for the castration after the use of anesthesia (27.192 s). However, it was observed that adding the duration of the vocalization from the time of administration of anesthesia to the surgical procedure (39.729) the total signal's duration was larger than that when castration is performed without anesthesia. These results suggest that despite the use of local anesthesia to reduce the pain and stress of castration surgical procedure, this effect is lost by the additional stress caused by the anesthesia shot.

Table 2. Comparison of the mean values for the distinct studied managements.

Procedure	**Signal duration (s) (p=0.000)**	**Signal energy (Pa^2s) (p=0.014)**	**Amplitude (Pa)**		
			Max (p=0.000)	**Min (p=0.000)**	**Interval (p=0.000)**
A	3.926 d	0.025 b	0.144 b	-0.161 a	0.305 b
B	2.875 d	0.000 b	0.032 b	-0.036 a	0.069 b
C	9.348 d	0.275 b	0.402 a	-0.429 b	0.628 a
D	39.729 b	1.898 a	0.549 a	-0.557 b	1.106 a
E	63.875 a	1.142 ab	0.459 a	-0.483 b	0.942 a
F	27.192 c	0.080 b	0.501 a	-0.531 b	1.032 a
G	2.117 d	0.000 b	0.016 b	-0.020 a	0.036 b
H	2.465 d	0.005 b	0.085 b	0.089 a	0.173 b
I	3.839 d	0.005 b	0.106 b	-0.107 a	0.213 b

Same letters indicate equal value ($\alpha \geq 0.05$).

Results from this experiment differ from those found by Leidig *et al.* (2009). The compared the vocalization of piglets during castration and found that piglet castrated without anesthesia emitted calls of stress during 50.8% of the time of the trial, while the piglet with local anesthesia emitted calls during just 30.7% of the time, during the procedure.

The amount of energy recorded does not seem to be the best parameter to differentiate stressful situations. The energy emitted in the vocalization during the anesthesia shot (1.898 Pa) did not differ ($\alpha \geq 0.05$) from that emitted during castration, but it was higher than the energy emitted in other studied procedures. According to Cordeiro *et al.* (2009) during calls of painful events the amount of energy used is higher than when the animal is sound.

According to Marx *et al.* (2003), parameters of energy emission, frequency and duration of calls, are particularly appropriate to characterize the type of call. No significant difference ($\alpha \geq 0.05$) was found for the values of maximum amplitude, minimum amplitude and amplitude range of the procedure of handling, giving anesthesia shot, performing castration without anesthesia, and performing castration after the anesthesia shot. This fact indicates that the use of anesthesia during castration of piglets needs further studies, as the shot of anesthesia in the piglet testicles causes stress equal to that of the surgery, besides increasing the time of piglet handling/holding, causing additional stress during the surgical procedure of castration.

The parameters, maximum amplitude, minimum amplitude and amplitude interval made possible the identification of two distinct levels of stress (Table 2) during the process of castration which was divided into moderate and acute stress (Table 3).

Table 3. Level of stress registered in piglets exposed to several management procedures

Stress level	Occasion when the level was reported
Moderate stress	A, H, B, G, I
Acute stress	C, D, E, F,

Results of this research suggest that the procedures of contention (C), anesthesia shot (D), castration without anesthesia (E), and the castration after the shot of anesthesia (F) lead to acute stress in piglets, while moderate stress was found in the other handling procedures.

Conclusion

Today's piglet castration surgical procedure needs further studies. The surgical method of castration uses two stressful situations, first the local shot of anesthesia in the testicles, and second the surgical procedure. Both actions involve higher level of stress than the castration without anesthesia and lead to animal low welfare.

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References

Cordeiro, A. F. S., Pereira, E. M., Nääs. I. A., Silva, W. T. and Moura, D. J. 2009. Medida de vocalização de suínos (*Sus scrofa*) como um indicador de gasto energético. (abstract in English). Revista Brasileira de Engenharia de Biosistemas **2** 143-152.

Leidig, M. S., Hertrampf, B., Failing, K., Schumann, A. and Reiner, G. 2009. Pain and discomfort in male piglets during surgical castration with and without local anesthesia as determined by vocalization and defense behaviour. Applied Animal Behaviour Science **116** 174-178.

Manteuffel, G. and Schon, P. C. 2004. Measuring pig welfare by automatic monitoring of stress calls. Bornier Agratechnische Bericht **29** 110-18.

Marx, G., Horn, T., Thielebein, J., Knubel, B. and Borell, E. 2003. Analysis of pain-related vocalization in young pigs. Journal of Sound and Vibration **266** 687-698.

Schrader, L. and Todt, D. 1998. Vocal quality is correlated with levels of stress hormones in domestic pigs. Etology **104** 859-876.

Weary, D.M. and Fraser, D. 1997. Vocal response of piglet to weaning: effect of piglet age. Applied Animal Behaviour Science **54** 153-160.

Sound analysis toward heat stress assessment in swine farming

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Abstract
In intensive swine farms stressful conditions that relate to climate, affect animal behaviour, welfare and production quality. This research aims to record animal vocalizations coming from a selected group of piglets, bred in standard intensive conditions, and exposed to increased temperature three times per week. This temperature increase had as a goal to stimulate heat stress specific related behaviours and vocalizations. The recorded sounds were subsequently labelled. The study of sound acoustics features such as frequency, duration and amplitude, together with the analysis of the environmental parameters increased our understanding of animal vocalisations and facilitated the development of an automatic monitoring system based on a sound analysis algorithm.

Keywords: heat, stress, sound analysis, vocalisation.

Introduction

Heat stress is widely recognized as a stressful condition that affects animal behaviour, animal welfare and production quality. It is a problem affecting most livestock populations in intensive livestock farming. This influence strikes among several latitudes and in Europe especially during the months of July and August. The effect of high temperature on pig growth performance and health has been extensively studied and published (Holmes and Close, 1977; Close, 1981; Le Dividich *et al.*, 1994; Patience *et al.*, 2005). During the summer season short-term, high intensity hot weather patterns are referred to as heat waves, may even lead to animal mortality. Short term adaptive changes in behavioural, physiological and immunological functions are the initial responses to acute events, while longer-term challenges impact performance orientated responses. Generally pigs respond to high ambient temperature by nutritional and physiological adaptation to maintain homoeostasis. Above the upper limit of the thermo neutral zone (approximately 29°C for weaned pigs), an increase of temperature results in a decrease of the average daily feed intake to limit heat production and an increase of respiratory rate to remove excess heat (Fuquay, 1981; Kamada & Notsuki, 1987). Beside physiological body responses, behavioural reactions to distress exist including animal vocalizations. Past studies have shown pigs respond to pain or distress with specific vocalizations and that these responses might be used to assess animal welfare in intensive farming conditions (White *et al.*, 1995, Marx *et al.*, 2003; Schön *et al.*, 2001; Manteuffel, *et al.*, 2004). Understanding negative animal responses and observing and recognizing animals in distress is a key skill to implement appropriate practices in order to reduce the stress effects. A possibility toward this goal is applying sound analysis, in livestock farming compartments, as a tool for early detection of disease and distress from continuous recording and automatic processing of animal sounds. The capabilities of such a system, based on classification algorithms, have been tested in previous studies investigating respiratory diseases (Exadaktylos *et al*., 2008) or animal welfare (Schön *et al*., 2004). This research will observe and record several animal vocalizations from piglets bred in standard intensive conditions coupling them with environmental and physiological parameters. The aim is to increase our understanding of animal vocalisations by studying the acoustic parameters and to use this to develop a continuous automated monitoring system based on a sound analysis algorithm.

Materials and methods

Heat stress trials have been performed at the experimental farm "CZDS" of the Milan Veterinary faculty in Lodi. The experiment utilized 7 litter mates crossbreeds (Large White X Landrace) females and males, with an average initial live weight of 4,92± 0,35 kg. The piglets were observed for 120 days. Piglets were housed in a mechanically ventilated building. The pen was 2,1x2,5 m large and the floor was fully slatted (PVC slats). Water was available ad libitum. The piglets were fed a pelleted diet, formulated to meet or exceed NRC (1998) recommendations for all nutrients, twice a day. Piglets were weighted every day during the heat stress trial using a weigh crate. Temperature in the study compartment ranged from 32,2°C, when animals were 4,92± 0,35 kg, to 25,2°C in the last week of the trials. Room temperature was adjusted for thermal comfort zone of weaned piglets (Le Dividich & Herpin, 1994). Relative humidity ranged from 20 to 30% and ventilation rate was 3 $m^3.h^{-1}$. These climate parameters were on line available from the central control panel placed outside the room.

<u>Heat stress</u>

Groups of two or three piglets were assigned to high temperature treatments (29°C up to 41°C). During this period animals were exposed to one hour long temperature increase in order to stimulate specific related behaviours and vocalizations , to simulate summer diurnal climate. Temperature in the pen was maintained in the comfort zone limits throughout the study. For the temperature treatment it was set to increase from 29°C and 41°C within 1 hour. During the trial, the piglets were placed in a solid wall crate 0,5x 0,5 m large. This crate was placed inside the pen where the animals were normally living. On top of this crate two infrared lamps (150W) were hung 50 cm above the animals (Fig. 1). Temperature inside the crate was measured at time 0 (t_0) and after 20 (t_1), 40 (t_2) and 60 (t_3) minutes using a standard mercury glass thermometer placed on the wall of the crate at floor level. Rectal temperature (RT) and respiration rate (RR, breaths per minute) were recorded as indicators for heat distress. Rectal temperature was measured at t_0 and t_3 from a commercial digital pocket thermometer. Respiration rates were determined by counting flank movements and recorded as frequency per minute at t_1, t_2 and t_3.The normal physiological respiratory rate 35-40 acts per minute (Brow-Brandl *et al*., 2001; Renaudeau *et al*., 2007).

Figure 1. Heat stress test crate with two infrared lamps and microphone hanged 50 cm above the animals.

<u>Sound recordings</u>

Vocalizations from piglets kept in the trial crate, were recorded for one hour during every trial. A long gun directional microphone (Sennheiser ME 67) was placed on the top of the crate 50 cm above the animals. The sensor was connected to the external microphone input of a handheld digital recorder (Marantz PMD 620) and the sound was recorded on a SD flash media. Sound was recorded as uncompressed WAV files 24-bit and 44.1 kHz sample rate. Normal activity sounds (e.g. games, socialization) were also recorded, with the procedure described above, for one hour before the heat stress trial.

<u>Sound labelling and analysis</u>

Audio playbacks were processed using Adobe® Audition® 3 to label vocalizations from piglets before and during the trials. Sound recordings were manually selected and divided in two main groups Heat Stress (HS) and Non Stress (NS). Each recording was analysed for peak frequency. To calculate peak frequency, a smoothed AR spectrum was estimated for each sound and subsequently, the frequency with the highest value was selected (Fig. 2). The analysis was performed with Matlab® 2009b.

Statistical analysis

Climate and acoustic data were analysed using the Pearson Correlation procedure of SAS 9.2. Pig weight, compartment temperature (T) and relative humidity (RH), temperatures measured during trial: t_0, t_1, t_2, t_3, respiratory rate (RR) at t_1, t_2, t_3, rectal temperature (RT) at t_0, t_3 and number of heat stress vocalizations were considered in the model. One-way Anova was also performed over the peak frequency calculated on HS and the NS sounds to examine the effect of high temperature exposure on the acoustic quality of vocalizations to search a discriminant for an automatic sound classification.

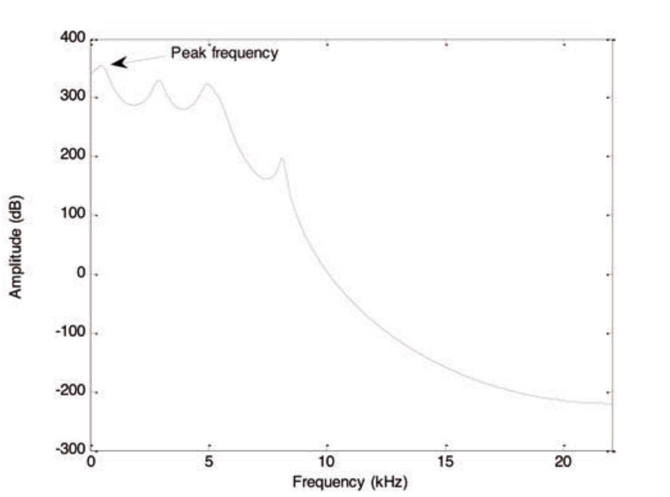

Figure 2. AR spectrum of a sound and the automatic extraction of the peak frequency

Results

Physiologic parameters

Rectal temperature measured at t_0 and t_3, of the HS trial, showed an average increase of 0,41°C from 39,3°C to 39,71°C. This smooth increase in body temperature was positively associated ($P<0.05$) to the increase of air temperature from t_0 to t_3 ($\mu\Delta t = 5\pm3$°C) during the time of the trial and with the RR ($P<0.05$). The latter increased from t_1 to t_3 of 120 bpm ranging from an average of 34 to an average of 116 bpm. RR measured at t_2 was used as a marker to test if the increase of breathing was rising constantly, according to the increase of temperature, otherwise it was stable or decreased subject to thermal physiologic adaptation. RR and increased Δt were positively correlated for the 91% ($P<0.001$) during HS. RR was also correlated ($P<0.05$) with animal weight showing an increase in bpm as the animals were growing (52%; $P<0.05$).

Sound analysis

Eleven heat stress trials were performed during which 991 sounds were collected from the piglets confined in the test crate and 442 vocalizations came from recordings made before the test in normal group situations when the animals were together in their pen (tab.1). Peak frequency analysis allowed distinction between two types of sounds according to their energy content. Since sounds can be of any nature, extracting the peak frequency of the sounds of each category (HS and NS) allowed distinguishing signals with a peak frequency of less than 1000 Hz and others with a higher frequency. This is plotted for the NS case in Fig. 3 and summarised in Table 1.

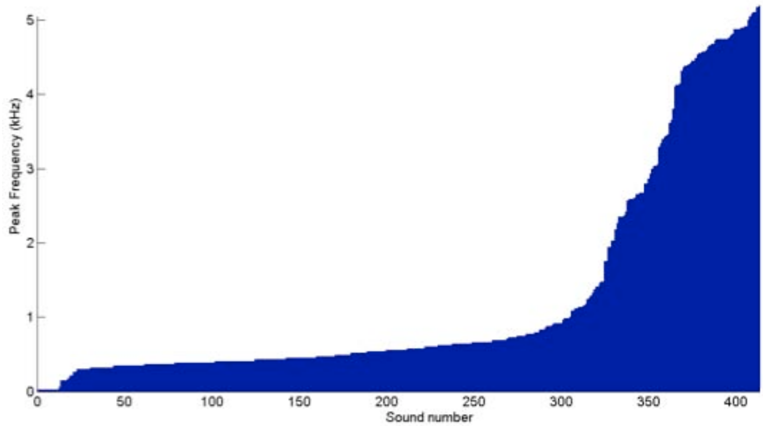

Figure 3. Peak frequency for every vocalization during NS

Most sounds analysed had peak frequency lower than 1 kHz both for HS and NS (respectively 89% and 93,5%) and they were classified as grunts. Their average mean peak frequency was found to be 445±132 Hz in HS and 407±144 Hz in NS. Sounds that exceed the 1 kHz were significantly less frequent 11% and 6,5% respectively and due to their high frequency were classified as screams. Their average was 3.309±1.393 kHz in HS and 2.432±1.366 kHz in NS. HS grunts were positively related with RT and rising temperature in the test crate ($P<0.001$) showing a linear increase of about 80% from t_0 to t_3. HS screams occurred the most during the central 20 minutes period (from minute 20 to minute 40) and were negatively correlated ($P<0.001$, -78%) with the room temperature which was kept at thermal comfort optimum for the age and weight of the piglets. Screams didn't show any relevant correlation with climate parameters involved in heat stress.

Table 1. Number of sounds during heat stress and no heat stress classified on the their peak frequency

Type	Nr sounds	Nr Peak frequency >1000 Hz	Nr Peak frequency <1000 Hz
HS	991	110	881
NS	442	29	413

The comparison between peak frequencies of all HS and NS sounds demonstrated relevant difference between the two classes of sounds $P<0.001$ (Table 2).

Table 2. Peak frequency least squares means and significance between HS and NS sounds

Type	Peak freq. LSMeans (Hz)	SEM	P
HS	745	28	<0.001
NS	563	42	

Discussion

Short-term HS trials were performed to simulate real summer heat waves. In most of the published studies on the effect of thermal stress on pig performance, animal-related measurements were done with a prior adaptation of 4 to 20 days to the experimental temperature as reviewed from (Renaudeau *et al*., 2008). However, in practice during summer heat waves, especially in temperate climates, pigs are suddenly exposed to high temperatures with negative consequences on their health and their performance (Nienaber & Hahn, 2007). Physiological responses of pigs have been studied intensively and RR and RT have been shown to behave predicatively, increasing with rising temperature (Liao & Veum, 1994; Brown-Brandl *et al*., 1998). As pigs do not sweat they heavily rely on evaporative losses via the respiratory tract. Thus respiration rate provides an easily observable measure of animals thermal state and can be a valuable physiological parameter in conjunction with additional information such as ambient temperature, rectal temperature, humidity, air velocity and age and weight of piglets. During this trial the increase of RT was directly associated with higher temperature in the trial crate and with RR showing the efficacy of this method to induce heat stress in the piglets. RT linearly increased during the trial, indicating that mechanisms, implied in heat production reduction and increase in heat loss, are not sufficient to prevent a rise in body temperature. In previous studies decrease in body temperature was observed in long-term exposure to heat stressful conditions. Therefore the RR was measured of at three different periods to monitor the trend of breaths per minute. The correlation between RR and Δt of the trial at $P<0.001$ excluded thermal adaptation in this kind of trial. Since physiologic parameters show stressful condition in piglets we can assume the vocalization recorded during the trial are typical of heat stress. The analysis of the peak frequency showed a certain percentage of sounds having energy over the 1000 Hz. However, these sounds were not a significant sample of vocalizations under heat stress conditions. On the other hand, the positive correlation between the number of vocalizations and the rectal temperature showed that animals in distress emit great amount of specific sounds (991 HS vs 442 NS) and the comparison of the peak frequency showed acoustic differences between stress and non stress which is crucial for the development of an intelligent algorithm to count and classify heat distress sounds.

Conclusions

Animals punctual observation and distress recognition is crucial to rapidly take action and ameliorate welfare and production. In this direction, heat stress may be evaluated by continuous acoustic analysis applied to pig farming improving management by warning farmers about a higher level of vocalizations during hot summer season. Vocalisation must be considered as good indicator to assess heat stress as well as physiologic parameters, climate or feed intake that are widely adopted to quantify this stress level. Nowadays intensive sustainable livestock farming require advanced planning of production management systems wich may adapt dynamically to the animals conditions. On line stress levels, as well as diseases, must be recorded and processed in order to study the appropriate action: shade, sprinkling, air movement or active cooling are among those correction which may be helpful in case of heat stress.

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References

Brown-Brandl, T.M., Nienaber, J.A., Turner, L.W. 1998. Acute heat stress effects on heat production and respiration rate in swine. Trans. ASAE **41** (3) 789–793.

Brown-Brandl, T.M, Eigenberg, R.A, Nienaber, J.A, Kachman, S.D. 2001. Thermoregulatory profile of a newer genetic line of pig. Livestock Production Science. **71** 253–260.

Close, W.H. 1981. The climatic requirements of the pig. In Environmental aspects of housing for animal production (ed. JA Clark), Butterworths, London, pp. 149–166.

Exadaktylos, V., Silva, M., Ferrari, S., Guarino, M., Aerts, J.M., Berckmans, D. 2008. Time-series analysis for online recognition and localization of sick pig (Sus scrofa) cough sounds. J. Acoust. Soc. Am. **124** 3803–3809.

Fuquay, J.W. 1981. Heat stress as it affects animal production. J. Anim. Sci. **52** 164-174.

Holmes, C.W., Close W.H. 1977. The influence of climatic variables on energy metabolism and associated aspects of productivity in the pig. In Nutrition and the climatic environment (ed. W Haresign, H Swan and D Lewis), Butterworths, London, pp. 51–73.

Kamada, T., Notsuki, I. 1987. Effects of environmental temperature, humidity and air movement on heat loss particularly that of latent heat. Japanese Journal of Zootecnical Science. **58** 147-154.

Le Dividich, J., Herpin, P. 1994. Effects of climatic conditions on the performance, metabolism and health status of weaned piglets: a review. Livestock Production Science. **38** (2) 79-90.

Liao, C.W., Veum, T.L.1994. Effects of dietary energy intake by gilts and heat stress from days 3 to 24 or 30 days after mating on embryo survival and nitrogen and energy balance. J. Anim. Sci. **72** (9) 2369–2377.

Manteuffel, G., Puppe, B., SchÖn, P.C. 2004 . Vocalization of farm animals as a measure of welfare. Appl. Anim. Behav. Sci. **88** 163–182.

Marx, G., J. Horn, B. Thielebein, E. Knubel, and M. Von Borrel. 2003. Analysis of pain related vocalization in young pigs. J. Sound Vibr. **266**(3) 687-698.

Nienaber, J.A, Hahn, G.L. 2007. Livestock production system management responses to thermal challenges. Int J Biometeorol **52** 149–157.

NRC. 1988. Nutrient Requirements of Swine, 9th ed. National Academy Press, Washington, DC.

Patience, J.F., Umboh, J.F., Chaplin, R.K, Nyachoti, C.M. 2005. Nutritional and physiological responses of growing pigs exposed to a diurnal pattern of heat stress. Livestock Production Science, **96** 205-214.

Renaudeau, D., Huc E., Noblet J. 2007. Acclimation to high ambient temperature in Large White and Caribbean Creole growing pigs. J. Anim. Sci. **85** 779–790.

Renaudeau, D., Kerdoncuff M., Anais C., Gourdine J. L. 2008. Effect of temperature level on thermal acclimation in Large White growing pigs. Animal **2** (11) 1619-1626.

Schön, P.C., Puppe, B., Manteuffel, G. 2001. LPC-analysis and Self Organizing Feature Map (SOFM) as tools to classify stress calls of domestic pigs (*Sus scrofa)*. J. Acoust. Soc. Am. **110** 1425-1431

SchÖn P.C., Puppe, B., Manteuffel, G. 2004. Automated recording of stress vocalizations as a tool to document impaired welfare in pigs. Anim. Welfare **13** 105–110.

White, R.G., DeShazer, J.A., Tressler, C.J., Borcher, G.M., Davey S., Waninge A., Parkhurst, A.M., Milanuk. M.J., Clemens, E.T. 1995. Vocalization and physiological response of pigs during castration with or without a local anaesthetic. J. Anim. Sci. **73** 381–386.

Audio approaches in Virtual Fencing.

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Abstract

Virtual Fencing is an interesting technological concept for extensive livestock farming, which is currently under development. However, current development often focuses on the use of electric shock as an aversive stimulus to guide and control livestock. Yet, this is not a legal option in some countries. Therefore, this paper explores the possibility of replacing electric stimuli by the use of audio stimuli to control livestock. Consequently, we set out to investigate audio-based approaches in prior art (e.g. patents and other publications). This paper gives a brief overview in that area, including information gathered from our own experiments.

Keywords: acoustic harassment, acute alarming sound, aversive stimulus, cattle, irritating sound

Introduction

The concept of virtual fencing has been discussed increasingly amongst scientists, nature conservationists and livestock managers. Since the first patent was filed in 1973 (Peck, 1973), many different approaches have appeared in the patent literature. Umstatter (2011) found that these patents can be categorized into three classes: 1. devices to contain animals in a defined area or keep them out of a defined area using devices that are animal-borne; 2. devices that aim to contain animals without mounting a device onto the animal; and 3. devices that aim to keep animals apart with a moving fence line or using a virtual fence as a remote gathering device.

Almost all of the inventions work with aversive stimuli and specifically mention electric shock as a possible negative stimulus. However, so-called "shock collars" developed for dog training are banned in a number of countries e.g. in Wales, Germany and Switzerland. Moreover, it is well known that the use of electric stimuli can have a negative impact on animal welfare. It is therefore important and necessary to investigate alternatives to electric stimuli. One possibility is to use sound as an aversive stimulus. The use of sound, e.g. as a warning stimulus, to indicate that an electric shock might be triggered soon, is already frequently mentioned in the patents and the integration of a loudspeaker into the device is possible. Because it is feasible to integrate sound stimuli into these devices, we set out to have a closer look into the possibility of using sound as an aversive stimulus.

Hearing ability in herbivore livestock

The ability of an animal to hear sounds at various frequencies is very species specific and depends inter alia on the scale of middle ear (Hemilä *et al.*, 1995) and functional inter-aural distance (Heffner and Heffner, 1983). Hence, if sound is to be used for virtual fencing, it needs to be tested for the specific species it is to be used on. Heffner and Heffner (1983) published audiograms (a graphic record of hearing ability) for horses and cattle. The cattle audiogram was established on the basis of two polled Hereford cows. Both of the cows showed a similar response and a "point of best hearing at 8 kHz", ranging from 23 Hz to 35 kHz. The finding that animals are very sensitive to stimuli around 8 kHz makes sense in evolutionary terms, as it has been shown that calf distress calls (made during hot-iron branding) have spectrographically detectable harmonics up to 7 or 8 kHz (Watts and Stookey, 2000). Philips (1993) also states that the overtones of the pitch of the calf call can reach 4 to 8 kHz in the en syllable.

Wollack (1963, as cited in Heffner and Heffner, 1983) identified an audiogram for sheep which, like cattle, shows a well-defined best point of hearing in the region of 8 – 10 kHz. According to the audiograms, above 10 kHz sheep have the most sensitive hearing, compared to cattle and horses. The sheep audiogram also indicates that sheep have a slightly higher upper limit of 42 kHz (Wollack, 1963, as cited in Heffner and Heffner, 1983). Horses differ more from sheep and cattle. Heffner and Heffner (1983) report that horses show the best sensitivity in the range of 1 to 16 kHz and with an overall range from 55 Hz to 33.5 kHz. They do not seem to have a well-defined point of best hearing as cattle do. Another point reported by the authors is that the audiogram was based on a dataset of three horses and hearing ability differed in the high frequencies. There is likely to be variability between individuals and this could affect the response to any warning cues or aversive stimuli.

Using sound as a cue or stimulus also means that the age of the animal needs to be taken into consideration. It is known that hearing ability, especially of higher frequencies, can be related to age. Much research has been done on that subject in animals and humans. For example, the Mongolian gerbil has a similar average hearing loss, when ageing, of a 60 year old human male (Boettcher *et al.*, 1993). Mice are used to study hearing loss in aging as a model species for humans (Leong *et al.*, 2011). Unfortunately, there is no study on hearing loss of ageing large herbivores, as far as the authors know.

Audio experiments

<u>Positive reinforcement</u>

The idea of using audio cues to guide cows is not new. In 1966, Albright *et al.* showed that cattle respond to an auditory stimulus and could be herded using this. Different approaches for the use of sound can be identified. The first one is to use sound as positive reinforcer. Anderson *et al.* (2008) used this approach in his experiment to gather cows remotely to a corral. The author recorded the noise occurring during manual gathering of livestock. Once the animals reached the corral, they were fed with a treat. The cows associated the noise with the treat and that increased the motivation to go to the corral. However, the use of positive reinforcer in virtual fencing approaches is not a common occurrence.

Negative reinforcement

Acute alarming sounds

There are two options in the use of sound as a negative reinforcer. Acute alarming sounds can be used to 'scare' the animals and make them move away from a virtual fence line. Umstatter *et al.* (2009) undertook an experiment to test if animals can be deterred from crossing a fence line. Within the experimental approach used, the results showed that it was possible to stop cows from crossing a virtual fence line for 53% of the attempts. However, the authors reported that many improvements could be made to increase the success rate. Butler *et al.* (2004) also reported the use different acute alarming sounds from a sound library. One issue in using acute alarming sounds is, the individual difference of response between animals (Bishop-Hurley *et al.*, 2007; Umstatter *et al.*, 2009). This might be an issue across species. Cox (2008) undertook an internet-based psychoacoustic experiment with people, testing a range of aversive sounds. The author found that the response to aversive sounds varies with gender, location and age. One can envisage that different previous experiences of animals can also subsequently lead to different attitudes and responses.

Irritating sounds

The idea of using irritating sounds to deter animals is also not new. The approach is well known from devices manufactured to repel rodents from certain areas. Special devices, transmitting a high ultrasound noise, are available on the market. The idea can even be used on humans. A device, marketed under the name "Mosquito ultrasound device", works on the basis of a frequency of ultrasound which mainly affects humans under 25. The noise is supposed to become increasingly irritating with continued exposure. Stapleton (2007) invented this device to disperse teenagers if they gather in front of shops.

Research into the area of irritating deterrent devices is also carried out in aquatic systems. Johnston (2002) reported that many salmon aquaculture sites in the Bay of Fundy, Canada, employ acoustic harassment devices (AHD's) to deter seals from approaching fish pens. The author analysed the impact on porpoises and found a reduction of porpoise density in the areas when these devices are switched on. The initial idea of an AHD was to repel seals, but Vilata *et al.* (2010) stated that there is a strong suspicion that the efficacy is site-specific. Other authors, such as Nelson *et al.* (2006), found an ineffectiveness of AHDs. It is very likely that the problem is rather complex, and that many characteristics of the sound, such as the sound level and the type of sound, play a major role in the efficiency of these systems.

However, a similar approach might be valuable to deter livestock from remaining in defined areas, and act as a kind of fence. We therefore, undertook an experiment to test two different irritating noise treatments, and as a comparison two acute alarming sounds were also used. The acute alarming sounds were identified in a previous experiment (Umstatter *et al.*, 2009). The irritating sounds studied were in the acoustic range between 8 and 10 kHz, which is in the region of best hearing range of cattle. In this study (Umstatter *et al.*, in prep.), irritating sounds were played continuously when the animals were within a pre-defined exclusion area. It was found that cattle spent significantly less time in this pre-defined area compared to the control days, when no sound was played. Tiedemann *et al.* (1999) also used a similar frequency, 8.5 kHz, but as a warning cue before the electric stimulus was triggered, and reported that cattle would sometimes react as though they had received an aversive stimulus, although they were not near the boundary. However, in this case, a link between electric shock and the audio cue was already established. The authors linked this to the fact that many insect sounds common in pasture were similar to the 8.5 kHz frequency used and as a consequence, changed the warning cue sound to a lower frequency. In our approach, where we attempt to using the sound as irritating cue, the similarity to insect sounds might even be very useful and could support the approach.

Discussion of different approaches

The most often discussed approach in virtual fencing is the one where an animal wears the device (Category 1). Approaches from Category 2 are less likely to be practical because infrastructure needs to be provided in every area that it is used in. Moreover, in our experiment with irritating sounds (Umstatter *et al.*, in prep.), the use of infrastructure and motion sensors in a field with undulating topography proofed to be difficult. The 'straight line' beam of a motion detector would not always detect a passing animal, meaning that more sensors would have to be used in this type of terrain. Besides, the variable success rate of the AHDs seems to indicate that location-specific factors play a role in the effectiveness of such as system. This might be due to the problem that the sound is not distributed evenly in the entire area where animals should be excluded. Therefore, a sound emitting device which is attached to the animal could show more continuous response rates.

Using irritating sound as a replacement aversive stimulus for electric stimuli could be successful, because they do not habituate to irritating sounds but do to alarming sounds. Sound is being used here as a possible, more welfare-friendly, alternative to electric stimuli. However, it needs to be determined whether the impact of sound as an aversive stimulus over a long period of time has got a lower impact on animal welfare than a well controlled electric stimulus. When sound turns into noise, there may be negative effects, because noise is defined as "unwanted sound or a combination of sounds that has adverse effects on health" (Seidman & Standring, 2010). Hébert *et al.* (2004) also stressed the importance of the stress-inducing power of external noise, which has been well documented in human psychoneuroendocrine research. Topf and Dillon (1988) found a link between burnout syndrome and noise-induced stress in care nurses. Morales *et al.* (2010) experimented with an entirely different species, and found that continuously playing classical music at 20dB above background noise reduced the lifespan of *Drosophila melanogaster*.

The effect of noise on livestock has not been thoroughly studied as yet, but the literature gives an indication that the use of sound as a negative reinforcer needs to be very well controlled to maintain the welfare standard of livestock. Nosal and Gygax (2005) looked at airborne noise levels as a stress factor in milking dairy cows. The authors found, that the reduction of noise levels in a milking parlour can improve the cows' udder health in terms of a decrease of cell numbers in the milk. However, the key issue, for any negative impact of sound on animal health and welfare is the perception of controllability (Dess, 1983; Schalke *et al.*, 2007). Dess (1983) and Schalke (2007) both found that there was a reduced cortisol level in animals which were able to control the negative reinforcer. This is exactly, what should happen when using a virtual fence. The animals have the possibility to avoid the punishing stimulus if they stay within the predetermined boundaries.

The idea of using sound to manage the location of animals or people is not new and through the years, many positive responses have been reported. It is interesting to note that not many of these approaches were put into practice. One reason for this could be the importance of the intensity of sound. Most of the approaches dealt with systems similar to virtual fencing systems of Category 2. This means, that sound emitting devices such as loudspeakers are not attached to the animal. The drawback of this system is that the level of sound decreases rapidly with increasing distance from the source of the sound. When mounting a device onto an animal, the sound level will be continuously on a similar intensity level. Therefore, the effect of the sound on the animal can be more consistent and this might be the key aspect for the success of such a system.

Conclusions

We can conclude that the approach of using sound as an aversive stimulus in a virtual fencing system is promising. Nevertheless, there is a strong indication that the device needs to be mounted onto the animal. Moreover, the use of sound could have a strong impact on the animal and studies regarding animal welfare need to be conducted to ensure welfare standards. On the other hand, one should keep in mind that in the scenario of a virtual fencing system, the animals have a choice between being exposed to sounds and staying away from the sound source. Therefore, negative effects on animal welfare could be avoided.

The sounds played over longer periods of time, instead of acute alarming sounds, should be the measure of choice. Current AHD work on the basis of using irritating sounds, instead of acute alarming sounds, might be a better option in the long run to avoid the negative effects of habituation.

Acknowledgement

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References

Albright, J.L., Gordon, W.P., Black, W.C., Dietrich, J.P., Snyder, W.W., Meadows, C.E. 1966. Behavioral responses of cows to auditory training. Journal of Dairy Science 49, 104-106.

Anderson, D.M., Rus, D., Detweiler, C., Schwager, M., Vasilescu, I. 2008. Husbandry of free-ranging cows using virtual fencing concepts. In: XXI International Grassland Congress, VIII International Rangeland Congress, Hohhot, China.

Bishop-Hurley, G.J., Swain, D.L., Anderson, D.M., Sikka, P., Crossman, C., Corke, P. 2007. Virtual fencing applications: implementing and testing an automated cattle control system. Computers and Electronics in Agriculture 56, 14-22.

Boettcher, F.A., Mills, J.H., Norton, B.L., Schmiedt, R.A. 1993. Age-related changes in auditory evoked potentials of gerbils. II. Response latencies. Hearing Research 71, 146-156.

Butler, Z., Corke, P., Peterson, R., Rus, D. 2004. Networked Cows: Virtual fences for Controlling Cows. In.

Cox, T.J. 2008. Scraping sounds and disgusting noises. Applied Acoustics 69, 1195-1204.

Dess, N.K. 1983. Immediate and proactive effects of controllability and predictability on plasma cortisol responses to shocks in dogs. Behavioral Neuroscience 97, 1005-1016.

Hébert, S., Paiement, P., Lupien, S.J. 2004. A physiological correlate for the intolerance to both internal and external sounds. Hearing Research 190, 1-9.

Heffner, R.S., Heffner, H.E. 1983. Hearing in large mammals: Horses (*Equus caballus*) and cattle (*Bos taurus*). Behavioural Neuroscience 97, 299-309.

Hemilä, S., Nummela, S., Reuter, T. 1995. What middle ear parameters tell about impedance matching and high frequency hearing. Hearing Research 85, 31-44.

Johnston, D.W. 2002. The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. Biological. Conservation. 108, 113-118.

Leong, U.C., Barsz, K., Allen, P.D., Walton, J.P. 2011. Neural correlates of age-related declines in frequency selectivity in the auditory midbrain. Neurobiology of Aging 32, 168-178.

Morales, R.F., Seong, K., Kim, C., Jin, Y., Min, K. 2010. Effects of auditory stimuli on the lifespan of Drosophila melanogaster. Entomological. Research. 40, 225-228.

Nelson, M.L., Gilbert, J.R., Boyle, K.J. 2006. The influence of siting and deterrence methods on seal predation at Atlantic salmon (*Salmo salar*) farms in Maine, 2001-2003. Canadian. Journal of Fisheries. and Aquatic. Sciences. 63, 1710-1721.

Nosal, D., Gygax, L. 2005. Noise and vibration as stress factors in milking: causes, effects and possible solutions. 177-183.

Peck, R.M. 1973. Method and apparatus for controlling an animal. U.S. patent 3 753 421, Aug. 21, 6 p., Int. Cl. A01K 15/00.

Phillips, C.J.C. 1993. Cattle Behaviour. Farming Press, Ipswich, UK.

Schalke, E., Stichnoth, J., Ott, S., Jones-Baade, R., 2007. Clinical signs caused by the use of electric training collars on dogs in everyday life situations. Appl. Anim. Behav. 105, 369-380.

Seidman, M.D., Standring, R.T. 2010. Noise and quality of life. International Journal of Environmental Research and Public Health 7, 3730-3738.

Stapleton, H. 2007. Sound emitting device. GB patent 2 421 655 B, Jan. 17, 11 p., *A01M29/02; G08B15/00; G08B3/00;* A01M29/00; G08B15/00; G08B3/00.

Tiedemann, A.R., Quigley, T.M., White, L.D., Lauritzen, W.S., Thomas, J.W., McInnis, M.L. 1999. Electronic (Fenceless) Control of Livestock. Res. Pap. PNW-RP-510. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, U.S.

Topf, M., Dillon, E. 1988. Noise-induced stress as a predictor of burnout in critical care nurses. Heart and Lung 17, 1567-1574.

Umstatter, C., Tailleur, C., Ross, D., Haskell, M.J. 2009. Could virtual fences work without giving cows electric shocks? In: Lokhorst, C., Groot Koerkamp, P.W.G. (Eds.), Precision livestock farming '09, Wageningen Academic Publishers, Wageningen, pp. 161-168.

Umstatter, C. 2011. The evolution of virtual fences: A review. Computers and Electronics in Agriculture 75, 10-22.

Vilata, J., Oliva, D., Sepulveda, M. 2010. The predation of farmed salmon by South American sea lions (*Otaria flavescens*) in southern Chile. ICES. Journal of Marine. Science 67, 475-482.

Watts, J.M., Stookey, J.M. 2000. Vocal behaviour in cattle: the animal's commentary on its biological processes and welfare. Appl. Anim. Behav. 67, 15-33.

Wollack, C.H. 1963. The auditory acuity of the sheep (*Ovis aries*). Journal of Auditory Research 3, 121-132.

Using vocalization pattern to assess broiler's well being

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Abstract

This research aimed to analyze the sounds emitted by chickling under social isolation and specific interactions. Birds were placed in a semi-anechoic chamber and their vocalization was registered using a unidirectional microphone. Results showed that pullets vocalize different when isolated and in clusters. When isolated chicks emit a high intensity sound identified as "danger call". The amount of signal energy and the centroid were influenced by the chick weight.

Keywords: welfare assessment, signal analysis, broiler production

Introduction

Animal welfare is related to the way the animal interacts with its surroundings and it is important to learn about the physical, environmental and social aspects related to this matter (Fraser, 1999; Seamer, 1998; Le Neindre et. al., 2004).

Several studies indicate the effectiveness of the identification of certain sounds as a tool for assessing animal welfare status (Weary *et al*., 1997; Chistopher & Linda, 1999; Marx *et al*., 2001; Manteuffel & Schön, 2002; Hay *et al*., 2003). These analyzes have the advantage of being non-invasive and may be automated.

This research aimed to analyze the vocalization of broilers chickens in the first week of growth during the process of social isolation and interactions.

Methodology

<u>Birds and experimental procedure</u>
Sixty one chicklings from the genetic strain Cobb 500® in the first weeks of growth were used in the trial. The birds were reared under conditions similar to the commercial ones. The chicks were separated in groups of 15 (2 groups) and 10 (3 groups) of birds. The first group was subjected to the following procedure, which was repeated four times, for recording the sounds inside the semi-anechoic chamber: (a) The birds were grouped together and recording of the vocalization was done; (b) Five birds were removed leaving the remaining 10, and again the vocalization was recorded; (c) Three birds were removed maintaining seven birds and the sound recorded; and (d) This procedure was done until only one bird was left alone.

In the second group of 10 birds, the adopted procedure was repeated three times, as follows: (a) The birds were grouped and recording of the vocalization was done; (b) Five birds were removed leaving the remaining 5, and again the vocalization was recorded; (c) Three birds were left together and the sound recording was done; and (d) This procedure was done when only one bird was left alone.

The birds were randomly chosen from the total of chicks, when selecting them to stay inside the chamber.

<u>Recording and analyzing the sounds</u>
The semi-anechoic chamber where the birds were placed (Figure 1 a) had the dimensions of 80 cm (height) x 80 cm (long) x 100 cm (length). The chamber temperature was controlled within the thermoneutral zone for the birds (30-31 °C).

Sounds were registered using a unidirectional microphone connected to a sound board in a notebook (Figure 1b). The software Audacity® 1.3.0 was used for recording the sounds which were digitalized for the analysis with a frequency of 51.2 kHz. Fourier Transform was used (Oppenheim, 1989) with 512 points using hanning window with a superposition of 51.2%, for obtaining the total spectrum of the vocalization and extraction of the signal parameters. The following parameters were measured and classified as: normal, short and afflictive, according to Marx *et al.* (2003). Sound data were analyzed as proposed by Rabiner & Juang (1993).

Student T-test was applied for mean values of data, and significance was accepted when p-value ≤ 0.05. Statistical calculations were done using the software Minitab® 1.4.


(a)


(b)

Figure 1. Semi anechoic chamber (a) where the chicks where placed and the sound recorded using a unidirectional microphone (b).

Results and discussion

Results of the amount of energy from the vocalization was found to be highly correlated to weight (p-value = 0.0276). Cordeiro *et al.* (2009) found that animals expressing large amount of vocalization may lose weight. When the pullet was alone it vocalized using the largest amount of energy (Figure 2), which decreased slightly until there were 7 chicks together, and increased after that reaching the value of 19.49 with 15 chicks altogether. This may be an indication of social distress.

Data from the centroid were also highly correlated to the weight of the birds (p-value = 0.0001). The centroid value was low when the pullets were clustered. Energy, centroid and weight varied during the trial as shown in Figure 3.

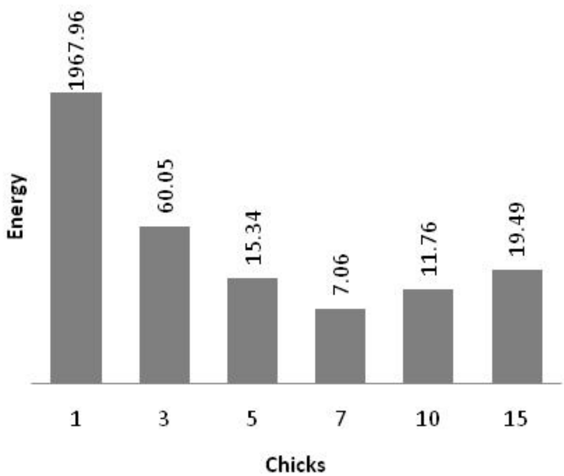

Figure 2. Variation of energy used in the vocalization of the chicks

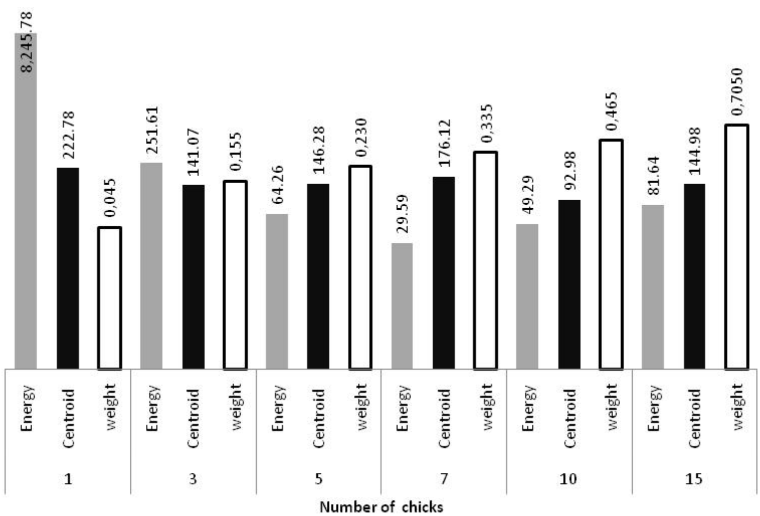

Figure 3. Variation of the wave characteristics registered from the vocalization of the pullets when they were under the test

Results showed difference in the vocalization of pullets isolated and in group, and it was identified as the "call for danger" (Figure 4).

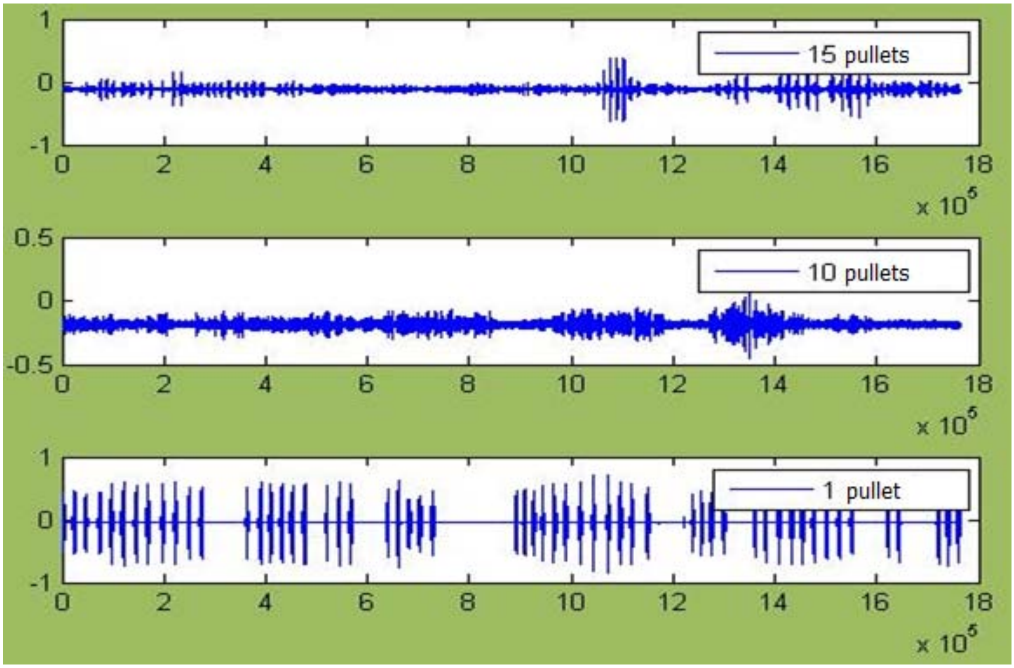

Figure 4. Results of the variation in vocal response of chicks as function of the total of birds clustered, from 15 to 1

According to the authors Collias (1952) and Andrew (1964) when a chick is isolated and kept away from the female breeder, it presents a trend to emit a sound of high intensity known as "danger call". Other study reports that high intensity calls are meant to call the "mother" that emits back a characteristic sound "calling" the chick, which also presents high intensity, identifying a degree of communication between the "mother" and the "brood" (Guhl, 1968; Collias, 1987; Christopher & Linda, 1999). Current literature also enhances that pullet vocalization tend to decrease when adult female vocalizes (Collias & Joos, 1953; Wood-Gush, 1971; Evans & Marler, 1994).

Conclusions

Chicks vocalize different when isolated or in cluster. When isolated chicks emit a high intensity sound identified as "danger call". The amount of energy and the centroid were influenced by the chick weight.

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References

Andrew, R. J. 1964. Vocalisation in chicks, and the concept of stimulus contrast. Animal Behaviour **12** 64-76.

Christopher, S. E., Linda, E. 1999. Chicken food calls are functionally referential. Animal Behaviour **58** 307 – 319.

Collias, N. E. 1952. The development of social behaviours in bird. The Auk **69** 127-159.

Collias, N. E. 1987. The vocal repertoire of the red jungle fowl: a spectrographic classification and code of communication. The Condor **89** 510-524.

Collias, N. E., Joos, M. 1953. The spectrographic analysis of sound signals of the domestic fowl. Behaviour **5** 175-188.

Cordeiro, A. F. S., Pereira, E. M., Nääs. I. A., Silva, W. T., Moura, D. J. 2009. Medida de vocalização de suínos (*Sus scrofa*) como um indicador de gasto energético. (abstract in English). Revista Brasileira de Engenharia de Biosistemas **2** 143-152.

Evans, C. S., Marler, P. 1994. Food calling and audience effect in male chickens, *Gallus gallus*: their relationships to food availability, courtship and social facilitation. Animal. Behaviour **47** 1159 - 1170.

Fraser, D. 1999. Animal ethics and animal welfare science: bridging the two cultures. Applied Animal Behavior Science **65** 71-189, 1999.

Guhl, A.M. 1968. Social behavior of the domestic fowl. Transactions of the Kansas Academy Science **71** 379-384.

Manteuffel, G., Schön, P. C. 2004. Measuring pig welfare by automatic monitoring of stress calls. Bornier Agratechnische Bericht **29** 110-18.

Marx, G., Leppelt, J., Ellendorff, F. 2001. Vocalization in chicks (*Gallus gallus dom*.) during stepwise social isolation. Applied Animal Behaviour Science **75** 61 – 74.

Marx, G., Horn, T., Thielebein, J., Knubel, B., Borell, E. 2003. Analysis of pain-related vocalization in young pigs. Journal of Sound and Vibration **266** 687-698.

Oppenheim, A. V.; Schafer R. W. 1989. Discrete-Time Signal Processing. Prentice-Hall International, International edition.

Rabiner, L., Juang, B. H. 1993. Fundamentals of Speech Recognizations. Prentice Hall, Upper Saddle River, NJ, pp117-124.

Seamer, J.H. 1998. Human stewardship and animal welfare. Applied Animal Behaviour Science **59** 201-205.

Weary, D.M., Fraser, D. 1997. Vocal response of piglet to weaning: effect of piglet age. Applied Animal Behaviour Science **54** 153-160.

Wood-Gush, D.G.M. 1971. The behaviour of the domestic fowl. London: Heineman, 1971. p 231.

Section 6
Pigs

Analysis of feeding behavior of group housed grow-finish pigs

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Abstract

Feeding behavior contains valuable information that can be used for managing livestock, identifying sick animals, and determining genetic differences within a herd. A system was developed to determine individual animal feeding behavior in an industry type feeding system. The system used radio-frequency identification (RFID) technology and a series of multiplexers. Data was collected on 960 pigs (mixed barrows and gilts) over 4 grow-out periods. The animals entered the facility at 24.6±5.4 kg and exited the facility at 101.4±13.8 kg. Time spent at the feeder was analyzed for the effects of days on feed, sex, weight gain, and health effects. The amount of time spent at the feeder averaged 68.8 min/day/pig over the grow-out period, and increased from day 0 (1.28 min/day/pig) until plateauing at day 40 (76.7 min/day/pig). At the plateau, barrows spent 13.6 more minutes per day at the feeder than gilts. Pigs classified as 'as high gaining' spent more time at the feeder than pigs classified as either 'normal' or 'low gaining.'

Keywords: group housed pigs, feeding behavior, RFID, health, weight gain, age, animal density.

Introduction

Feeding behavior contains important information that can enable producers to better manage livestock; similarly researchers can benefit by better understanding factors that influence feed intake. Systems are currently available to measure feed intake in association with feeding behavior for cattle (Basarab *et al*., 2003; Chapinal *et al*., 2007; Kelly *et al*., 2010), swine (Andree and Huegle, 2001; Hyun and Ellis, 2002; Nienaber *et al*., 1991), small livestock (Basarab *et al*., 2003; Gipson *et al*., 2006; Gipson *et al*., 2007; Goetsch *et al*., 2010), and poultry (Puma *et al*., 2000). While some of these systems provide the user with feed intake data in addition to feeding behavior, they require feeders to be accessed by a single animal at a time and due to the cost only a limited number of feeding stations are placed in a pen. Limited access to the feeder can alter feeding behavior. Therefore, systems that allow recording of feeding behavior (without feed intake) may be more applicable to production animal facilities.

Systems that record feeding behavior could provide a useful tool in managing production animals. Research has indicated that feed intake and feeding behavior changes can occur with relation to thermal conditions (Nienaber and Hahn, 2000), diet (Adijaoude *et al*., 2000; Fuller *et al*., 1995), social interactions (Goetsch *et al*., 2010), dominance ranking (Chapinal *et al*., 2008; Soltysiak and Ogalski, 2010; Val-Laillet *et al*., 2008; Walker *et al*., 2008), number of animals in a pen (Korthals, 2000), and health status (Griffin, 2001). However, most of these data were collected from small groups or individually housed animals. There is a need to investigate the dynamics of feeding behavior in livestock species within a commercial setting.

To fully develop a tool to help producers manage animals, the data must be filtered or otherwise processed, as the raw data is of little value to the producer. With the continued improvement in instrumentation, animals' responses need to be better understood to ensure proper care for the animals for their improved well-being, for profitability of operations, and to ensure the correct use of antibiotics in our meat animals.

The objectives of this research were to describe the development of a feeding behavior system, then use the system to collect data to (1) determine how time spent eating varies with pig age, (2) quantify differences in feeding behavior between barrows and gilts, (3) determine the impact of weight gain on time spent eating, and (4) evaluate the impact of health on feeding behavior.

Materials and Methods

Equipment

The core of the feeding behavior monitoring system includes a radio-frequency identification (RFID) system that was designed around a commercial reader (Texas Instruments, Series 2000 High Performance Remote Antenna-Reader Frequency Module [RA-RFM][RI-RFM-008B-00]). The radio-frequency signal was distributed to a series of antennas using a multiplexer (MPX) designed and constructed by the authors.

Multiplexers were designed to function as multiple (eight switch locations) switches connecting the signal from the RA-RFM to the correct antenna. Figure 1 shows a block diagram of a MPX; an input to the MPX can be directed to any of eight outputs with double pole switching. Multiplexer switching was controlled by a four-wire system: three control lines and a ground. The MPX control signal originated with the Series 2000 Control Module where control lines were latched under control of TFX-11 micro-controllers via RS232 communication. Multiplexer control switching was designed as a current loop, with a 0 or 4 milliamp signal representing 0 and 1 respectively. Current loop control was chosen for noise immunity over long wire runs. The control currents were used to drive LEDs in optical isolators, making the MPXs electrically isolated and immune to potential ground loops. Optical isolator boards were designed to couple the control lines that originated at the Series 2000 Control Board to the MPXs. The TFX-11 micro-controller sent a serial command to the Series 2000 Control Board, which latched the correct binary code for the correct feeder and the correct antenna within the feeder. Binary coded optically isolated lines distributed the signal to the MPXs, which latched the correct relays providing a pathway to and from the RA-RFM.

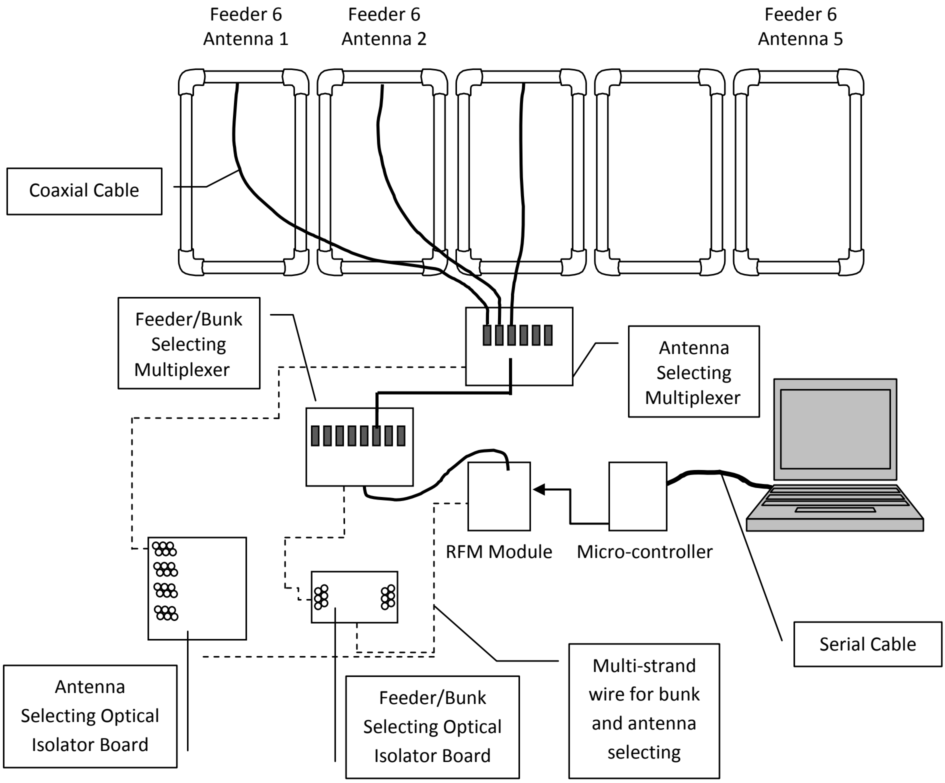

Figure 1. Schematic of the feeding behavior monitoring system including all components needed to collect feeding behavior data from one pen of animals. Additional eight multiplexer boards can be added to this system for expansion up to 64 antennas. Expansion beyond 64 antennas requires an additional micro-controller, RFM module, a feeder selecting optical isolator board, an antenna selecting optical isolator board, feeder selecting multiplexer and a set of antenna selecting multiplexer boards.

Software

The software was designed in two separate components. The first component was the main computer which was designed for timing, data management, and display. The second component was a micro-controller designed to control the sequence of the antennas and to capture the data. This approach was used for ease of expansion; multiple micro-controllers can be added to the system for larger installations.

The operational software for the PC host computer was written using HT Basic (HT Basic for Windows, Ver. 9.5. TransEra Corp., 375 East 800 South, Orem, UT 84097). The host system determined the timing of each scan (a sequence of powering each antenna and recording the EID number if present). This timing can be changed and was determined by the speed of the host computer; for this application a 20-second time base was used. After the host computer initiates the scan, it was available to summarize the number of hits of each antenna or for each animal upon the user's request. At the end of the scan, the micro-controller sent an "end" statement to the host computer, which initiated a data dump from each micro-controller in sequence. The data were received and then written to the comma delimited file; the appropriate information was transferred to the antenna and animal history files for ease of creating summaries. The host computer remained idle until the time to initiate the next scan.

The micro-controller, TFX-11 micro-controller, was programmed using TFBasic (TFTools, Ver. 1.1.1.4, Onset Computer Corp., 536 MacArthur Blvd., Pocasset, MA 02559). The micro-controller provided the interface to the Series 2000 Control Board, with operational software written for the TFX-11 micro-controller initiating scans, controlling the pen scan sequence, the antenna scan sequence, and the collection of tag ID information during the scan. At the end of the scan, the ID information was transferred from the TFX-11 micro-controller to the PC host computer. The micro-controller waited until the next scan is initiated.

Site installation

The swine system had six pens; each had one feeder designed for 5 animals to eat at a time. The swine system was designed with only one micro-controller controlling 30 antennas and transferring the data within a 20-sec scan time.

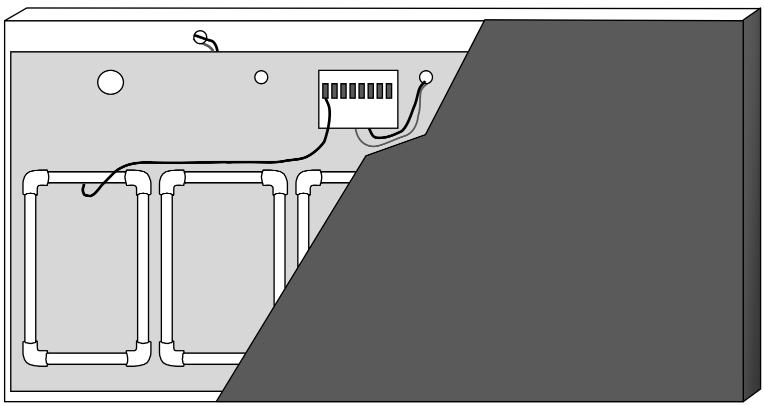

Figure 2. Schematic of the panel designed to be installed as a feeding behavior monitoring system. The panel was constructed using PVC sheets and 5- by 5-cm square tubing that was cut in half. The antenna and multiplexer was installed on a single sheet of PVC, which was slid inside.

Existing stainless steel pig feeders were used at the swine facility. A multiplexer and a series of five antennas were mounted on a single sheet of PVC (1.18 m wide x .0.65 m tall x 5 mm thick). This PVC sheet, with the equipment mounted, was then slid inside a PVC panel (1.2 m wide x 0.7 m tall x 0.04 m thick), shown in figure 2. A single water-tight connector was added to the back of the panel to run the coaxial cable and the multi-strand wire for control and data collection. This PVC panel was installed on the front of the feeder using an aluminum channel along the bottom edge of the panel for support and an aluminum flange to hold the top edge of the panel. The panels were installed on the existing feeders with a total of seven 2 mm screws to hold the flanges and a single 2.4-cm hole to run the wires through the feeder and into the panel (figure 3). Tests with EID tags demonstrated sufficient range and sensitivity for the pig feeder system.

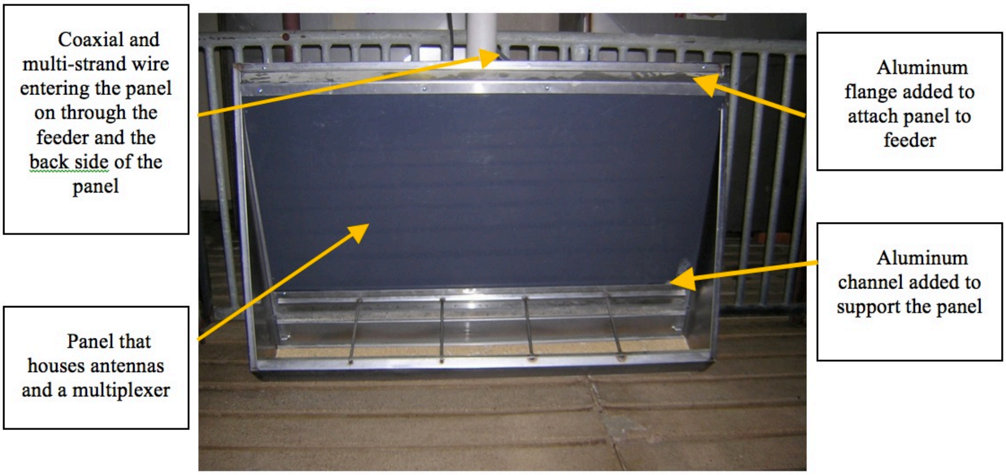

Figure 3. Picture of the installation of the feeding behavior monitoring system in the swine facility.

Animals

The facility used in this study was divided into eight pens (six grow-out pens and two sick pens). The instrumentation was installed in the six grow-out pens; these pens are designed to hold 40 pigs/pen. Since the instrumentation was installed in the building (Fall 2008), a total of four groups of pigs, approximately 240 each period, have been raised in the facility (Fall, 2008 through Fall 2010). The pigs initially weighed 24.6±5.4 kg and left the facility weighing 101.4±13.8 kg. Three of the four periods were stocked with mixed sex (barrows and gilts) grow-finish pigs. The fourth period was stocked with 5 pens of gilts, saved for breeding, and 1 pen of barrows. The pigs had ad-libitum access to feed and water and were checked for health concerns at least once a day.

Before the pigs were moved to the facility, a half duplex ID tag was inserted in the right ear of each pig. Data were checked on a weekly basis to ensure that all the tags were still installed and working properly. Animals without any recorded feeding events were checked for health issues and missing or malfunctioning tags.

For three of the four periods, the animals were weighed at 14 weeks, 22 weeks, and prior to slaughter. For the fourth period, the animals were weighed at 22 weeks. Gains were calculated using a linear regression to determine the slope of the weights and weigh days. Gains were not calculated on the 4th group of pigs. For the purposes of statistical analysis, gain categories were assigned as follows: high – average daily gain (ADG) ≥ 0.94 kg/day, low – ADG < 0.7 kg/day; all other pigs were considered in the normal group. The gains for these pigs appeared to be normally distributed. Levels were set based on the available data, the top 12% of the pigs were considered “high” and the bottom 15% were considered “low”.

Data

The data were collected and stored in separate files every day. The computer was located in the swine facility, and was connected wirelessly to the internet to allow download and backup at least 3 times a week. The data were loaded on the database and total hits per day per animal were summarized. Meal data on an animal basis (total number of meals per day, average length of meals) were also calculated, but not used in the analysis for this manuscript.

Four different data analyses were completed using the general linear model procedure in SAS®. The first analysis evaluated the effects of days on feed (age of the animals); the model statement included effects of period and days on feed. The second analysis investigated the effects of weight gain on feeding behavior, so the model statement included the effects of period, days on feed, weight gain category (high, low, or normal) and the interaction effect of days on feed and weight gain category. The third analysis investigated the effects of sex on feeding behavior. The model statement included effects of period, days on feed, sex (barrows and gilts), and the interaction of days on feed and sex. These two analyses (weight gain and sex) were completed in periods 1 through 3, as period 4 contained mainly gilts raised for breeding.

The fourth analysis evaluated the effects of health on time at the feeder. The model statement included effects of period, days on feed, and diagnosis. No interaction term was added. The only diagnosis that was analyzed was pneumonia, due to the lack of numbers on the other health related issues.

Differences were determined significant at the $P=0.05$ level. Least square means were used to determine the differences in treatments and the interaction terms.

Results and Discussion

The pigs were moved into the facility at approximately 65 days of age where they remained on feed for approximately 112 days – this ranged between 98 and 129 days on feed. The number of pigs in each pen varied from day to day as some of the pigs being treated for severe health issues were moved out of the pen during their treatment and a few tags were lost and replaced during the experiment.

The total time spent eating was affected by days on feed and period ($P < 0.001$). The average total time spent eating for a pig in the facility started at about 24 min/day and increased steadily at about 1.28 min/day until day 42. After day 42, the time spent at the feeder stabilized at approximately 76.7 min/day until the pigs were removed from the pens in different slaughter groups. As pigs were removed from the pen, the remaining pigs spent more time at the feeder (Figure 4). Using a feed intake system (FIRE, Osborne Industries), Hyun *et al.* (1997) reported a similar amount of time spent at the feeder (approximately 75 min/day/pig). However, this was an average for the entire experiment (pigs ranging in weight from 24 to 89 kg). Thus, Hyun's results are slightly higher that observed in this experiment.

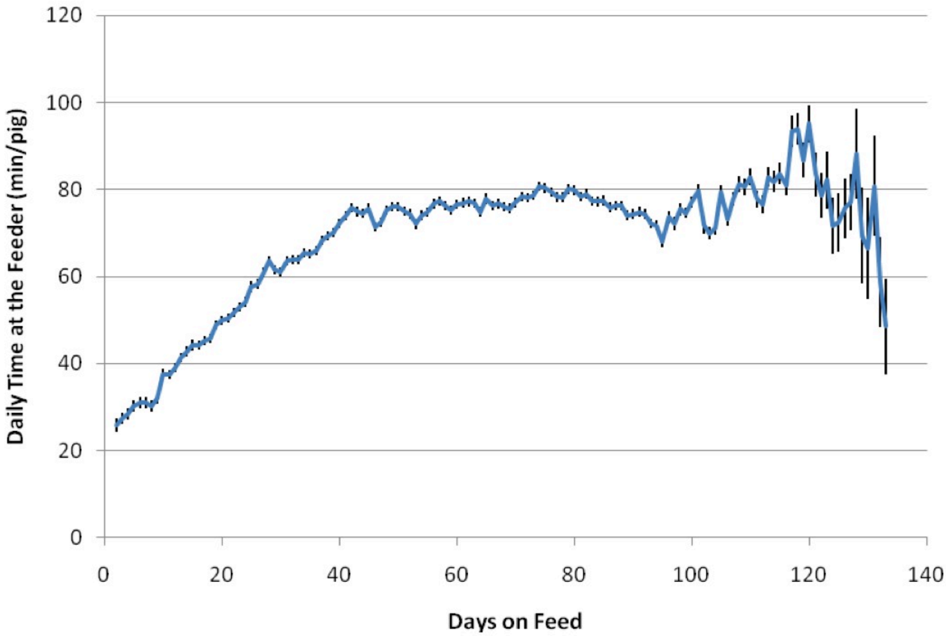

Figure 4. Average time spent at the feeder (min/day/pig) as the pigs aged. Day 0 on the graph depicts the day the pigs were moved into the facility (at approximately 65 days of age). Number of pigs varied on a daily basis, due to sick pigs being moved out and pigs being marketed. The average number of pigs on a single day was 205 pigs.

When the differences between sexes were analyzed, effects of period, days on feed, sex, and the interaction of days on feed and sex were all significant ($P < 0.001$). Barrows and gilts were fed the same diets in mixed sex pens. Barrows spent significantly more time at the feeder between day 26 and day 93 than the gilts. They reached a plateau at about 85 min/day/pig, while the gilts reached a plateau at about 71 min/day/pig (Figure 5). Hyun *et al.*, (1997) reported no difference in time spent at the feeder nor feed intake between barrows and gilts. However, differences in feed intake between barrows and gilts have been reported in the literature (Campbell and Taverner, 1988; Fuller *et al.*, 1995). Hyun *et al.*, (1997) suggested that the possible reason for not seeing a difference in their study was the feeding stations were affecting feeding behavior and intake. These data suggest that in a typical industry setting barrows would spend more time at the feeder possibly to consume more feed.

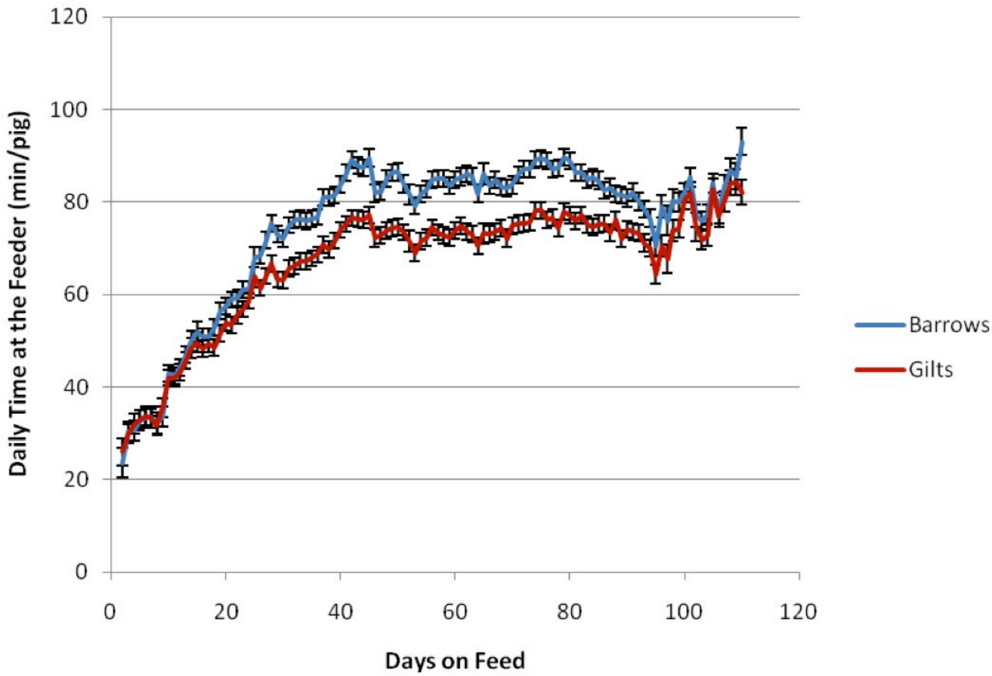

Figure 5. Average time spent at the feeder (min/day/pig) throughout the grow-out period for barrows and gilts. Day 0 on the graph depicts the day the pigs were moved into the facility (approximately 65 days of age). Number of pigs varied on a daily basis, due to sick pigs being moved out and pigs being marketed; average number of pigs during the first three periods was 102 barrows and 103 gilts.

The highest gaining pigs in a pen are most likely the pigs that eat the most feed. When time spent at the feeder was analyzed, period, days on feed, gain category, and the interaction of gain category and days on feed were highly significant ($P<0.001$). The pigs classified as high gaining pigs (gain≥0.94 kg/day; N=63 pigs) had the highest average time spent at the feeder (79.1±0.45 min/day), followed by the normal pigs (0.7 kg/day < gain < 0.94kg/day; 71.0±0.15 min/day; N=510), and the low gaining pigs (gains<0.7kg/day) had the lowest average time at the feeder (63.6±0.35 min/day; N=63) ($P<0.001$ for all differences).

Figure 6 illustrates the changes in time spent at the feeder over the grow-out period for the high and the low groups. It was noted that the low gain group quickly separated from the high group (by day 7). Interestingly, after the high group was marketed the low gain group's time at the feeder quickly .increased. This increased feeding activity was possibly due the social interaction of the pigs. This illustrates that importance of social interaction in a production setting, an aspect that is most often overlooked.

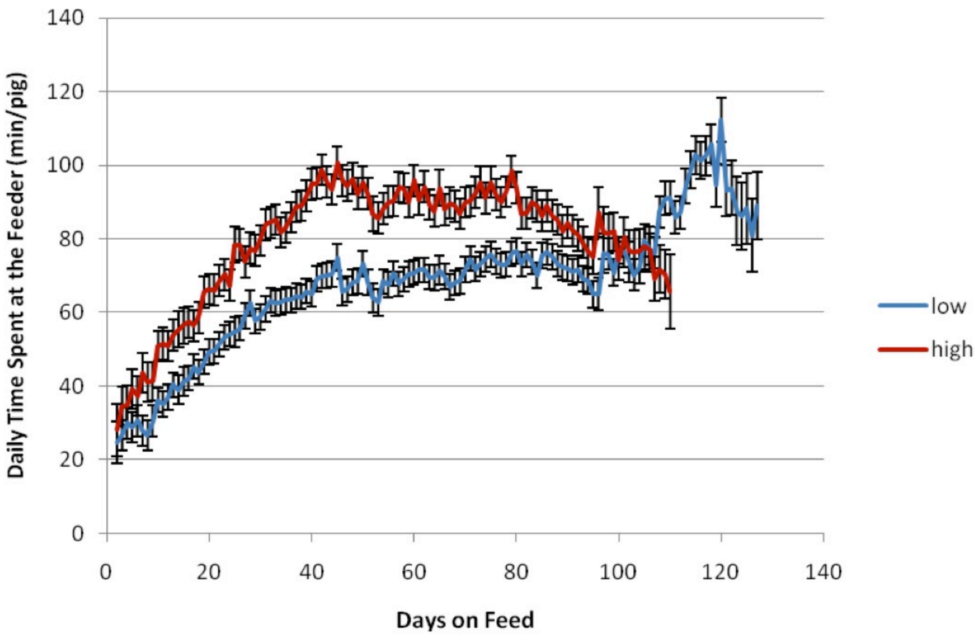

Figure 6. Average time spent at the feeder (min/day/pig) throughout the grow-out period for high and low gaining pigs. Day 0 on the graph depicts the day the pigs were moved into the facility (approximately 65 days of age). Number of pigs varied on a daily basis, due to sick pigs being moved out and pigs being marketed; average number of pigs in the high category was 54 (63 Maximum), low 80 (97 Maximum).

Out of 960 pigs, 458 pigs were treated for illness at least one time. Due to the lack of frequency of many of the health concerns, only pneumonia was analyzed. Three hundred seventy-nine pigs were treated for pneumonia over the course of the study. The analysis for health concerns revealed that time spent at the feeder was impacted by period, days on feed, and diagnosis ($P<0.001$). The pigs that were treated spent less time at the feeder than those who were never treated (treated 64.1±0.2 min, non-treated 69.4±0.2 min; $P=0.0189$).

While this information is important in developing tools for producers to use to identify animals affected by a disease, the information that is needed is "What happened immediately preceding diagnosis and following treatment?" Figure 7 illustrates the average response from a group of pigs during a pneumonia outbreak where the animals in the building were all treated with antibiotics. In analyzing this graph it can be noted that time spent feeding started to decrease two days before the animals were treated. It can also be noted that the pigs responded to the treatment fairly quickly and were back to feeding levels equal to pre-treatment levels by 4 days post treatment.

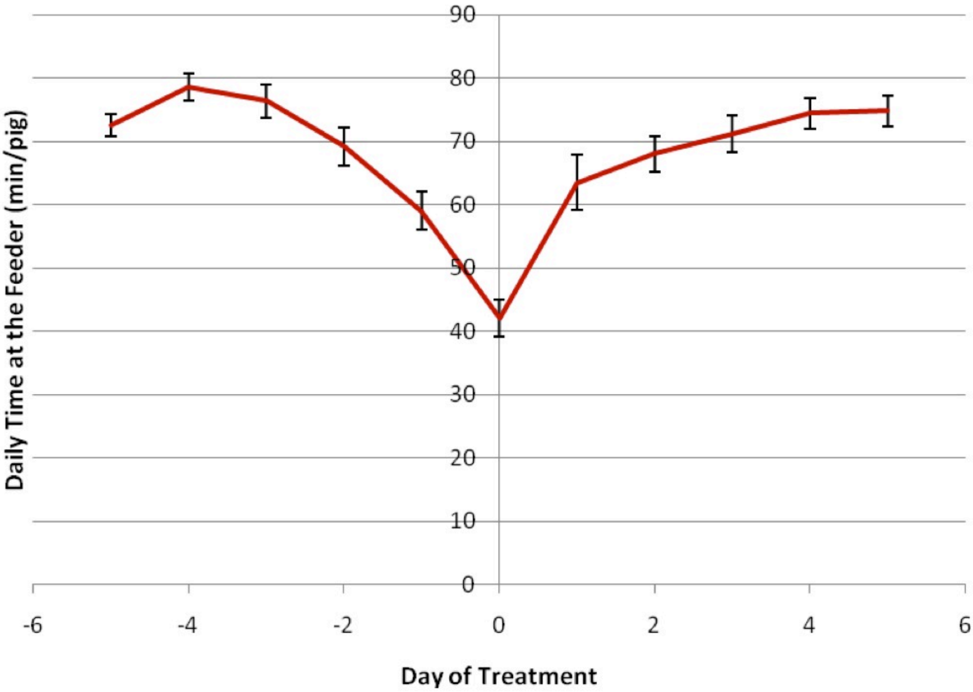

Figure 7. Average time spent at the feeder during a major pneumonia outbreak. All pigs in the building were treated with antibiotics on Day 0; days preceding and following day 0 are added for informational purposes.

However, the extremes are always lost in an average, so Figure 8 illustrates two extreme feeding behaviors during that same outbreak. The two pigs were selected from the same litter to reduce the impact of genetics. One of the pigs (200909602) is obviously not impacted by disease, while the second animal (20090605) is very much impacted by the disease.

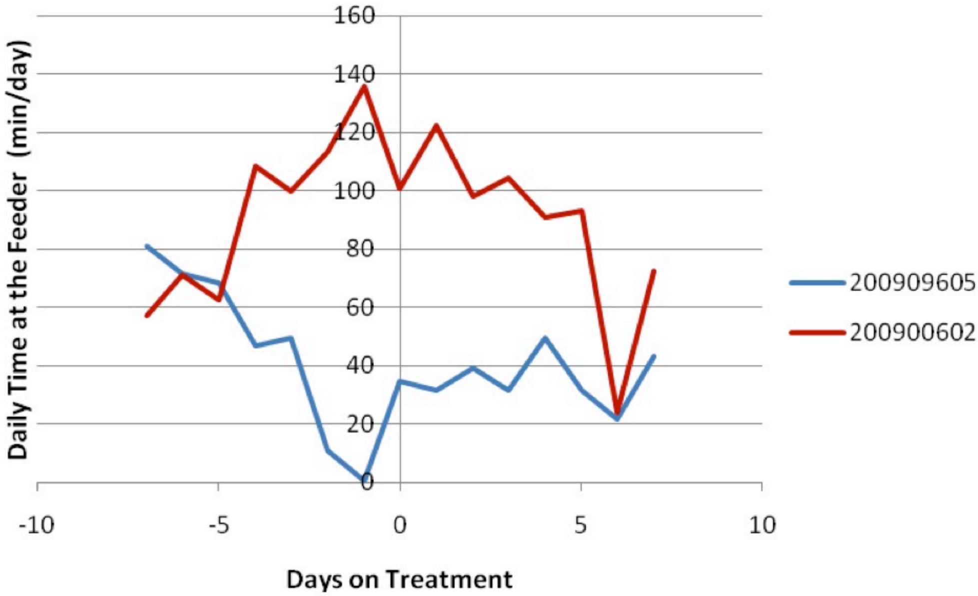

Figure 8. Time spent at the feeder for two pigs with different responses during a major pneumonia outbreak. Pig Number 200909602 and Pig number 200909605 are littermates.

So, the question arises, "How many animals were impacted during this outbreak?" To answer that question, pigs were classified in three groups (not affected, affected, and unknown). The "affected" group was defined as pigs that spent less than 33 minutes at the feeder, the "not affected" group was defined as pigs that spent more than 66 minutes at the feeder, and the unknown group was composed of those who were intermediate. The number of pigs in each group changed on a daily basis before and after the outbreak (Figure 9). Tracking the feeding behavior of individual animals may lead to earlier diagnosis, quicker treatment, and better tracking of recovery.

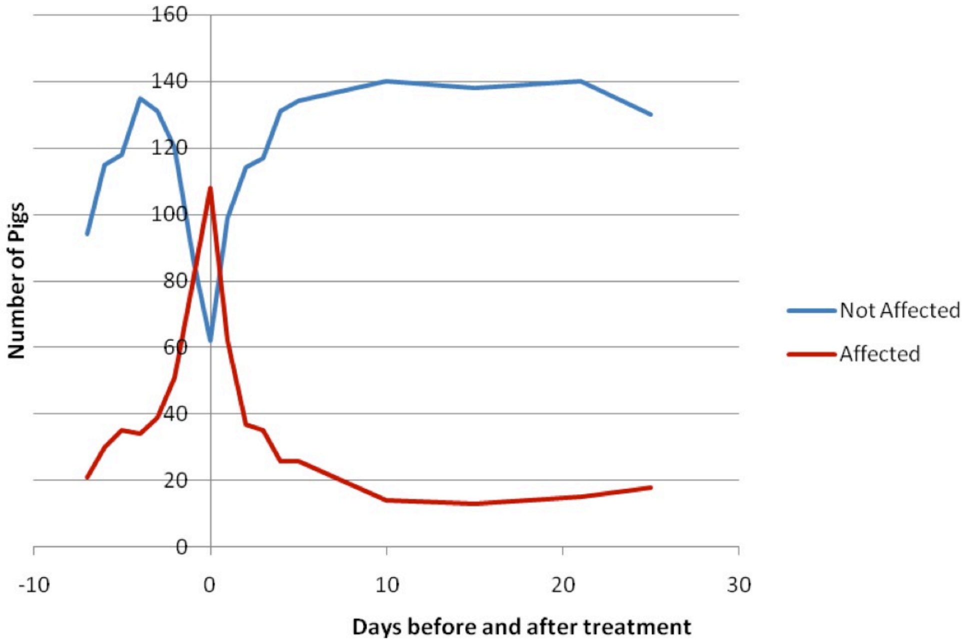

Figure 9. Daily count of pigs classified as affected (pigs that spent <33 minutes at the feeder) and pigs classified as not affected (pigs that spent >66 minutes at the feeder) preceding and following a major pneumonia outbreak in the facility.

While using the standard statistical models on these data provided some new and useful information, generally the information is in support of literature data. However, the current analysis has only considered a small amount of the information that is available. The data collected by this system and other feed intake systems that are collecting vast amounts of data that provide a considerable amount of information about each individual animal on at least a daily basis if not on an hourly basis. Being able to track changes in an individual animal's feeding behavior could provide a wealth of information. However, the systems to provide this type of analysis have not been developed.

Currently, there are two limitations to developing a system to track feeding behavior and provide information to a producer: the knowledge of the animal system, and analysis methods that can work in tandem with the data collecting or data-basing software. Questions to be addressed concerning the knowledge of the animal system include:

- What feeding level is normal and abnormal?
- What are the boundaries on a normal feeding level?
- If feeding behavior is identified as abnormal,
    - Can the problem be identified?
    - What solution needs to be applied?
    - How fast a rate of recovery should be expected?

While scientists have determined mean feed intake, or in this case, the mean time spent at the feeder, two questions remain: what are the boundaries of the normal range? and what is the normal day to day variation associated with a single animal? Future research will be focused on answering these questions.

Conclusions

A system to collect feeding behavior using RFID technology was developed and installed in a swine facility. The data were collected on 4 groups of pigs for a total of 960 individual animals. The system was used to determine differences in feeding behavior as related to age, sex, gain classification, and health.

- The system was used to describe the changes in time spent at the feeder during the grow-out phase. The pigs increased their time at the feeders until day 42 when their time at the feeders reached a plateau at 76.7 min/day.
- The barrows spent more time at the feeders than the gilts (85 min/pig/day compared to 71 min/pig/day).
- The data from the system revealed that the pigs in the high weight gain class spent more time at the feeder than either the normal gaining pigs or the low gaining pigs. The high gaining pigs spent about 79 min/day at the feeder compared to 71 min/day for the normal gaining pigs and 64 min/day for the low gaining pigs. It was noted that the low gain group quickly became significantly different from the high gain group. Interestingly, the low gain group's time at the feeder increased dramatically after the high gain group was removed from the pen (as they reached market weight). This indicated that some of the differences between the two groups were related to the social interaction of the pigs.
- The amount of time spent at the feeder decreased during a pneumonia outbreak. Overall, pigs treated for pneumonia spent less time at the feeder than those not diagnosed with pneumonia. We determined that the system provides useful information for determining the impact that a disease has on an individual animal.

References

Adijaoude, J. A., P. Morand-Fehr, J. Tessier, Ph. Schmidely, and D. Sauvant. 2000. Diet effect on the daily feeding behaviour, frequency and characteristics of meals in dairy goats. *Livestock Production Science* 64: 29-37.

Andree, H., and T. U. Huegle. 2001. Effect of single animal feeding stations and group size on growing performance of group housed fattening pigs. *American Society of Agricultural and Biolgocial Engineering* Meeting Paper No. 014026: St. Joseph, MI: ASAE.

Basarab, J. A., M. A. Price, J. L. Aalhus, E. K. Okine, W. M. Snelling, and K. L. Lyle. 2003. Residual feed intake and body composition in young growing cattle. *Canidian Journal of Animal Science* 83(2): 189-204.

Campbell, R. G., and M. R. Taverner. 1988. Genotype and Sex Effects on the Relationship Between Energy Intake and Protein Deposition in Growing Pigs. *Journal of Animal Science* 66(3): 676-686.

Chapinal, N., J. L. Ruiz-de-la-Torre, A. Cerisuelo, M. D. Baucells, J. Gasa, and X. Manteca. 2008. Feeder use patterns in group-housed pregnant sows fed with an unprotected electronic sow feeder (Fitmix). *Journal Applied Animal Welfare Science* 11(4): 319-336.

Fuller, M. F., M. F. Franklin, R. McWillian, and K. Pennie. 1995. The responses of growing pigs, of different sex and genotype, to dietary energy and protein. *Animal Science* 60: 291.

Gipson, T. A., A. L. Goetsch, G. Detweiler, R. C. Merkel, and T. Sahlu. 2006. Effects of the number of yearling Boer crossbred wethers per automated feeding system unit on feed intake, feeding behavior and growth performance. *Small Ruminant Res.* 65(1-2): 161-169.

Gipson, T. A., A. L. Goetsch, G. Detweiler, and T. Sahlu. 2007. Effects of feeding method, diet nutritive value and physical form and genotype on feed intake, feeding behavior and growth performance by meat goats. *Small Ruminant Research* 71(1-3): 170-178.

Goetsch, A. L., T. A. Gipson, A. R. Askar, and R. Puchala. 2010. Invited review: Feeding behavior of goats. *Journal Animal Science* 88(1): 361-373.

Griffin, D. 2001. How health status and environment influence the feeding behavior of feedlot cattle. 3rd Annual Intermountain Nutrition Conference, Utah State University, Logan, Utah 117-124.

Hyun, Y., and M. Ellis. 2002. Effect of group size and feeder type on growth performance and feeding patterns in finishing pigs. *Journal Animal Science* 80(3): 568-574.

Hyun, Y., M. Ellis, F. K. McKeith, and E. R. Wilson. 1997. Feed intake pattern of group-housed growing-finishing pigs monitored using a computerized feed intake recording system. *Journal Animal Science* 75(6): 1443-1451.

Kelly, A. K., M. McGee, D. H. Crews, Jr., A. G. Fahey, A. R. Wylie, and D. A. Kenny. 2010. Effect of divergence in residual feed intake on feeding behavior, blood metabolic variables, and body composition traits in growing beef heifers. *Journal Animal Science* 88(1): 109-123.

Korthals, R. L. 2000. Evaluation of space requirements for swine finishing feeders. *Transactions of the American Society of Agricultural and Biolgocial Engineering* 43(2): 395-398.

Puma, M. C., H. Xin, R. S. Gates, and D. J. Burnham. 2000. Feeding and drinking patterns and growth performance of individual broilers at selected cyclic air and constant drinking water temperatures. *American Society of Agricultural and Biolgocial Engineering* Meeting Paper No. 004068 ASAE.

Nienaber, J. A., and G. L. Hahn. 2000. Feeding behavior and energetics of growing -finishing swine as influenced by environmental temperature. ASABE Meeting Paper No. 87-4512: St. Joseph, MI 49085: American Society of Agricultural Engineers.

Nienaber, J. A., T. P. McDonald, G. I. Hahn, and Y. R. Chen. 1991. Group feeding behavior of swine. *Transactions of the American Society of Agricultural Engineering.* 34(1): 289-294.

Soltysiak, T., and Z. Ogalski. 2010. The effects of social hierarchy in a dairy cattle herd on milk yield. *Polish Journal of Natural Sciences* 25(1): 22-30.

Val-Laillet, D., D. M. Veira, and M. A. G. von Keyserlingk. 2008. Short communication: Dominance in free-stall-housed dairy cattle is dependent upon resource. *Journal of Dairy Science* 91(10): 3922-3926.

Walker, S. L., R. F. Smith, J. E. Routly, D. N. Jones, M. J. Morris, and H. Dobson. 2008. Lameness, activity time-budgets, and estrus expression in dairy cattle. *Journal of Dairy Science* 91(12): 4552-4559

Use of feeding data from electronic sow feeders to detect impairments of health

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Abstract

In group management systems of pregnant sows with electronic sow feeders (ESF) animal control is difficult. Earlier studies show that sows approximately have the same feeding order on consecutive days. The present investigation analysed retrospectively if an illness may influence the feeding order. The research centre Futterkamp provided station data and treatment information. Sows who received treatment for a disease retrieved feed from ESF later in the day than those sows without treatment. This result serves as a basis for the detection of sick sows by observing the individual visit order to the ESF. Variations in the individual series of feeding places could activate an alarm function implemented in the management software.

Keywords: electronic sow feeder (ESF), animal control, health control, feeding order

Introduction

Group management systems with ESF are often used in large dynamic groups of more than 60 pregnant sows. The sows in the pen move between an activity, lying and feeding area. Sows can't feed at the same time; they have to visit the ESF in succession. In dynamic groups the farmer can't rate the sows on their weight or body condition because the sows are in different stages of gestation. Summarized those conditions are leading to a more difficult animal control in such group management systems.

The feeding order is the sequence in which the sows come to the ESF after the start of feeding. It reflects the social hierarchy in the group which depends on age and parity of each sow. Those first places in the feeding order are taken up by sows with a high parity number (Hunter *et al*., 1988; Jensen *et al*., 2000; Ritter and Weber, 1988). The feeding order is stable and shows a definite pattern (Bressers *et al*., 1993). The correlation of the ESF visit ranking on consecutive days is high for each sow. Correlation coefficients of W = 0.856 (Hunter *et al*., 1988) and r = 0.89-0.95 (Hoy *et al*., 2007) are calculated.

Cornou *et al*. (2008) tried to detect health disorders by modelling the individual eating rank. The sensitivity for detecting health disorders ranged between 0 % and 75 %.

This investigation indicates that sows who are sick differ in their individual ranking of ESF visits. It should be possible to determine a time span or range for each sow in which the feeding places of this sow is normal. Included in a management system, it might be an aiding device for the detection of ill sows.

Material and Methods

The research centre Futterkamp allocated the data of the visits to the ESF (company Schauer) and the recordings of treatments. The sows were kept in a group of approximately 210 sows on three ESF. All three ESF were available for all sows to use. The sow groups were performed in a one-week period.

The software of the ESF recorded the following data: ESF-use number, date (year, month, day), time of access (hour, minute, second), animal number, feed amount and time of exit (hour, minute, second). The visits of the sows were sequenced by their arrival at each ESF for each feeding cycle. This is the feeding order at the ESF. Only the first visit of a sow at each day was considered. Each sow got a visit number for each day.

The documentation of disease treatments to the sows included the animal number, the reason of the treatment and the date. Treatments of each sow were marked with an index at the corresponding day of visit to the ESF. The medicated sow had days with treatment (index 1) or without treatment (index 0). This is shown in table 1.

Table 1. Assignment of visit number and animal day.

Date	Time of Visit	Animal number	Visit number	Index treatment	Animal day
1.1.	00:01	11	1	0	Healthy
1.1.	00:13	13	2	0	Healthy
1.1.	00:24	8	3	0	Healthy
1.1.	00:37	17	4	0	Healthy
1.1.	01:03	23	5	0	Healthy
...	…	...	...	...	...
2.1.	00:00	11	1	0	Healthy
2.1.	00:10	8	2	0	Healthy
2.1.	00:23	37	3	0	Healthy
2.1.	00:34	17	4	0	Healthy
2.1.	00:48	13	5	1	Treatment

The study included 117 days of observation with a total number of 25,030 station visits of 396 sows.

The focus was to analyse the coherence between diseases and ESF visit number. The ESF visit number of medicated sows on their days without treatment (Index treatment = 0) was compared to their visit number on days with treatment (Index treatment = 1). 5,092 visits were complied with this choice. The ESF visit numbers were compared with a boxplot and a Mann-Whitney-Test.

For sows with more than one treatment a correlation matrix of the visit number for a period of 5 days before the first treatment was done. Sows with more than one treatment probably have a more severe impairment of their “normal” feeding behaviour than sows with just one treatment.

Results

3.7 % of all visits at the ESF were the second or greater visit of one sow for this day. Normally, all sows eat their full ration during one visit to the ESF. The 25,030 visits to the ESF divided into one third for each station. The three stations were used to capacity with an average of 70 visits per day.
Medicated sows came later to the ESF than un-medicated sows. The descriptive statistics of the ESF visit number of only medicated sows is shown in a boxplot (figure 1).

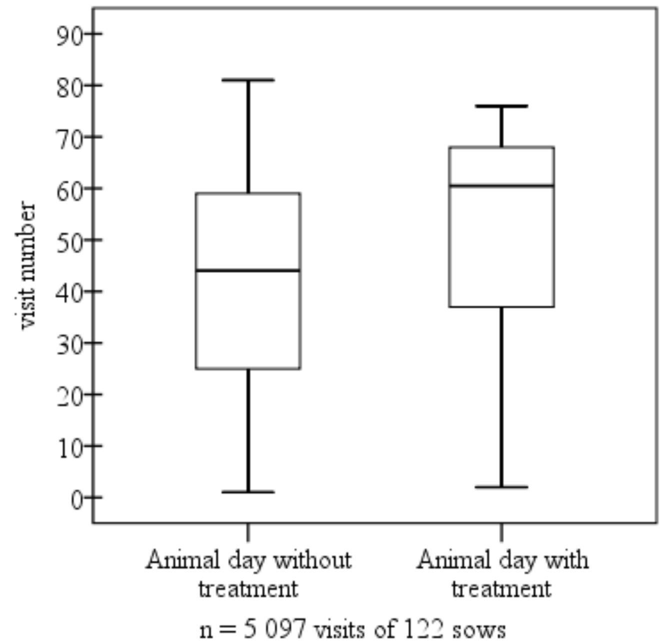

Figure 1. Descriptive statistics (boxplot) of the visit number of medicated sows on their days with or without treatment.

Sows on days without treatment
50 % of all daily visits to the ESF occurred before place 44 in the visit order (median). The frequency of use of the ESF was 70 visits, normally 50 % of the visits took place before visit number 35. The sows with treatment during the observation period tended to come in later to the ESF than the sows without treatment. The inter-quartile range started at place 25 and ended at place 59. It showed that the distribution was located equally around the median.

Sows on days with treatment
50 % of the sows used the ESF 16 places later in the sequence on days when treated with an average visit number of 60. Assuming that the average visit duration was approximately 10 minutes, those sows visited the ESF 2.5 hours later than on days without treatment. The minimum visit number (= high rank in the feeding order) on days with treatment was 2, the maximum visit number was 76. The 25-%-quartile started at slot 36 and the 75-%-quartile

ended at slot 68. Half of the ESF visits on days with treatments happened within the limits of 16 visit numbers (median until maximum). 50 % of the sows ate in the last quarter of the feeding order on their days with treatment.
The difference between the visit number on days with or without treatment is significant with $P < 0.01$ according to the Mann-Whitney-Test.
The correlation of the visit number on consecutive days was around 90 % in the whole group. The frequently medicated sows showed such a high correlation on their days before treatment as well. The difference between the correlation of the visit number before treatment (day -1) and the treatment day was 0.787 (table 2).

Table 2. Correlation matrix of the visit number from 37 frequently medicated sows in the period of 5 days before their first therapy.

Correlation coefficient	Day -5	Day -4	Day -3	Day -2	Day -1	Day treatment
Day -5	1	0.922	0.867	0.889	0.863	0.807
Day -4		1	0.898	0.896	0.846	0.793
Day -3			1	0.926	0.924	0.856
Day -2				1	0.907	0.853
Day -1					1	0.787
Day Treatment						1

All correlations are significant on a level of $P < 0.01$.

Discussion

It was shown that medicated sows came later to the ESF on their days with treatment. Those sows mainly eat in the last quarter of the feeding order. Some sows came earlier to the ESF. They were the sows that normally were at the top of the feeding order. A reason for this could be that only one day was defined as a day of illness. But illness is an incident covering more than one day. Perhaps some sows already came later to the ESF on days before their day of treatment. But those visit numbers were determined as days without treatment.
Normally, the correlation of the ESF visit number on consecutive days is around 0.9. The correlation of the visit number between the day before treatment and the day of treatment was approximately 10 % lower than on the days before. Related to the descriptive statistics, the ESF visit number at days with treatment becomes higher, indicating that the sows come later to the feeder.

Further investigations

It could be shown, that sows with impairments to health visited the ESF later. Now we are trying to define a corridor in which the sow's "normal" visit number ranges according to their last visits to the ESF. In cooperation with a company we will implement this span into the management-system in order to provide an alarm function for the farmer if a sow eats much later than usually. Provided such a span or range can be defined, the farmer is given a tool to support the animal health control.

Acknowledgements

We thank the research centre Futterkamp for the allocation of information.

References

Bressers, H. P. M., Te Brake, J. H. A., Engel, B. and Noordhuizen, J. P. T. M. 1993. Feeding order of sows at an individual electronic feed station in a dynamic group-housing system. Applied Animal Behaviour Science **36**, pp. 123-134.

Cornou, C., Vinther, J. and Kristensen, A. R. 2008. Automatic detection of oestrus and health disorders using data from electronic sow feeders. Livestock Science **105**, pp 262-271.

Hoy, S., Weirich, C. and Krauss, V. 2007. Untersuchungen zum Sozialverhalten von Sauen an elektronischen Abrufstationen (Investigations on social behaviour of sows at electronic feeding station). Proc. Aktuelle Arbeiten zur artgemäßen Tierhaltung. KTBL-Schrift 461, pp. 186-193.

Hunter, E. J., Broom, D. M., Edwards, S. A. and Sibly, R. M. 1988. Social hierarchy and feeder access in a group of 20 sows using a computer-controlled feeder. Animal Production **47**, pp. 139-148.

Jensen, K. H., Sørensen, L. S., Bertelsen, D., Pedersen, A. R., Jørgensen, E., Nielsen, N. P. and Vestergaard, K. S. 2000. Management factors affecting activity and aggression in dynamic group housing systems with electronic sow feeding: a field trial. Animal Science **71**, pp. 535-545.

Ritter, E. and Weber, R. 1988. Soziale Rangordnung und Belegung der Futterstation bei zwei verschiedenen Abruffütterungsanlagen (Social hierarchy and occupation at two different electronic sow feeders). Proc. Aktuelle Arbeiten zur artgemäßen Tierhaltung. KTBL-Schrift 336, pp. 132-141.

Individual online-monitoring of feeding frequency and feeding duration of group-housed weaned piglets via high frequent radiofrequency identification (HF RFID)

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Abstract
The individual feeding frequency and feeding duration of the piglets was recorded continuously online in the form of an attendance check at the trough via high frequent radiofrequency identification (HF RFID). Data from the 3 pigs with the highest and the 3 pigs with the lowest body weight gains were grouped as High and Low Performers, respectively. From the HF RFID data, a great degree of variability could be determined in the feeding frequency and feeding duration, which was reflected in the increase in body weight. The pigs classified as High Performers had a significantly higher increase in body weight than the Low Performers. The High Performers also showed an obviously longer time spent each day at the feeder during the first 10 days as well as shorter pauses between their meals. In the future, decision-making models for precision livestock farming can be developed from such data so that errors within the production chain can be discovered early on and that improvements can be made, thereby minimizing financial losses.

Keywords: feeding frequency, feeding duration, high frequency, performance, radio frequency identification (RFID), weaned piglets

Introduction

Modern pig husbandry is characterised by an increasing enlargement of the herd size per production unit. Already in 1974, Weniger (1974) described that with the development of intensive husbandry completely new solutions would be needed in pig fattening, especially for the monitoring of health and performance within the herds.
Even though monitoring was originally considered to be an important part of passive process control, computer-aided monitoring has been developed as an instrument of active process control - the so-called precision livestock farming (PLF). The aims of PLF is to record process-relevant data online and non-invasively from the animals during the production process and to then use the data in process controlling in control and decision-making models (e.g. feeding strategies, monitoring of growth) (Hessel, 2009). The most important prerequisite for online monitoring with respect to PLF is the successful use of sensors for the automatic, online registration of animal- and process-relevant information (Berckmans, 2004). A key PLF technology is the electronic animal identification with the aid of radio frequency identification (RFID). Normally low frequency (LF) transponders are used for individual animal identification. However the main disadvantage of LF transponders is that they can only be read individually in the radio reception field (Kern, 2006). For certain uses, it is, however, necessary to be able to read a number of transponders simultaneously. Therefore, the use of an innovative simultaneous individual animal recognition system at the feeder was undertaken in piglet rearing in this study. The new animal identification system was based on RFID

technology using high-frequency (HF) transponders in conjunction with an anti-collision system and achieves a very high identification accuracy > 97% (Reiners *et al.* 2009). The use of this system for the continuous online recording of feeding frequency and feeding duration for management purposes is presented in the following.

Animals, materials and methods

Experimental design

The monitoring period in the present study comprised the first 3 weeks in which piglets weaned at the age of 21 days were reared and included 2 rearing cycles. The study was carried out in a single pen of an automatically ventilated and heated nursery with 4 identical pens. Each pen measured 8.30 m² in size; the floor area was divided into an activity area of 3.25 m² covered with slatted flooring and a resting area of 5.05 m² with a concrete-lined surface. Each pen housed 20 piglets. The animals were taken to the research facility on the day of weaning. The experimental pen was equipped with a conventional tube mash feeder (Lean Machine, Big Dutchman, Vechta, Germany). The storage tank of this feeder was made of plastic. The piglets had to actively move 2 dosing brackets arranged horizontally above the plastic trough for the feed to be released. Subsequently, the animals could blend the feed to mash with water from 2 spray nipples, also arranged above the trough. The feeder had 6 feeding places. Feed was available ad libitum.

Simultaneous individual animal identification**.**

For this study, special troughs were made out of plastic as plastic can be permeated more easily by the magnetic radiation of the antenna than metal (Dittmann, 2006). Circular HF antennas made of copper wire were integrated into the round troughs of the feeder. The integration of the antennas into the troughs provided protection against moisture. They were connected to the RFID reader via a coaxial cable. The antenna used in the present study had a data transmission rate of up to 25 kbit/s and thus offered sufficient reading speed to simultaneously register several transponders using the anti-collision system. The RFID reader used in this study was a HF long-range reader (LR 200, Feig Electronics, Weilburg, Germany) with an operating frequency of 13.56 MHz and 2 W transmitter power. It had a range of 30 cm in the present study. A single reading took 0.12 to 0.15 seconds.
Before the beginning of the experiment, every piglet was tagged with a so-called passive HF transponder with an operating frequency of 13.56 MHz (IN tag 300l-Code SLi, Sokymat, Granges, Switzerland). The round transponders were clipped onto the ear tags of the piglets (Allflex, Hamburg, Germany). Further details about the technology used can be found in Reiners *et al.* (2009), a common publication of the Division Process Engineering of the University of Goettingen and the Institute for Agricultural Engineering and Animal Husbandry of Bavarian State Research Centre for Agriculture.

Animals and Feeding

All the animals in both nursery periods of the experiment had the same origin. Newly weaned piglets [(Large White × German Landrace) × Pietrain] were used. The piglets were weaned on a pig farm at 21 days of age and were transported to the nursery on a commercial pig trailer immediately after weaning. The transport distance was 12 km. In order to balance the effect of sex, the gender ratio was adjusted (10 male and 10 female pigs) in the experimental pen. The piglets were introduced to the experiment at an initial body weight of 5.97 ± 0.75 kg in the first rearing period and 5.72 ± 0.78 kg in the second rearing period. Four pigs had to be removed from the investigation before the end of the trials. The decision to reject these pigs from the experiment was not taken on the basis of the RFID data but due to the visual impression the pigs gave. During the first period, 2 pigs appeared to have a very poor body condition and so were removed from the group on days 5 and 11, respectively. The third pig was removed due to injuries on day 12. On day 3 of the second period, a fourth pig was removed due to its extremely poor body condition.

For the first 10 days after weaning, the piglets received a pre-starter feed with 16.30 MJ ME/kg DM and 21% CP. From day 11 until the end of the nursery period, a feed with 13.52 MJ ME/kg DM and 18% CP was offered. Feed and water were was available ad libitum throughout the experiment.

Data Collection

The trough visits (entering and leaving of the trough zone) of individual animals were registered to the millisecond by simultaneous individual identification. Each reading lasted between 0.12 and 0.15 seconds. The registered trough visits were digitally transmitted to a PC and stored in ASCII files using specific software. Afterwards, the data segments required for evaluation were transferred to Microsoft Excel. A trough visit was defined, if an animal stayed more than 10 seconds within the range of the antenna. Furthermore, each piglet was weighed individually on the day of weaning and at weekly intervals during the 3-week nursery period.

Statistics

In total, data were obtained from 40 piglets in 2 rearing periods. The data from the 4 pigs that had been prematurely removed from the experiment were analysed separately. For these pigs, the time spent each day at the trough was determined until the animals left the experiment. This was then compared to the group mean of those pigs that remained throughout the experimental cycle (21 day).

For each of the 36 pigs which remained in the experiment, the time spent at the trough each day was calculated. In addition, using the hourly means the time until the first visit to the trough, the daily feeding routine and the number of hours not spent at the trough each day were calculated. The data were presented as means and standard deviations (SD).

In order to correlate animals' feeding frequency and feeding duration with performance, the 3 pigs with the highest total body weight gain and the 3 pigs with the lowest body weight gain in each batch after 21 days of rearing were assessed together as the High Performers and Low Performers, respectively. The analysis of the performance data was performed using the GLM procedure of the software program SAS 9.1 (SAS Inst. Inc., Cary, NC). Both the group membership and the rearing period were considered as the fixed effects. The results are reported as means ± standard errors (SE). The significance level was $P \leq 0.05$ (t-test).

Results

Trough visits of individual pigs

With the aid of simultaneous individual animal identification, a total of 67751 trough visits from 36 pigs were registered in the first 21 days of both rearing periods; 31305 in Period 1 and 36446 in the Period 2. The number of registered visits per pig was at a similar level in both periods (Period 1: 1842 trough visits per pig; Period 2: 1918 trough visits per pig). The duration of a trough visit was slightly longer in the second period than in the first (mean: 56.6 s vs. 48.6 s, respectively; median: 30 s vs. 28 s, respectively) (Table 1).

Table 1. Number and duration of registered trough visits according to rearing period

Rearing period	Number of pigs	Trough visit			
		Number of registered visits	Mean visits per pig	Duration (sec)	
				Mean	Median
1	17	31305	1841.5	48.6	28
2	19	36446	1918.2	56.6	30

In the following, the monitoring potential of simultaneous individual animal identification using RFID in combination with HF transponders will be discussed using the investigated 2 3-week rearing periods as an example.

Feeding frequency and feeding duration on a daily basis

Each batch of pigs was placed in the pen at 15.00 on the first day of the rearing period. The registration of the visits of individual pigs to the trough was started at the same time using the simultaneous individual animal identification system. Due to the late start, the first day of recording was only 9 hours long and so was at first considered separately from the other 20 days of each trial period.

After being penned, on average, the pigs were first registered as being at the trough after 61 min in Period 1 and after 46 min in Period 2 (Table 2). Within a rearing period, this value was highly variable with a range extending over 132 min in Period 1 and 89 min in Period 2. The mean total time spent at the trough also varied greatly between the individual animals within the 9-hour observation period on the first day. This was clearly higher in Period 2 (20 min) than in Period 1 (8 min). This difference was due to the extremely long time spent at the trough by a single pig in Period 2 of 125 min.

Table 2. Mean, SD, minimum and maximum time (min) until the first visit to the trough, and the total time spent at the trough (min) per pig on the first day of observation according to rearing period

	Rearing period	
	1	2
Number of pigs	17	19
Time taken until the first trough visit/pig (min)		
Mean (SD)	60.9 ±31.8	45.9 ±19.1
Minimum	35	24
Maximum	167	113
Total time spent at the trough/pig (min)		
Mean	7.98 ±8.21	20.44 ±31.67
Minimum	0.56	1.11
Maximum	30.7	124.95

As on the first day, the total time spent each day at the trough was highly variable, though the mean time spent at the trough each day was, however, at the same level in both groups: 72.99 (±40.86) min/day in Period 1 and 89.73 (±46.55) min/day in Period 2 (Table 3).

Table 3. Mean, SD, minimum and maximum total time spent at the trough (min) per animal and day according to rearing period, 2nd to 21st day of the rearing period

	Rearing period	
	1	2
Number of pigs	17	19
Total time spent at the am trough/pig and day (min)		
Mean (SD)	72.99 ±40.86	89.73 ±46.55
Minimum	6.42	16.77
Maximum	326.24	287.21

Performance

The pigs were weighed individually when penned and at the end of the first, second and third week of the rearing period. With exception of the second week, when the body weight increase was significantly higher in Period 2, the body weight increase did not differ between the 2 batches of pigs (Table 4).

Table 4. Mean and SD of the body weight when placed in the nursery, weekly body weight gain and the total body weight gain after 21 days of rearing in Periods 1 and 2

Rearing period	Initial body weight	Body weight gain			Total body weight gain
		Week 1	Week 2	Week 3	
1, n = 17	5.97 [a] ± 0.17	1.29 [a] ± 0.16	2.43 [a] ± 0.15	2.85 [a] ± 0.20	6.56 [a] ± 0.36
2, n = 19	5.72 [a] ± 0.16	1.29 [a] ± 0.15	3.16 [a] ± 0.14	2.73 [a] ± 0.21	7.16 [a] ± 0.34

a,b = within a column, means without a common superscript differ (*P* <0.05).

In each batch of pigs, the 3 animals with the highest body weight gain and the 3 with the lowest body weight gain were considered together as the High Performers and the Low Performers, respectively. Table 5 shows the mean initial body weight on introduction to the nursery, the weekly body weight gain and the total body weight gain after 21 days of these animals. There were no significant differences between the initial body weight of the High and Low Performers within a rearing period, however, significant differences were already apparent after the first week of rearing between these groups. The High Performers also gained significantly more body weight in the second and third week, so that their body weight was 3.92 kg higher at the end of Period 1 than that of the Low Performers, while in Period 2 the difference was 4.55 kg.

Table 5. Least Square Means (SE) of the body weight when placed in the nursery, weekly body weight gain and the total body weight gain after 21 days of rearing of the High and Low Performers according to rearing period

	Rearing period				SE
	1		2		
Body weight	Low Performers[1]	High Performers[2]	Low Performers[1]	High Performers[2]	
Initial	5.83 [a]	6.41 [b]	5.55 [a]	5.85 [a]	0.43
Week 1	0.80 [a]	2.02 [b]	0.97 [a]	2.77 [c]	0.24
Week 2	1.73 [a]	3.07 [b]	3.16 [a]	3.70 [b]	0.31
Week 3	2.30 [a]	3.67 [b]	1.20 [a]	3.37 [b]	0.40
Total (week 1-3)	4.83 [b]	8.75 [b]	5.28 [a]	9.83 [b]	0.48

a,b,c = within a row, means without a common superscript differ (*P* < 0.05).
[1]Low performers (n=3)
[2] High performers (n=3)

Relationship between feeding frequency/feeding duration and body weight gain

The number of visits to the trough and the total time spent at the trough during the 9-hours first day of observation of the Low and High Performers are shown in Table 6. No clear differences could be found between the High and Low Performers with respect to group membership on the first day of observation. The total number of trough visits was very low in both groups. Also the total time spent at the trough was very short. The High Performers were registered at the trough for only 7.04 (8.42) min (Period 1) and 5.53 (4.12) min (Period 2). This value was 6.67 (7.62) min during Period 2 for the Low Performers and just 1.83 (1.39) min in Period 1.

Table 6. Mean (SD), minimum and maximum values for the number of visits to the trough, and the total time spent at the trough per pig on the first day of rearing according to performance (high vs. low) and rearing period

	Rearing period			
	1		2	
Performance	Low[1]	High[2]	Low[1]	High[2]
Number of visits to trough				
Mean (SD)	4.00 (1.00)	6.00 (4.36)	7.00 (6.67)	7.00 (4.36)
Minimum	3	3	4	2
Maximum	5	11	13	10
Total time spent at the trough/pig, min				
Mean (SD)	1.83 (1.39)	7.04 (8.42)	6.67 (7.62)	5.53 (4.12)
Minimum	1.01	1.55	2.26	0.80
Maximum	3.43	16.73	15.46	18.32

[1]Low performers (n=3)

[2] High performers (n=3)

The amount of time spent each day at the trough by the High and Low Performers from the second day of the rearing period is shown in Figure 1. Up until the 10th day of rearing, the High Performers spent more time at the trough each day than the Low Performers. From the 11th day onwards, this relationship changed and the time spent at the trough was higher for the Low Performers.

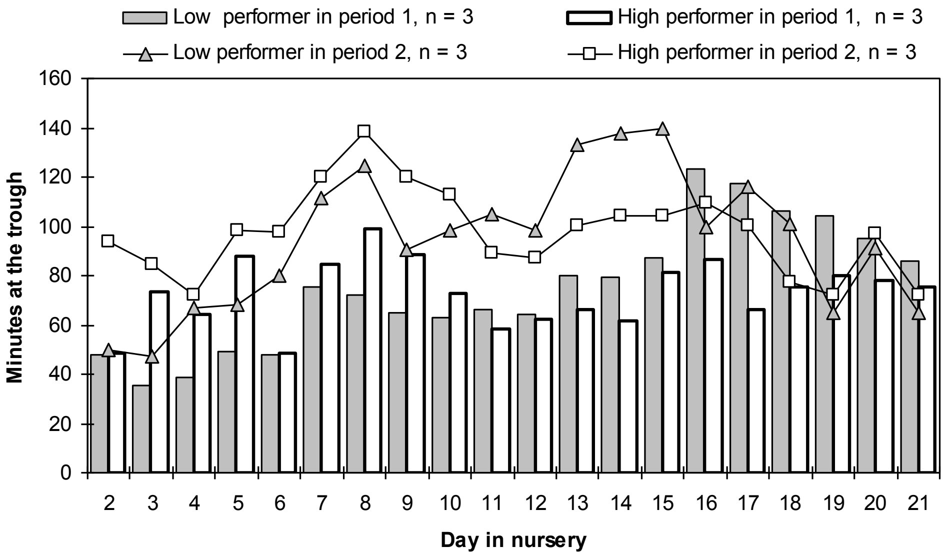

Figure 1. Total time spent at the trough (min/day) in the High and Low Performers according to day and rearing period

Using the mean hourly values from Period 1 as an example, the number of hours not spent at the trough were calculated (Figure 2). The High Performers spent on average a total of 2.89 hours per day away from the trough, whereas the Low Performers were not at the trough for an average of 4.38 hours per day. During the rearing period, the number of hours spent away from the trough in the first week was obviously higher than in the second and third week. In addition, until day 17, the Low Performers spent significantly more hours without ingesting food than the High Performers. Towards the end of the rearing period, both the Low and the High Performers frequented the trough virtually every hour.

The greatest difference in time spent at the trough per day between the High and Low Performers occurred in the first week. Also the feeding frequency and feeding duration during the day differed between these groups during this week. Using Period 1 as an example, the mean hourly duration of time spent at the trough of the whole batch and for the 3 High and the 3 Low Performers in week 1 were determined (Figure 3). The typical biphasic feeding behaviour of pigs with peaks in the morning and afternoon is clearly visible. However, the High Performers obviously spent more time at the trough between 6 am and 14 pm and 21 pm and midnight than the Low Performers.

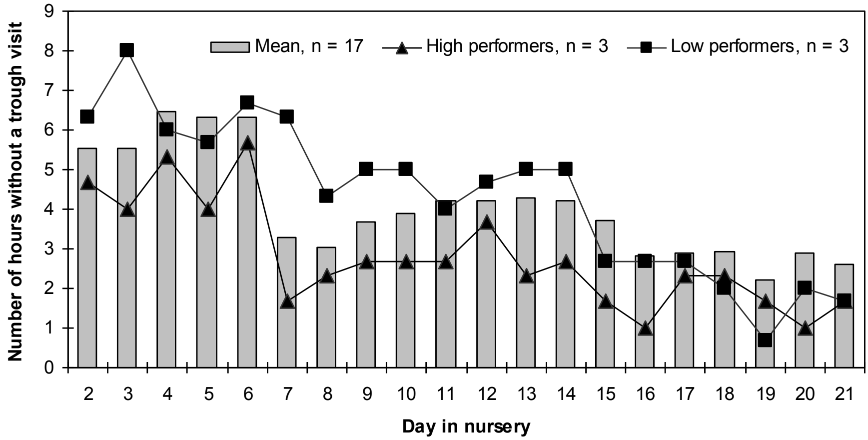

Figure 2. Number of hour spent away from the trough each day as a mean of all the pigs and for the High and Low Performers according to day in Period 1

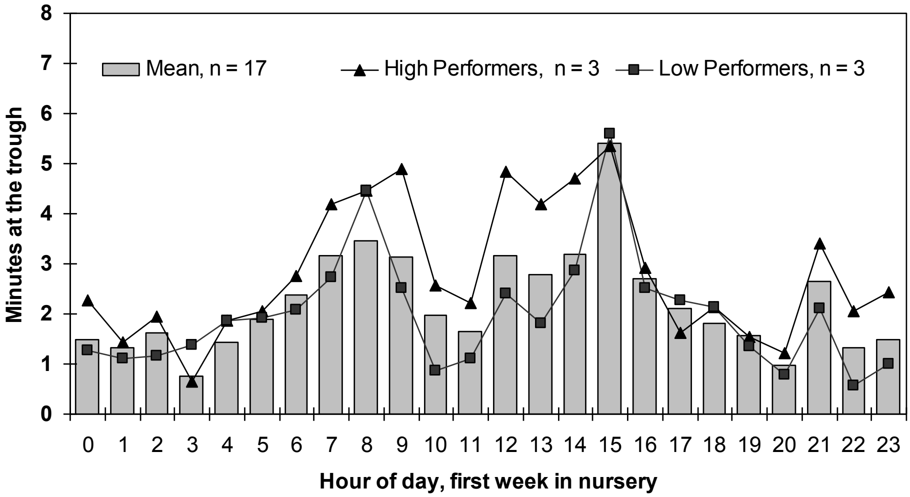

Figure 3. Daily duration of the trough visits as a mean of all the pigs as well as for the 3 High Performers and the 3 Low Performers according to hour of the day during week 1 in period 1

Removed pigs

The 3 pigs which were prematurely removed from the investigation due to poor body condition showed clearly shorter times spent at the trough than the average for the pigs that remained in the investigation. However, before being removed these pigs had already spent 1 to 2 days in the group during which they had not gone to the trough. The fourth pig, which was removed due to its injuries on day 12, spent as much time at the trough as the mean for the group up until day 11 (Figure 4).

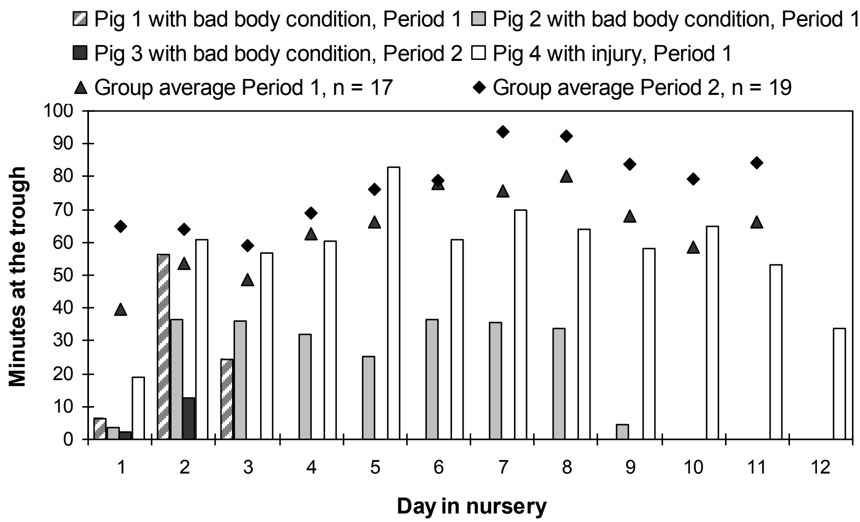

Figure 4. Total time spent at the trough (min/day) for the removed pigs as well as the mean total time spent at the trough by the pigs in Periods 1 and 2 according to day of rearing.
Pig 1 was removed on day 5, Pig 2 was removed on day 11, Pig 3 was removed on day 3, and Pig 4 was removed on day 12.

Discussion

Devices for electronic animal identification have facilitated the implementation of sophisticated livestock management schemes, with optimal attention and freedom for the individual animal (Eradus & Jansen, 1999). RFID plays a key role in electronic monitoring systems, which are inherently related to sensing systems (Geers *et al.*, 1997). With unequivocal identification, processes can be steered according to the animal (e.g. automatic feeding, automatic body weight measurement) and work processes can be further automated. This technology also allowed a switch from intensive to semi-extensive animal husbandry systems (e.g. group housing of sows). For farm management, the farmer will get more profit from identification and monitoring system than from identification alone (Geers *et al.*, 1997).
LF transponders (134.2 kHz) controlled by international standards (ISO 11784 and ISO 11785) are usually used for animal identification. The transmission speed of LF transponders is very slow in comparison to HF or Ultra High Frequency (UHF) transponders, so that for the transmission of large quantities of data long periods of time are required. Another disadvantage of this system is the short reading range of less than 1 meter. In most cases, these are read-only transponders, meaning that it is only possible to read the stored data. LF transponders have already been used in previous investigations to register individual feed uptake, as well as the number and duration of visits to the feeder (Georgsson & Svendsen, 2002; Hyun *et al.*, 1997). However, many errors arose during the electronic registration of the animals (De Haer & Merks, 1992; Slader & Gregory, 1988). In addition, the registration of the animals was only possible if the system was so set up that only 1 animal was at the feeder at a time (Hyun *et al.*, 1997). As weaned piglets and fattening pigs are usually held in groups and

in this form of husbandry extensively used feeding techniques are used in which more than 1 pig can feed at the same time, a simultaneous individual animal identification utilizing RFID technology in combination with HF transponders was developed, so that individual animal data about the feeding frequency and feeding duration of pigs in groups could be automatically recorded online. HF transponders transmit in the range of 13.56 MHz. This type of transponder is very flat and can be laminated with paper or plastic for use as standard labels (Kaiser & Steinhagen, 1994). They have the advantage of a high data transmission rate, a greater reading distance (especially in the smaller versions) and better anti-collision properties. HF transponders can therefore be read almost simultaneously. With respect to material penetration and temperature durability, the robust characteristics of LF transponders can be achieved in HF transponders with the relevant design (Fleisch & Mattern, 2005).

The reason why the simultaneous individual animal identification utilizing RFID was used in weaned piglets in this investigation is the knowledge that the feed uptake within the first week after weaning is essential for the growth performance of these animals. One of the main problems after weaning piglets is their reduced feed intake, which is often associated with growth depression in the first week of rearing and which can have far reaching effects for the rest of the rearing period and the subsequent fattening of the pigs (King & Pluske, 2003). Which significance the body weight gain in the first week after weaning has and how these effects the growth of the pigs before they are slaughtered has been made clear by Pluske *et al.* (1995). In their investigation, they could show that piglets which had a daily body weight gain of more than 115 g in the first week of rearing reached the slaughter weight roughly 14 days earlier than piglets, whose daily body weight gain in the first week of rearing was under 100 g. Williams (2003) also investigated the influence of body weight gain development in piglets during the first week after weaning on the age of slaughtering. His investigation showed that piglets which had a daily body weight gain of 225 g during the first week of rearing were 8 kg heavier than piglets which maintained their weaning weight in the first week of rearing when slaughtered on day 156.

Accordingly, it is of great importance to promptly acquire trustworthy information about the feeding behaviour of individual animals. The feeding behaviour of a group, which in practice is normally recorded as the feed ingested by the group, only reflects the group average. The present investigation could show, however, that despite the small group of probands there was a great degree of variability in the feeding frequency and feeding duration of the apparently homogeneous group (same genetic background, homogeneous weaning weights, same husbandry during the suckling and rearing periods, same weaning age and time). Although with the simultaneous individual animal identification only the presence of the pigs at the feeder was registered and no data about the actual amount of feed ingested was recorded, the great variability in feeding frequency and feeding duration was reflected in the body weight gain. Pigs classified as High Performers stood out due to their having the highest body weight gain in the group after 21 days rearing period. The High Performers also showed significantly longer periods of time spent each day at the trough than the Low Performers (animals with the lowest body weight gains after 21 days of rearing). With the aid of simultaneous individual animal identification, not only could the daily values for feed intake be won but also it could be shown how the pigs' feeding behaviour changed during the day. It could be determined, for example, that the High Performers spent more time at the trough than the Low Performers between 6 am to 14 pm and 21.00 pm to midnight. In addition, the High Performers spent

fewer hours away from the trough during the day. This indicates that the length of the pauses between feeding also influence the growth performance.
Those pigs who appeared to have lower growth rates than the others in the group and were removed from the group due to having visible signs of poor body condition, spent obviously shorter periods of time at the trough each day. Indeed 1-2 days before they were removed from the group, no trough visits were registered for these animals
Simultaneous individual animal identification appears to have a high potential both for the analysis of scientific questions and the implementation in practice for management purposes. For the scientific investigation of the feeding frequency and feeding duration of pigs, simultaneous individual animal identification offers the best prerequisites for the continual registration of individual pig's visits to the trough in the form of an attendance check. A far more precise assessment of an animal's trough visits can, therefore, be undertaken than with the standard method of video surveillance. The present investigation has shown that the mean length of individual visits to the trough of weaned piglets is, on average, less than 1 min. Hence for a meaningful observation of trough visitis of weaned piglets using video, it must be undertaken virtually continuously; this would require a great deal of time.
Another advantage of simultaneous individual animal identification is that the data about feeding frequency and feeding duration can be recorded in real time continuously online. With the use of computer-aided time series analyses of such data and utilizing predetermined PLF-relevant threshold values, early warning systems for potential drops in performance can be developed. With a clearly reduced number and duration of visits to the trough or even a lack of visits to the trough or too great a pause between visits to the trough, intervention in the production process can be undertaken in good time. This would mean that negative influences on animal health or economic losses (relating to growth depression or lack of growth) can be prevented. It is important to quickly detect errors within the production chain in order to make improvements possible that minimize financial losses.

Conclusion

The system used in this investigation presents a good method of identifying piglets simultaneously online at the trough of an automatic feeder. Housing and process-related factors which have an impact on the feeding frequency and feeding duration of weaned piglets will be able to be evaluated better in the future by using simultaneous individual animal identification at the automatic feeder. In the context of growing herd sizes, increased work load and management requirements, legal restraints and soaring data volumes, it is conceivable that this RFID system could be used in company-level internal process management as well as in management systems at the intercompany level. RFID systems are considered to be a key technology in precision livestock farming and will become increasingly important in the future.

References

Artmann, R. (1982): Elektronische Systeme zur Tiererkennung und deren Anwendung. [electronic systems for animal identification and its use]In: Landbauforschung Völkenrode, Programmierte Fütterung und Herdenüberwachung in der Milchviehhaltung, Sonderheft 62, 49-65, Braunschweig-Völkenrode; Germany.

Berckmans, D. (2004): Automatic on-line monitoring of animals by precision livestock farming. In: Animal production in Europe: The way forward in a changing world. International congress of the International Society for Animal Hygiene Saint-Malo, France, 27-30.

De Haer, L. C. M., and J. W. M. Merks. (1992): Patterns of daily food intake in growing pigs. Anim. Prod. 54:95–104.

Dittmann, L. (2006): Der angemessene Grad an Visibilität in Logistik-Netzwerken [The appropriate degree of visibility in logistical networks], Deutscher Universitäts-Verlag, Wiesbaden, 42–46, Germany

Eradus W.J., and M. B. Jansen (1999): Animal identification and monitoring. Comput Electron Agr 24:91–98

Fleisch, E., and F. Mattern (2005): Das Internet der Dinge [The internet of things] - Ubiquitous Computing und RFID in der Praxis, Verlag Springer, Berlin, Heidelberg, New York

Geers, R. Puers, B., Goedseels, V., Wouters, P. (1997): Electronic Identification. Monitoring and Tracking of Animals. CAB International. Wallingford.

Georgsson, L., and J. Svendsen (2002): Degree of competition at feeding differentially affects behaviour and performance of group-housed growing finishing pigs of different relative weights. J Anim Sci 80, 376-383.

Hessel, E.(2009): Zukunftsweisende Technologien in der Schweinemast. [Forward-looking technologies in fattening pig housing] In: Landwirtschaft im Umbruch – Herausforderungen und Lösungen; KTBL-Schrift 474, 224 – 231. KTBL-Vortragstagung from 18-19. 03.2009 in Goslar, Germany.

Hyun, Y., M. Ellis, F. K. McKeith, Wilson, E. R. (1997): Feed intake pattern of group-housed growing-finishing pigs monitored using a computerised feed intake recording system. J Anim Sci 75, 1443-1451.

ISO (1996a): ISO 11784. Radio frequency identification of animals - Code structure. International Organisation for Standardisation.

ISO (1996b): ISO 11785. Radio frequency identification of animals - Technical concept. International Organisation for Standardisation.

Kaiser, U., and Steinhagen, W. (1994): A low power transponder IC for high performance identification systems. Proceedings of the CICC, Custom Integrated Circuits Conference, San Diego, USA, 7-8

Kern, C. (2006): Anwendung von RFID-Systemen [Application of RFID systems], 1st edition, Berlin Heidelberg: Springer-Verlag

King, R. H., and J. R. Pluske (2003): Nutritional management of the pig in preparation of weaning. In: J. R. Pluske, J. Le Dividich and M. W. A. Verstegen (eds.): Weaning the pig – concepts and consequences. Wageningen Academic Publishers, Wageningen, The Netherlands, 37- 51.

Pluske, J. R., I. H. Williams, Aherne F. X. (1995): Nutrition of the neonatal pig. In: M. A. Varley (ed.): The neonatal pig - development and survival. CAB International, Wallingford, UK, 187-235.

Reiners, K., Hegger, A., Hessel, E., Böck, S., Wendl, G., Van den Weghe, H. (2009): Application of RFID technology using passive HF transponders for the individual identification of weaned piglets at the feed trough. Comput Electron Agr 68, 178-184.

Slader, R. W., and A. M. S. Gregory (1988): An automatic feeding and weighing system for ad libitum fed pigs. Comput Electron Agr 3, 157-170.

Weniger, J. H. (1974): Orientierung auf die Zukunft der Schweineproduktion [Orientation to the future in pig farming] Livest Prod Sci 1, 371 – 375.

Williams, I. H. (2003): Growth of the weaned pig. In: J. R. Pluske, J. Le Dividich, and M. W. A. Verstegen (eds.): Weaning the pig – concepts and consequences. Wageningen Academic Publishers, Wageningen, The Netherlands, 17-35.

Pre-parturition behaviour of sows measured by sensors

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Abstract

Piglet mortality reduction is realistic through the supervision of the farrowings. Such efforts are realistic only if the time of farrowing can be predicted well in advance. A prediction model for onset of farrowing is based on a Hidden Markov Model including major pre-parturition behavioural patterns of the sow. The observations are based on automatic measurements from different sensors, such as water consumption and video-activity, set up at each farrowing pen. The challenge was to extract the observations due to behavioural changes from those involving the diurnal rhythmic pattern. The present paper is focused on how to model the distribution of sensor observations conditioned on the latent behavioural states defined in the prediction model. The performance of the models was then checked by using them in the prediction model.

Keywords: Farrowing, Prediction, Phase-type Distribution, Hidden Markov Model

Introduction

The successful pig production enterprise rely to a large extent on intensive monitoring and management of the pigs to ensure the low mortality and hence the increased productivity. Piglet mortality is one of the major causes for the economic loss in pig production. Studies confirm that the reduction in the piglet mortality is possible through the motivated supervision of farrowings. However, this is only feasible if the farrowing time is known in advance so that the farmer can focus on the individuals which need special attention during the farrowing. Farrowing can be predicted to be 115days from the mating time with ≈ ±2 days. An improved farrowing prediction can be used for the better planning of the supervision and can be done so, by observing the pre-parturition behaviour and physiology of sows. Earlier studies suggest that the change in the sow behaviour is reflected in the change in the pattern of the automatically recorded sensor measurements. Erez and Hartsock (1990) described a system based on photo-cells to monitor peri-parturient activity of sows, and the experiment described by Bressers (1994) showed significant changes in the ear base temperature around farrowing. The technological possibilities for obtaining such sensor measurements have thus existed for a long time.

The optimal processing of these data has received less focus. However, recently several studies have focused on statistical methods for handling data from online measurements, e.g. to distinguish between behavioural patterns in the measurements. Different techniques have been used to extract these patterns, primarily different versions of the Kalman filter or

Dynamic Linear Models (West and Harrison). Madsen and Kristensen (2005) and Madsen *et al.* (2005) described a study where they looked at the models for monitoring the health condition of young pigs by their drinking behaviour using a Dynamic Linear models with a diurnal drinking pattern. In this study a CUSUM approach based on the V-mask was used for detecting changes in the drinking pattern. Cornou and Lundbye-Christensen (2008) developed an algorithm based on Multi-process Kalman filter to classify the sow activity from acceleration measures. In another study (Cornou *et al.* () electronic sow feeders were used to automatic detection of oestrus and health disorders for group housed sows.
Another approach is to base the modelling on the knowledge of physiological and behavioural state changes leading to the event that is monitored, for example farrowing. In this case the modelling is based on the changes in the pattern of the sensor measurements related to each of these states, as well as the expected duration of each state. This approach has recently been implemented in a comprehensive Danish Study. This paper is focused on how the sensor measures can be handled and modelled so as to capture various pre-parturition behaviour of the sow in order to furnish an input to the prediction algorithm of farrowing. Water- and video-activity measures from the Danish study are used as examples.

Materials and Methods

The development of the algorithm for farrowing prediction is based on a Danish study consisting of an experimental part with data collection and a methodological part, which is presented in the present paper, adapting statistical algorithms, estimating model parameters, and testing the validity of the algorithm and the results for the farrowing prediction.

Experimental data

The data used in this study was collected from late 2008 to early 2009 in the experimental farm at research center Foulum from 64 loose housed sows. Each farrowing pen measured 7.5 m^2 (2.9 x 2.6 m). The main part had solid concrete floor, and the dunging area slatted floor. The feeding trough with a drinking nipple was attached to the wall in the dunging area. The sows were introduced to the pen approximately seven days before expected farrowing. The sows were fed twice a day using automatic feeding systems. Management of the pen was restricted to a two hour period before the first feeding.

Each farrowing pen had a number of sensors installed, comprising temperature measurements, different means of monitoring activity and water-intake. The setup will be presented in detail in an accompanying paper. In addition, video-recordings of each pen were made from the time when the sow was introduced until after farrowing. The recordings where used as an automatic activity-sensor, but was also use for identifying behaviours and event times used for model fitting and validation. This visual analysis include identifying the start of farrowing (time of birth of first pig) as well as a time point when the sow was in the nest-building state.
In the present paper we will only use data from water-meter and the activity measures from the video recordings. The sensor information collected before 105^{th} day from mating were excluded from the study.

Water Consumption in sows: The sensor for water consumption measures the water consumed by the sow as the number of rotations of the water valve (approx. 2ml of water per rotation) for each 10 seconds interval. The water valve was placed within the drinking nipple in the food trough. The counts were summed up on every half an hour interval so as to give the total water consumption in that period. The logarithm of these counts at time '*t*' was denoted by Y_{wt}.

The Figure 1 illustrates the pattern for one sow. The water consumption pattern was highly time dependent. The sows consumed more water during feed intake and much less during the night. The figures also indicate a disruption of the pattern prior to farrowing. They consumed more water regardless of the time of the day prior to farrowing and the amount was very less as it approaches farrowing.

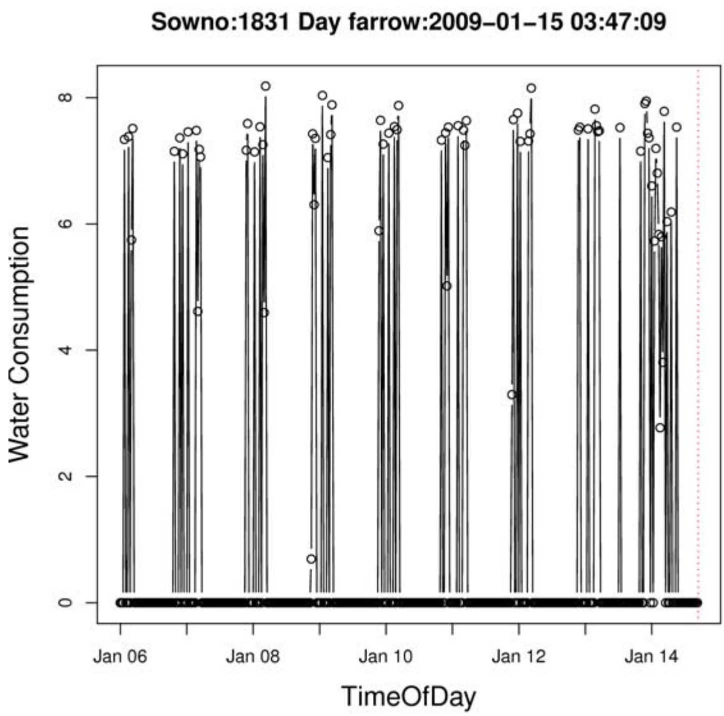
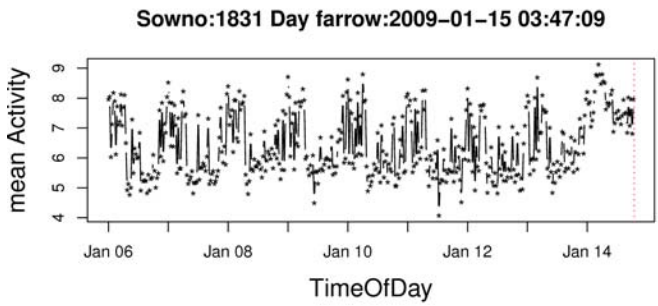


Figure 1. Example pattern of water consumption, for single sow, pooled over the discrete time points of half an hour. The dotted vertical line in the right indicates the actual time of farrowing

Activity of sows: Activity measures are based on video based observations at every minute. The activity measures from the the video recordings are the number of pixel changes from frame to frame. In this paper, two measures were defined to explain the sow activity. The meanActivity (*logarithm of meanActivity at time 't' is denoted by* Y_{Amt}), the activity averaged on every half an hour interval and sdActivity (*logarithm of sdActivity at time 't' is denoted by* Y_{Ast}), the standard deviation of the activity on every half an hour interval and they are illustrated in Figure 2. The meanActivity measures the mean change in the position of the sow in terms of pixels, whereas the sdActivity measures amount of variation in changing the position in half an hour. The sows were less active during the night as compared with their activities during the day. In addition to this, as shown in Figure 2, both meanActivity, sdActivity increased prior to and during parturition.



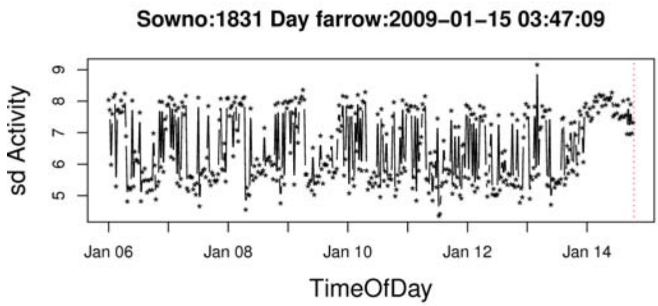


Figure 2. Example pattern of meanActivity and sdActivity, for single sow, over the discrete time points of half an hour. The dotted vertical line in the right indicates the actual time of farrowing

The water consumption data was collected from 45 sows and activity data from 64 sows. Among these, only 37 sows had both water and activity data in the period of 105th day from mating to farrowing. Thus 37 sows were used to estimate the parameters. Similarly, data from 39 and 43 sows, respectively, with water measurements and activity measurements were used to check how the models fit to the data in order to predict the farrowing.

Behavioural Background for the Modelling

The patterns seen in the sensor measurements in Figure 1 and Figure 2 are to a large degree caused by the sow's physiological state before farrowing. This section is a brief summary of the current understanding of the physiological and behavioural changes prior to farrowing, and how it is included in the model. The knowledge concerning these change is based both on study in semi-natural conditions and under production conditions.

The relevant period for the farrowing prediction in the production system is illustrated in Figure 3 and it starts, when the sow is mated. If she becomes pregnant she will farrow approximately 115 days later. Usually the sows will be transferred in to farrowing pen at day 100-110 after mating. The automatic monitoring of the sow starts this time.

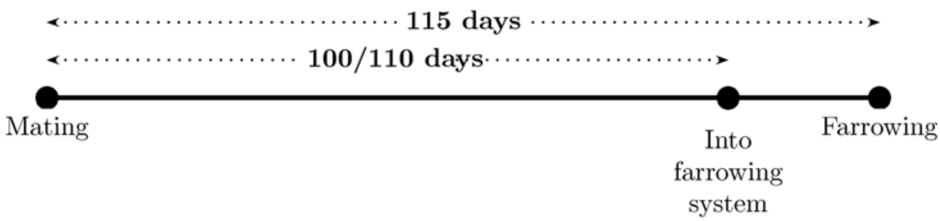


Figure 3. Time line for the gestation period of the sow (Not to scale)

From mating to 1-2 days prior to farrowing the sow will show more or less the same behavior, with a clear diurnal pattern, except for a temporary change in behaviour until the sow becomes familiar with the new surroundings in the farrowing pen. As the sow approaches the parturition, it shows the most noticeable changes in the behaviour. Between 15 to 19 hours prior to parturition, sows will be more restless and this restlessness will increase to agitation as the sow begins nest building. These behavioural changes could be due to the hormonal changes, in particular, the increase in oestrogen and decrease in progesterone leading to parturition and the sow becomes highly aroused and excited resulting high rates of activity (Baxter (1984)). Thus, the pre-parturition behaviour of a sow can be broadly classified into three states, *Before Nest Building (S_1), Nest Building (S_2), and Resting (S_3)*, as illustrated in Figure 4. The mean duration of each of these states varies from study to study, typically approximately 24 h for the nest building phase and 6 hours for the resting period and 114-116 days for the total duration of the gestation period. The variability in these durations is not well documented except for the total duration with a standard deviation of approximately 2 days and it is close to normal distribution.

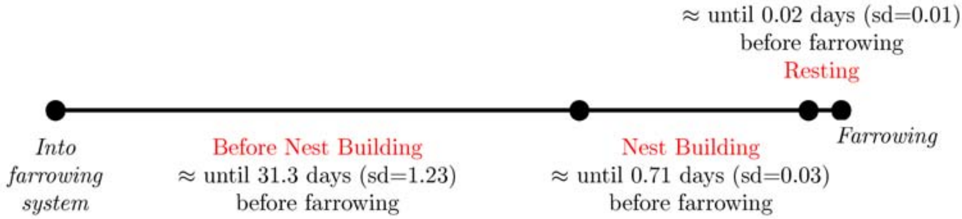


Figure 4. Pre-parturition behavioural states of the sow (Not to scale)

In the prediction model these pre-parturition *States* of the sow were defined and used in the propagation of the prediction algorithm. These *States* can be seen using both behavioural and physiological measures. The birth of first piglet defines the start of the *Farrowing* state. Thus, the *Resting* state could be the start of parturition process. The *Resting* state may be very short for some of the sows and hence not easily detectable from the observations, because resting behaviour will occur regularly throughout the gestation period. The *Nest Building* is characteristic because of the higher activity level due to the nest building. Also, the start and the duration of *Nest Building* state varies from sow to sow. Some studies suggest several states during nest building, that could distinguish physiological conditions of the sow during its nest-building behaviour. However, we restrict ourselves to only one. If we define the progress of the pre-parturition behaviour within each state of the sow in *phases,* which are small divisions within the state, we obtain the possibility to model both the mean and variance of the duration of each state. We assume that the sow passes through each of these phases in succession, and further through each states in succession. Technically the duration or sojourn time of each state is the sum of exponential distributed sojourn times of each phase and thus follows a Gamma Distribution.

This approach can be used to specify the Hidden Markov Models (Rabiner (1989; Dempster (1977) with Phase-Type Distribution (Cox (1955; Neuts (1975) to predict the farrowing (See Figure 5 and the details of the algorithm will be presented in a separate paper, which is being preparation).

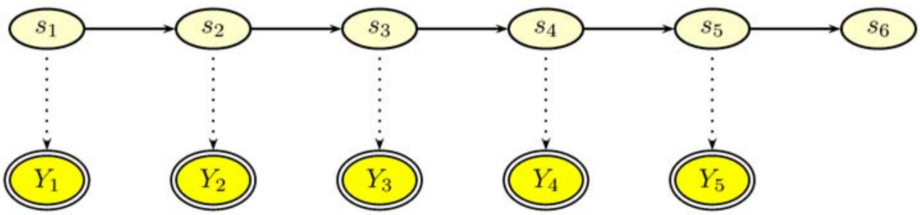


Figure 5. An analogue of the Hidden Markov process (HMM). The sequence $\{s_t\}$ denotes state progression with time t. *At time* t *the system stays in one of the three states, S_{it} i=1,2,3, which is unobservable. Y_t's can be observed due to being in the state S_{it}. Y_t could be any measure such as water consumption, activity, temperature etc at time* t.

The observation-vector Y from the sensors at each time point will depend on the state of the sow (s_t). We can model this conditional distribution of the sensor observations given the state

of the sow. Based on this distribution, we can revise the prior probability that the sow is in a given state at the time point to reflect the observations from the sensors.
Thus the distribution of the sensor observations conditioned on the phase/state allows us to distinguish the pre-parturition behaviour of the sow at each of the states and apart from the state we can include other factors in the modeling such as diurnal patterns.

Conditional Models of the Sensor Information

This section describes the model for estimating the conditional distribution of the three different sensor observations on phase as shown in Figure 5. The modelling tried to capture the characteristic patterns in the sensor observations as shown in Figure 1-2. These plots showed a characteristic diurnal pattern that seemed to change as farrowing approached. Initially, the diurnal rhythm was matched by discrete levels of time periods, but the final model strategy was based on the continuous variable of time **SOD** running over [0,24). The time variable was used in harmonic functions and different folding of these functions were tested to capture the pattern.

Distribution of Activity of the Sow: meanActivity and sdAtivity

The meanActivity and sdActivity observations were assumed to be independent and modelled independently. Let Y_{Am} and Y_{Asd} denote the meanActivity and sdActivity respectively as described in Sec.2.1. This information can be extracted by the linear models with four folded harmonic functions to capture the diurnal rhythm. In order to see the effect of states on sow's daily routine, interaction of states with the harmonic function was also included as a covariate. Thus

$$Y_{Amit} = \varphi_{Am} + \sum_{h=1}^{H} cs(h2\pi\omega)^{(Am)} + \gamma_i^{(Am)}S + (\sum_{h=1}^{H} cs(h2\pi\omega)_{\times} \times S)^{(Am)} \quad (1)$$

$$Y_{Asdit} = \varphi_{Asd} + \sum_{h=1}^{H} cs(h2\pi\omega)^{(Asd)} + \gamma_i^{(Asd)}S + (\sum_{h=1}^{H} cs(h2\pi\omega)_{\times} \times S)^{(Asd)} \quad (2)$$

where

$$cs(h2\pi\omega) = [\beta_{c_{ih}} \cos(h2\pi\omega) + \beta_{s_{ih}} \sin(h2\pi\omega)]$$

and

$$cs(h2\pi\omega)_{\times} = [\eta_{c_{ih}} \cos(h2\pi\omega) + \eta_{s_{ih}} \sin(h2\pi\omega)]$$

respectively; where ω = $\mathbf{SOD}_t/24$ and φs are the intercepts, β_c and β_s's are the regression coefficients of h^{th} harmonic functions (cosine and sine, respectively) at time t, η_c and η_s's are the corresponding coefficients for the interaction with the i^{th} state S with the variances

$$\hat{\sigma}^2{}_{Am} = \text{Residual variance of model} \tag{1}$$

$$\hat{\sigma}^2{}_{Am} = \text{Residual variance of model} \tag{2}$$

where $\hat{Y}$ is the estimates of Y, N is the total number of observations and i=1,2,3 over states.

Distribution of Water Consumption Data

The water consumption pattern was modeled by defining different levels of water consumption, called components. By assuming that the consumption pattern is different in different states, independent mixture models were fitted for the data from each state. The water consumption in each component was assumed to follow a distribution independent from the other component. The model was tested for different combination of number of components and harmonics. Finally, the observation from each state was modeled using mixture model technique with four-folded harmonic function as the concomitant model to capture the diurnal pattern. For each of the states, the number of clusters was chosen for the minimum *Bayesian Information Criteria* (BIC). The mean level of water consumption, μ_w, at time $\mathbf{SOD}_t \in [0,24)$ at the k=1,2,…,K^i level for state $S_i;\ i = 1,2$ was estimated by

$$\mu_{w_{ik\zeta}} = \varphi_{wik} + \beta_{ik}\boldsymbol{SOD}_t \tag{3}$$

with mixture probabilities $\pi_{ik\zeta}(\omega, \alpha_{ik}^c)$ where

$$logit\big(\pi_{ik}(\omega, \alpha_{ik}^c)\big) = \mu_{ik}^c + \textstyle\sum_{h=1}^{H}[\beta_{ikh}^c \cos(h2\pi\omega) + \gamma_{ikh}^c \sin(h2\pi\omega)] \times \boldsymbol{SOD}_t \tag{4}$$

such that

$$\sum_{k=1}^{K} \pi_{ik}(\omega, \alpha_{ik}^c) = 1 \ and \ \pi_{ik}(\omega, \alpha_{ik}^c) > 0 \ \forall \ k$$

where ω is the concomitant variable and $\alpha_{ik}^c = \{(\beta_{ikh}^c, \gamma_{ikh}^c); h = 1,2, \dots, H\}$; The superscript 'c' of the parameters are to denote the parameters of concomitant model. The mixture-model also gives estimates for the variances $\sigma_w^{(i)^2}$ for each component in a state. Since there were very few observations in *Resting* state, the mean level of water consumption was estimated by taking a simple mean of all the observations in that state.

Estimation and Validation of the Models

The estimation of the parameters of these models are the part of Hidden Phase-Type Markov model and were estimated iteratively using the modified EM algorithm. The algorithm has dissolved at 586th iteration. The parameters estimated were then used in the prediction algorithm. The prediction algorithm calculates the expected duration to farrowing for each sow at every half an hour when the values were updated with the most recent sensor observations. The purpose of the prediction is to send out warning signals that may e.g. activate heating equipment or alert the farmer for the special attention. In the present paper we will use a more heuristic approach. The warning strategy is defined to give a warning if the prediction algorithm finds that the expected time to farrowing is less than 12hrs. The results were analyzed by the plots of expected duration to farrow against the time for individual sow. Also, the average warning duration, with their standard deviation and mean duration of false-positive warnings (error) were calculated.

Computational Environment

The parameters of these models were estimated iteratively using the modified EM algorithm and validated through prediction algorithm by implementing in R Development Core Team (2010). The basic function `lm()` was used to fit the activity models (2.3.1), whereas the function `stepFlexmix()` of `flexmix2.2-8` package (Leisch (; Grün and Leisch (; Grün and Leisch (), was used for the mixture models (2.3.2) to classify the observations into different levels of consumption.

Results

Conditional Distribution of the Sensor Information on Phase and Time

Activity The plots of the estimated mean level (on logarithm scale) of meanActivity and sdActivity are as shown in Figure 6 and 7. The x-axes of the plots denote the 0-24 hours of a day. i.e. the plots show the variation of activity over the day. There is a clear indication that the activity (parameter φ in Eq. (1) and (2) was lower in *Before Nest Building* state (state-1) than in the other two states. In addition, the sows also showed a pronounced diurnal variation with clear peaks in the morning and afternoon in the first state.

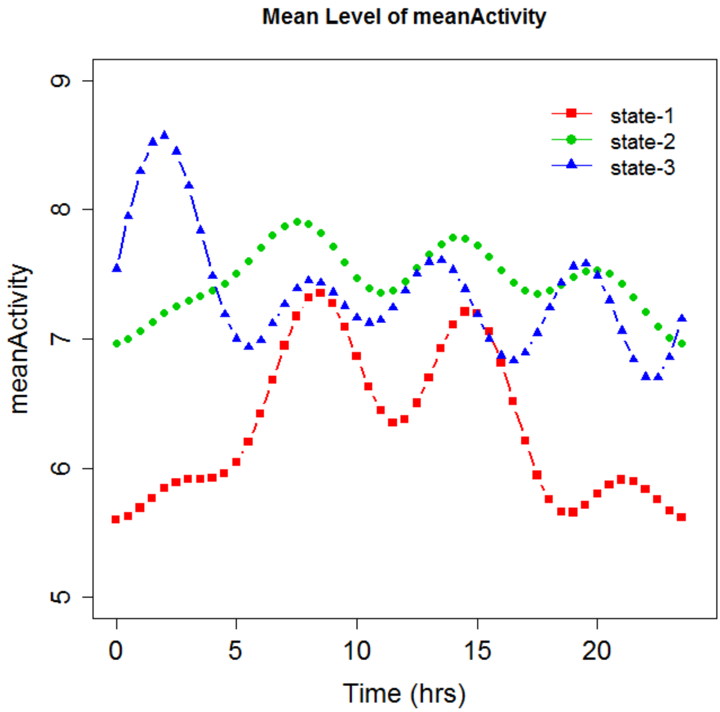


Figure 6. Mean level of meanActivity over a day in different states; state-1 (Before Nest Building) and state-2 (Nest Building) and staet-3 (Resting)

Water Mean level of water consumption was estimated with different clustering components for each state, but the model with the lowest BIC was with 3 components. These components can be seen as different types of drinking behaviour that the sow may select. The mean level for different components of *Before Nest Building* state was estimated to be [7.07, 2.09, 0] with the residual standard deviation $\sigma_w^{(S_1)} = [0.96, 1.14, 0.01]$. That is, the Component-1 corresponded to most drinking and Component-3 to no drinking activity. The corresponding mixing probabilities varied throughout the day and are shown in Figure 8 (The x-axis of the plot denotes the 0-24 hours of a day). Early morning and mid-night, the water consumption level was very low compared to that during the day time (Component-3). Also, the model captures the feeding times by showing large probability of drinking at around 8hrs and 15hrs of a day (the peaks for Component-1).

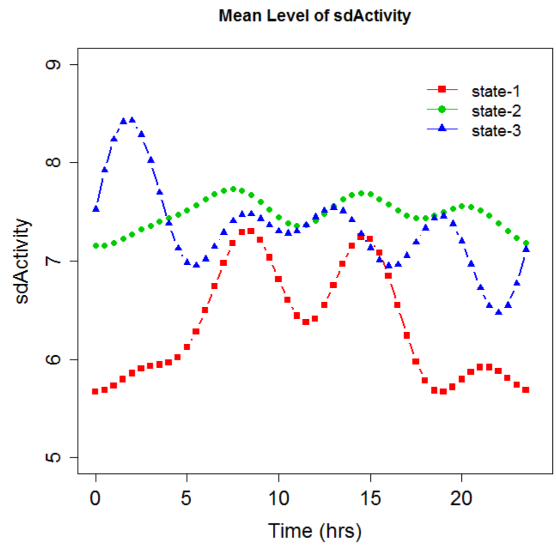


Figure 7. Mean level of sdActivity over a day in different states; state-1 (Before Nest Building) and state-2 (Nest Building) and staet-3 (Resting)

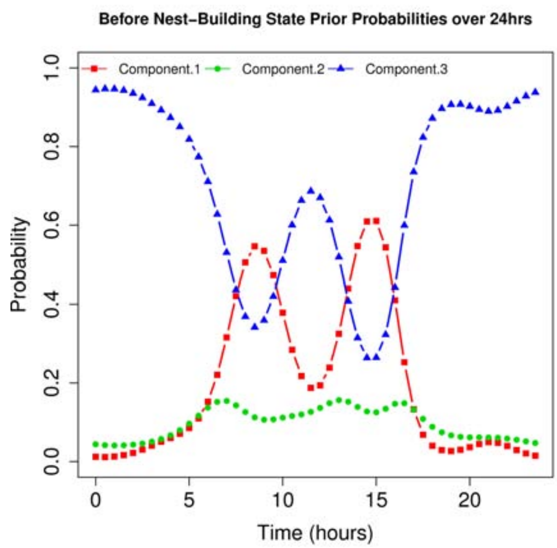


Figure 8. The mixture probabilities over a day for the components of Before Nest Building state. The consumption behaviour was classified into components: Components from 1 to 3 correspond to most-drinking to no-drinking activities. Further, P(Component-1) + P(Component-2) + P(Component-3) = 1, at a given time.

Apart from this lower and higher level of water consumption, the sow has also intended to consume some water during the night/day time with the very low probability as denoted by the dots for Component-2.

The estimates for mean level of water consumption over a day for *Nest Building* state were [7.14, 3.61, 0.001] with residual standard deviation $\sigma_w^{(S_2)} = [0.74, 2.0, 0.02]$. The plot of probabilities for the *Nest Building* state, *Figure 9*, clearly confirms the assumption of notable change in the water pattern in different states, though the mean level of water consumption was very close to that of *Before Nest Building*.

The plot shows more water activity even at the night time (after 20hrs to 4hrs)(Component-1). Since the *Resting* state has very short duration we consider only one component for the water consumption with mean level estimated to be 0.49 ($\sigma_w^{(S_3)} = 0.61$) (on logarithm scale).

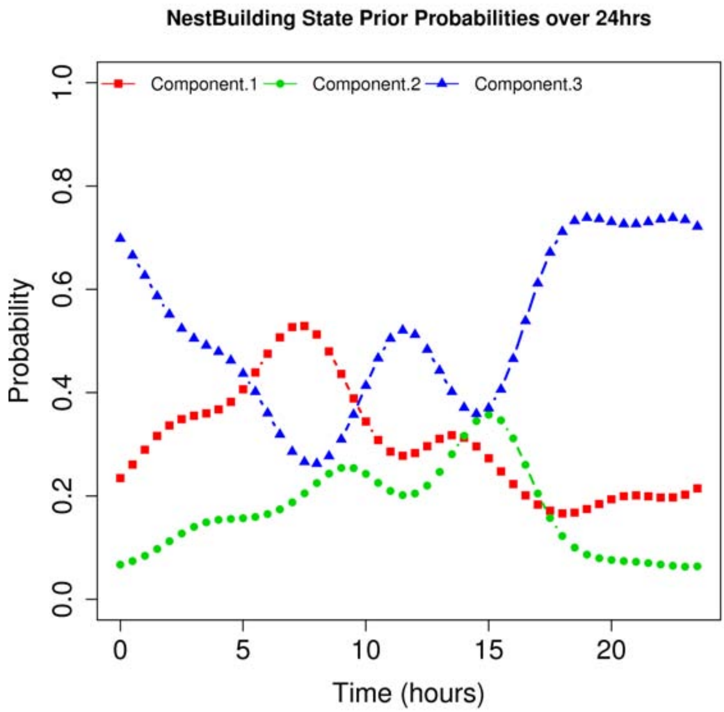


Figure 9. The mixture probabilities over a day for the components of Nest Building states. The consumption behaviour was classified into components: Components from 1 to 3 correspond to most-drinking to no-drinking activities. Further, P(Component-1) + P(Component-2) + P(Component-3) = 1, at a given time.

Validation of the Models

The prediction model analyzes the data over time since mating and uses sensor information from the day the sow is introduced into the farrowing system. We have chosen data from 3 sows showing different performance of the algorithm, Figure 10-12. The time-axis starts from the time of insertion, and the horizontal line is drawn to indicate the threshold for the warning strategy of 12 hours. The vertical line indicates the actual day of farrowing of that sow. Soon after insertion the expected duration to farrowing decreased more or less linear. The observations did not revise the probability distribution over phases, because the most likely state was the *Before Nest Building*. As time passed the Markov process implies that the other states become more likely, and the prediction began to change depending on the observations. A small drop on January 13th in Figure 10 was the clear indication of sow in nest building state. The plot showed a sudden drop in the expected duration when the sow was very close to farrowing and continued to decrease over time, indicating that the sow was approaching the farrowing state.

In Figure 11 around July 2, some of the observations lead to a marked drop in the time to farrowing. This prediction was revised later on. On July 5th, the observations clearly indicated a transition to the nest building state, and the expected time to farrowing dropped below 12 hours and a warning was raised as indicated by the cyan signature 8hrs before farrowing.

For the sow shown in Figure 12 though there was a true-warning according to the strategy, about 6hrs before farrowing, some of the observations lead to retract the warning. Hence there was no warning before farrowing, leading to a false-negative. The system will know the farrowing only after the farmer's visit to sow.

36 of the 38 sows gave satisfactory warnings with mean 11.2hrs (SD=4.2hrs). This includes a couple of sows where the algorithm gave one or two false warnings similar to the one shown in with the mean error of 0.7hours.

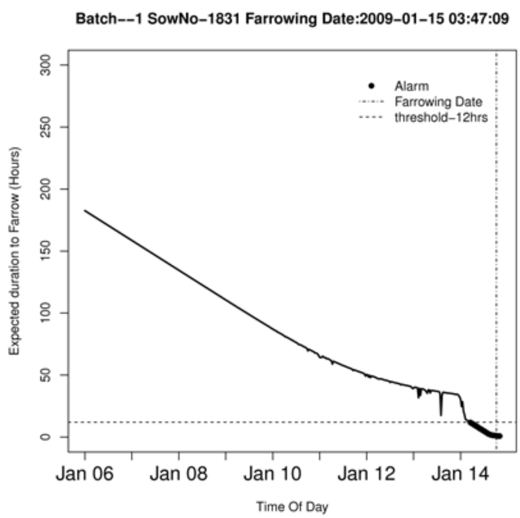


Figure 10. Plot of expected duration against time since farrowing system (refer Sec.3.2 for details)

The individual sensor information was also tested to see their performance. The Table 1 compares different combination of sensor information used in the prediction algorithm in accordance with the mean and SD of warning duration as well as the mean of false warning duration. Further, the algorithm using only water consumption information predicts only 24% of the true warnings, whereas the combination of water and video-activity information gives 95% of true-warnings. Though the video-activity gives maximum true-warnings, it results in larger standard deviation (14.2hours) of warning duration.

Table 1. Comparison of prediction algorithm for different combinations of sensors

	Warning Time (hours)		Mean duration of
	Mean	SD	False-Positive warning (hours)
Water and Video Activity	11.2	4.2	0.7
Water	11.7	2.2	3.1
Video Activity	14.0	14.2	0.4

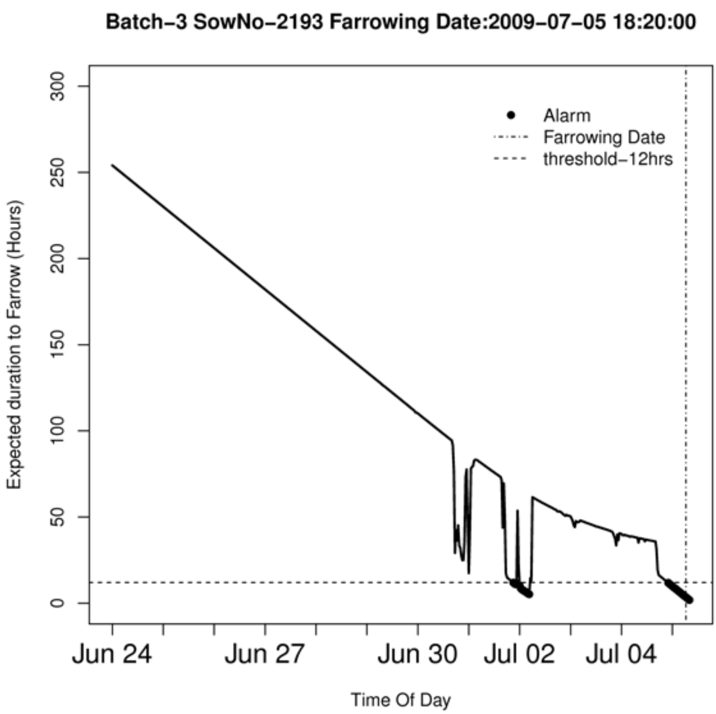


Figure 11. Plot of expected duration against time since farrowing system (refer Sec.3.2 for details)

Discussion and Conclusion

The biological knowledge of change in behavioural states of the sow in the farrowing pen gave a good modelling framework, for handling the different patterns in the sensor measures. One of the characteristics of the sensor measurements was a marked diurnal variation at least at the normal days. The harmonic components in the models were well used to describe this diurnal rhythm. The peaks in Figure 6-9 well distinguish this pattern. This has allowed a combination of the two time scales in the prediction model; the time of the day and the duration until farrowing as described in the Phase Type model.

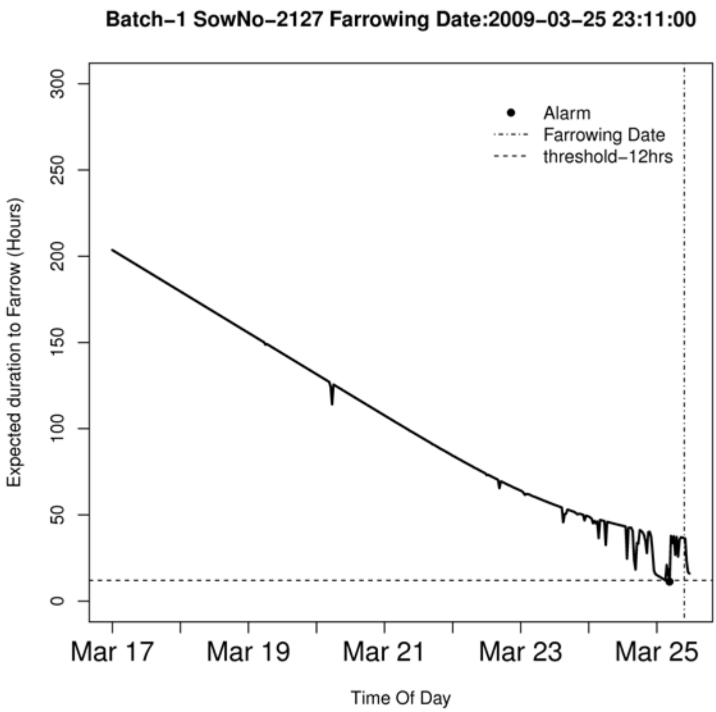


Figure 12. Plot of expected duration against time since farrowing system (refer Sec.3.2 for details)

The latent state/phase allows us to treat the different sensor measurements as independent given the state, and thus easily adapt the complexity of the modeling to each different sensor observations, as illustrated by the complex model for the water measurements. The simple linear model for video-activity sensor also measures the increased activity with changed state from *Before Nest-Building* to *Nest-Building*. On the other hand, different drinking behaviour patterns occurred with different probability throughout the day. To establish the level of water consumption at a given time and state it was thus necessary to use a more complicated mixture model. The diurnal variation of the estimated mixture probabilities in this more complicated model was actually what distinguished the water consumption during nighttime in the *Nest Building* state from the other states. Hence this model extension was necessary to give precise prediction of the farrowing.

Further, different combination of available sensor information can be used in the prediction algorithm. Although the individual performance of water or activity information can be utilized in the prediction model, the combination of these sensors is recommended.

It would be easy to extended the modeling further, e.g., to use phase number as a covariate to capture changes of the sow within the state, to use information of e.g. time of feeding, or to distinguish between the pattern of individual sows. Such extensions should be evaluated both for their improvement in prediction and the resulting increase in model complexity. Other issues could be to use a finer time interval for the observations than the half-hour interval. However, this may lead to a need to model the autocorrelation of the sensor observations, and thus an increase in model complexity.

The successful use of the present model for farrowing prediction indicates the model approach used here may be a promising strategy for future applications for use of sensor information in precision livestock agriculture.

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References

Baxter, S., 1984. Intensive pig production: environmental management and design. Granada Technical Books; London; UK.

Bressers, H., 1994. Monitoring individual sows in group - housing : possibilities for automation. Wageningen University, PhD Thesis, Wageningen University.

Cornou, C., Lundbye-Christensen, S., 2008. Classifying sows' activity types from acceleration patterns - an application of the multi-process Kalman filter. Applied Animal Behaviour Science 111 (3-4), 262–273.

Cornou, C., Vinther, J., Kristensen, A. R., 2008. Automatic detection of oestrus and health disorders using data from electronic sow feeders. Livestock Science 118 (3), 262–271.

Cox, D. R., 1955. A use of complex probabilities in the theory of stochastic processes. Mathematical Proceedings of the Cambridge Philosophical Society 51 (02), 313–319.

Dempster, A. P., Laird, N. M., Rubin, D. B., 1977. Maximum likelihood from incomplete data via the EM algorithm. Journal of the Royal Statistical Society 39, 1–38.

Erez, B., Hartsock, T., 1990. A microcomputer-photocell to monitor periparturient activity of sows and transfer data to remote location. Journal of Animal Science 68, 88–94.

Grün, B., Leisch, F., 2007. Fitting finite mixtures of generalized linear regressions in R. Computational Statistics & Data Analysis 51 (11), 5247–5252.

Grün, B., Leisch, F., 2008. FlexMix version 2: Finite mixtures with concomitant variables and varying and constant parameters. Journal of Statistical Software 28 (4), 1–35.

Leisch, F., 2004. FlexMix: A general framework for finite mixture models and latent class regression in R. Journal of Statistical Software 11 (8), 1–18.

Madsen, T. N., Andersen, S., Kristensen, A. R., 2005. Modelling the drinking patterns of young pigs using a state space model. Computers and Electronics in Agriculture 48 (1), 39–61.

Madsen, T. N., Kristensen, A. R., 2005. A model for monitoring the condition of young pigs by their drinking behaviour. Computers and Electronics in Agriculture 48 (2), 138–154.
Neuts, M. F., 1975. Probability distributions of phase type. In Liber Amicorum Professor Emeritus H. Florin, University of Louvain, Belgium, 173–206.
R Development Core Team, 2010. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0.
Rabiner, L. R., 1989. A tutorial on hidden markov-models and selected applications in speech recognition. Proceedings of the Ieee 77 (2), 257–286.
West, M., Harrison, J., 1997. Bayesian forecasting and dynamic models, 2nd Edition. Springer-Verlag, New York.

Section 7
Pigs

Evaluation of sensor recorded preference behaviour characteristics of pigs using log-transformation

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Abstract

The aim of this project was to evaluate the preference of fattening pigs concerning different floors in the resting area using sensor based identification. As a measure of preference the frequency of visit and duration of stay was used. The results of this study show high individual variations of these characteristics. The animals visited the resting areas to rest and to satisfy their need for exploration. Therefore we have to determine a critical time interval to distinguish between longer (rest) and shorter (exploration) visits. The logarithmic (ln) transformation of duration of stay results in two normal distributions. The cross of the two Gaussian curves marks the limit between longer and shorter durations of stay in the resting areas. The intersection of both distributions is defined as resting criterion. In this case the resting criterion is 36.6 minutes. On average, the resting areas were visited 11 times/pig/day, wherefrom only 4 visits/pig and day were connected to resting behaviour.

Keywords: fattening pigs, preference behaviour, resting behaviour, resting criterion

Introduction

Records of each resting event are the basis of preference behaviour analysis regarding flooring systems and other housing options. Duration of stay and frequency of visit are relevant metrics for evaluating animal-individual. It must be taken into account that the pigs manifest both characteristics to a different degree.
Studies about preference behaviour of pigs showed different duration of stay in the resting areas (Börgermann et. al., 2007). There are very active animals, who frequently visit the resting area. Other animals show lower visit frequencies and longer duration of stay. Generally resting events are separated by very short intervals. It is assumed that the pigs do not only visit the resting areas to rest, but also to satisfy their exploratory behaviour. Therefore a short duration of stay could be assigned to the exploratory behaviour while long visit duration is used for the satisfaction of the resting behaviour.
The definition of an exactly determined "**resting bout criterion"** should make possible to allocate the duration of stay for exploration as well as resting behaviour. The resting criterion was calculated based on methods established by Tolkamp *et al.* (1998) to determine the "meal criterion" by fitting a mixture of two normal distributions to the distributions of natural logarithm-transformed duration of stay.

Material and Methods

The investigations on preference behaviour were carried out in a facility that consists of two climate controlled resting areas (A and B) and a feeding area C (open space). The animals were given the alternative between different resting areas with different floors (Figure 1). The areas could be reached only by one passage gate and be left by a second one. In this experiment a slatted floor (area A) was compared with a partly slatted floor (area B). The totally slatted floor resting area was characterised by plastics fitted upon the floor with a slit width of 10 mm. In contrast, the partly slatted floor was only half perforated. The floor was divided on the longitudinal axis as follows: slatted floor at the front and solid floor at the rear side of the lying area. The feeding area C, was located in an open space outside the resting area and therefore had outdoor climatic conditions. The feeding area was provided with two automatic feeders and two drinkers which were equipped with animal identification facilities.

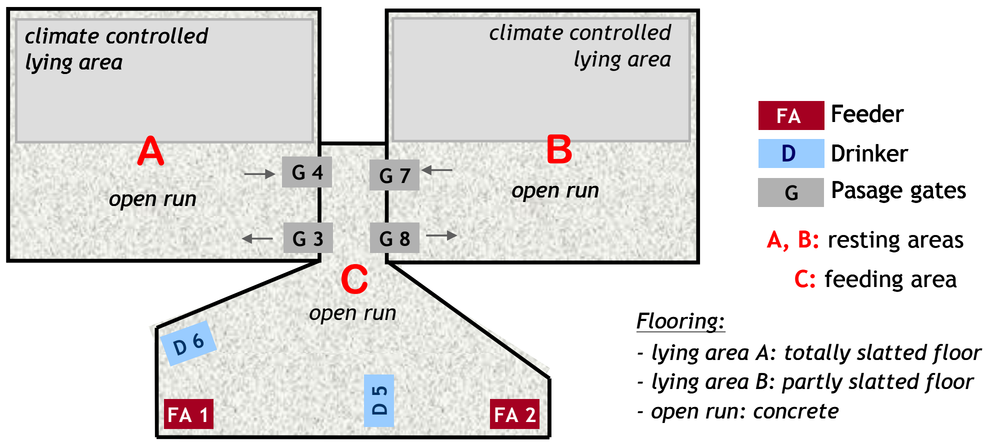

Figure 1. Experimental design

For this study, data from 21 fattening pigs were collected, with an initial body weight of 26.6 ± 3.7 (mean ± SD) kg. The fattening period was finished after 15 weeks when the pigs had an average weight of 110.8 ± 11.5 kg. Each identification of the pigs when entering or leaving the resting areas or when using the feeders and drinkers was transmitted to a PC by a data line and was stored. The individual electronic identification of the pigs was provided by ear tag responder. Moreover this electronic identification at first an inlet passage gate and then an outlet passage gate provided data to compute the visit duration in the resting area. Manual analysis of more than 6000 data sets per animal and experiment is not realistic, therefore a standardised and automated approach is needed.
shows the process of data preparation.

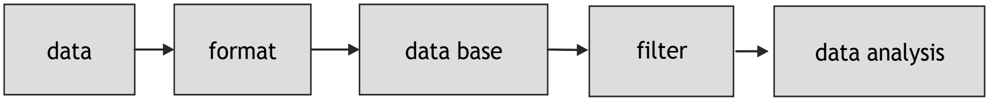

Figure 2. Data preparation

The recorded data were at first formatted and filtered for data mistakes and illogical successions. These can arise if animals are not forced to pass the passively working gates after entrance or if an animal passes a gate relatively slowly and is thus registered several times. Finally, the data were imported into an access data bank in which standardised complex evaluation structures were generated by linking with other criteria (e.g. living weight measured weekly). The statistical data-analysis was calculated using SPSS 18.0 for Windows.

Results

For the evaluation of the animal-individual preferences of resting areas the duration of stay and the frequency of visits were calculated. Table 1 summarises pig performance obtained during the whole fattening period. The analyses of the animal behaviour over the whole duration of the experiment showed that the animals visited the resting areas in average 11 times daily. The daily duration of stay was in average about 17 h/pig/d.

Table 1. Behavioural characteristics of all fattened pigs over the whole fattening period, before visits classification

	Average	S. D.	Minimum	Maximum
number of visits (n/pig/d)	11.1	7.7	1.0	47.0
duration of stay (min/pig/visit)	145.1	121.35	1.4	1343.5
daily duration of stay (h/pig/d)	16.7	5.6	0.0	23.7

The Figure 3 clearly shows the variability of individual pigs regarding the use of the resting areas. The results of the individual duration of stay range from 15.4 (pig 98) and 17.9 (pig 109) hours per day. The average frequency of daily visit ranged between 5.8 (pig 117) and 20.4 (pig109) visits per animal.

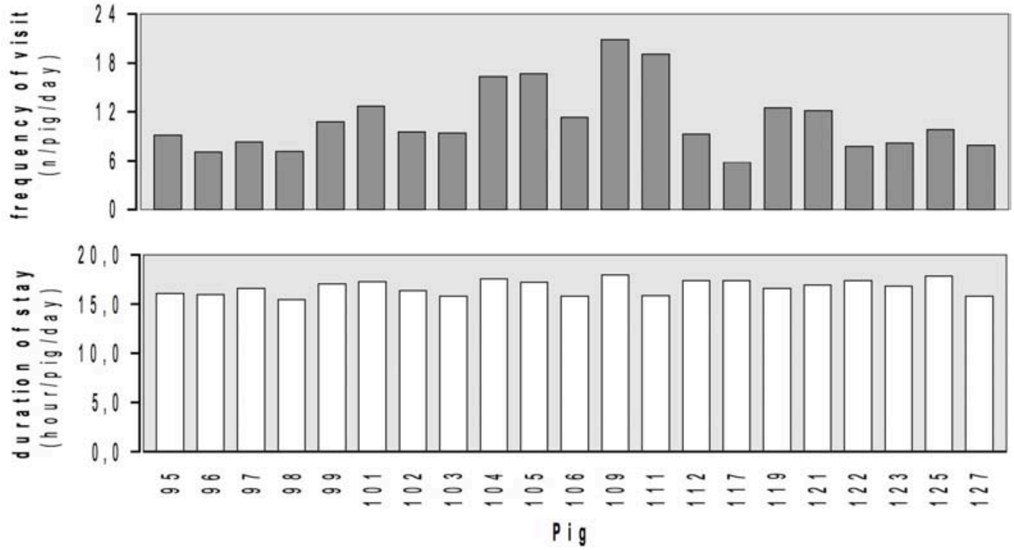

Figure 3. Average of duration of stay and number of visits in the resting area, per animal and day over the whole fattening period

The recorded average number of visits and of daily duration per animal show high individual variations of these characteristics. A possible explanation for the different results is that the pigs do not only visit the resting areas to rest, but also to satisfy their exploratory behaviour. To determine if a visit was part of the exploration or of the resting behaviour, a resting bout criterion was calculated Figure 4. The aim of this classification was to use only the resting period (the long visits in the resting area) for the evaluation of preference behaviour of pigs concerning different flooring.

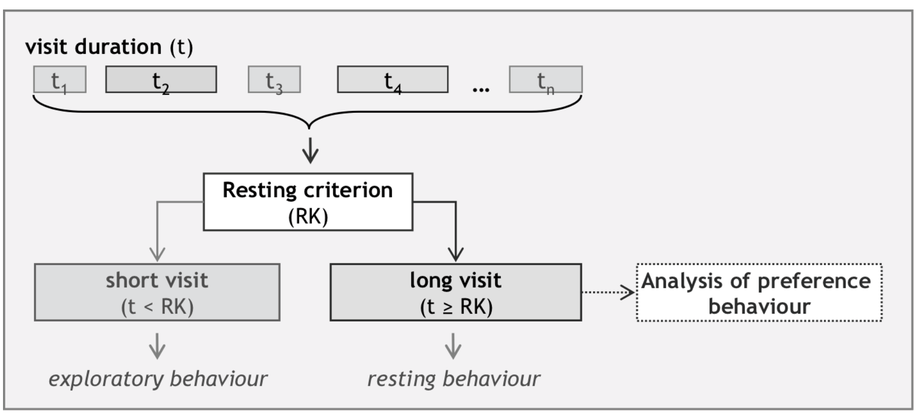

Figure 4. Data classification

For determining the “resting bout criterion” we used the method developed by Tolkamp *et al.* (1998, 1999) for determining the "meal criterion" by modelling the log-transformed frequency distribution of intervals between events. This method consists of obtaining maximum likelihood estimates of the parameters of a double log- normal model (Tolkamp *et al.,* 1998). Log-transformation of interval-length was also applied to pooled data (the individual pig visitation data were pooled) to estimate the resting criterion. Here we used a data set of 23 603 visit in the resting areas that was obtained during the whole fattening period of all 21 pigs.

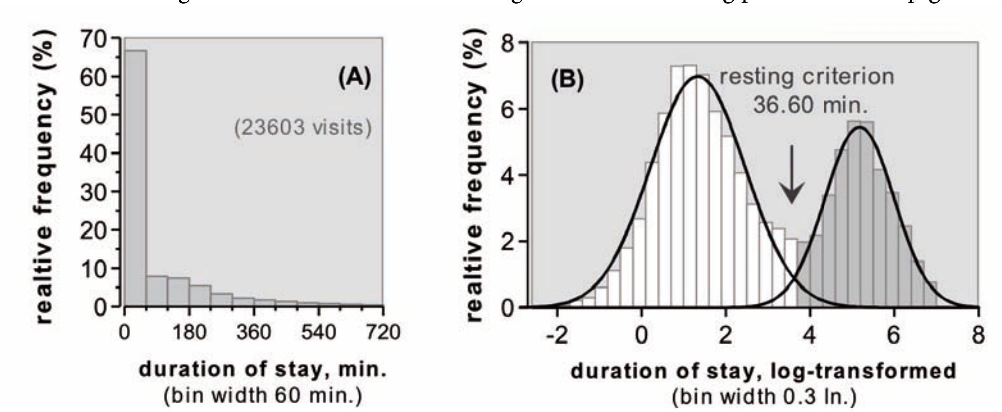

Figure 5. The relative frequency distributions of duration of stay in the resting areas, pooled data sets of all pigs (A) un-transformed; (B) log-transformed

Figure 5A shows the duration of all visits in both resting areas, as relative frequencies with a class-width of 60 minutes. Looking at the frequency distribution we can see that most visits (67%) did not exceed 60- min. The logarithmic (ln) transformation of all duration of stay results in two normal distributions for shorter (left distribution) and longer duration of stay (right distribution) in the resting areas. Maximum likelihood estimation was used to fit these mixture distributions. The cross of the two Gaussian curves marks the limit between longer and shorter visits Figure 5B. The resting criterion was determined as the point at which the distribution curve of short visits and the distribution curve of long visits intersect. In this case, the resting criterion from pooled data (for all pigs and over the fattening period) was 36.6 minutes. Based on this resting criterion, the visits were clustered into visits for exploring and visits for resting. Then, resting frequency, exploring frequency, resting duration and exploring duration were calculated. The resting frequency was calculated by counting the number of long visits per day and per pig that exceeded the length of the resting criterion. Daily rest duration (h/d/pig) was simply the sum of all resting durations in a day. The same method has been used to determine the characteristics of exploratory behaviour.

The differentiated analysis of visit frequency showed that on average, 7 visits/day/pig are assigned to the exploration behaviour and only 4 visits/day/pig were used for the satisfaction of the resting behaviour. Furthermore we found an average resting duration of 16 h/d/pig and less than 1 h/pig daily exploration (Table 2).

Table 2. Behavioural characteristics of resting and exploration behaviour of all fattened pigs over the whole fattening period

	Average	S.D.	Minimum	Maximum
number of visits for exploration (n/pig/d)	7.0	7.4	1	42
number of visits for resting (n/pig/d)	4.1	1.4	1	10
daily exploration duration (h/pig/d)	0.8	0.7	0.01	4.1
daily resting duration (h/pig/d)	15.9	5.8	0.6	23.5

After clustering the visits based on the estimated resting criterion the characteristics of resting behaviour showed less individual variation (Figure 6).

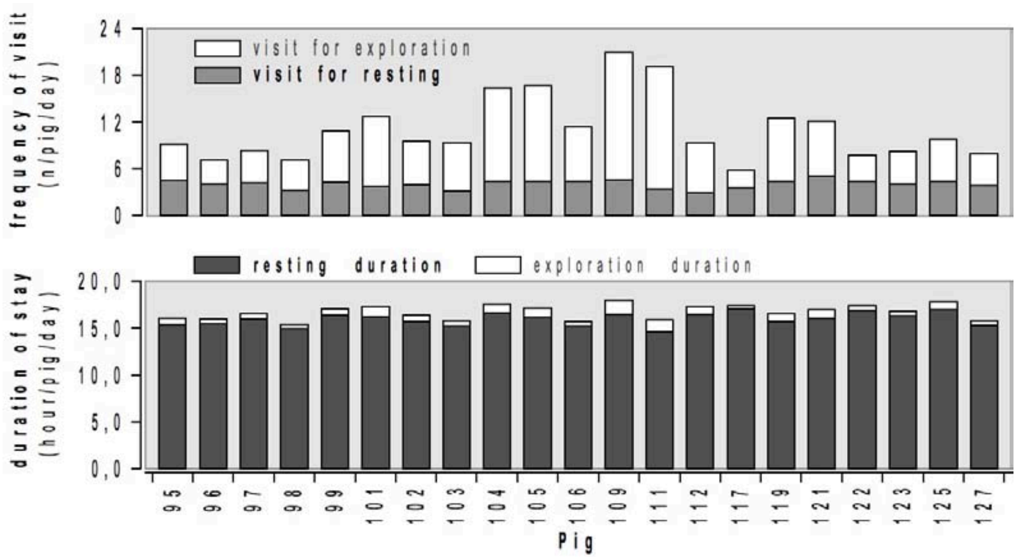

Figure 6. Average of duration of stay and number of visits in the resting area, per animal and day over the whole fattening period after visit classification

The number of visits for exploration varies from 2.2 visits (pig 117) to 16.3 visits/day (pig 109). In contrast, the individual differences of the resting frequency are much smaller (pig 112:3 visits and pig 121:5 visits/day). The resting duration ranges from 14.6 h (pig 111) to 16.9 h/day (pig 122) and the daily duration of exploration varies between 0.3 h (pig 117) and 1.5 h (pig 109).

Figure 6 demonstrates that the identification of a biologically relevant resting criterion is necessary to evaluate visits in the resting areas. Based on this procedure, we found high coefficients of correlations between parameters of preference behaviour after clustering the visits based on the estimated resting criterion. The correlations between the visit frequency and the duration of stay for all pigs after and before visits classification are shown in Figure 7.

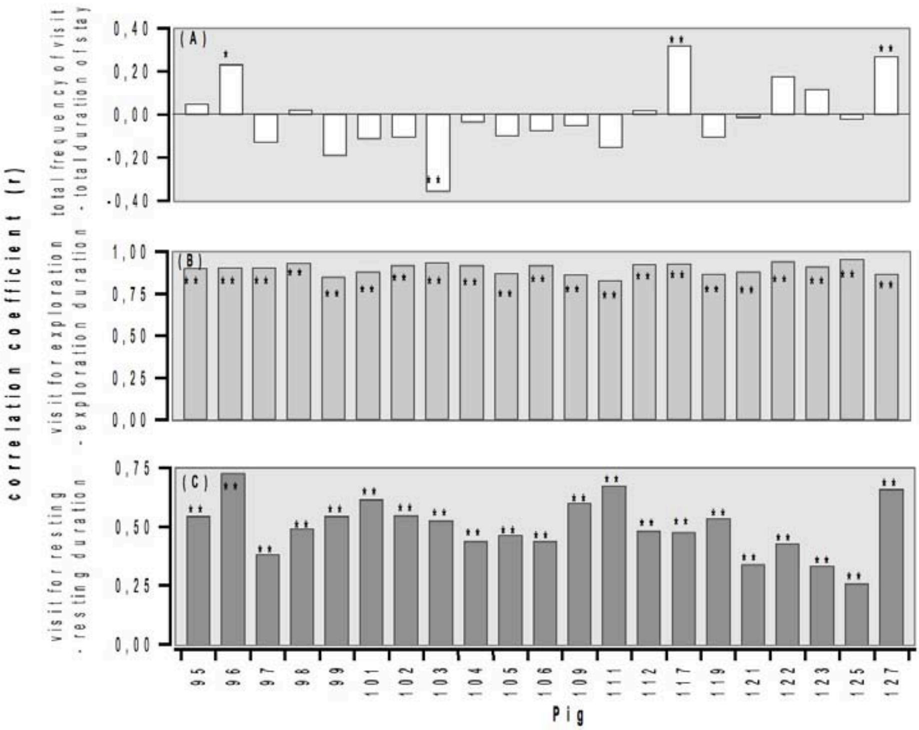

Figure 7. The correlations between the visit frequency and duration of stay for all pigs before (A: all visits) and after visits classification (B: only short visits and C: only long visits)

The next figure shows a comparison between frequencies of visits before and after data classification for both rest areas.
Figure shows the analysis of individual preference to the resting areas A and B during the fourth week of fattening.

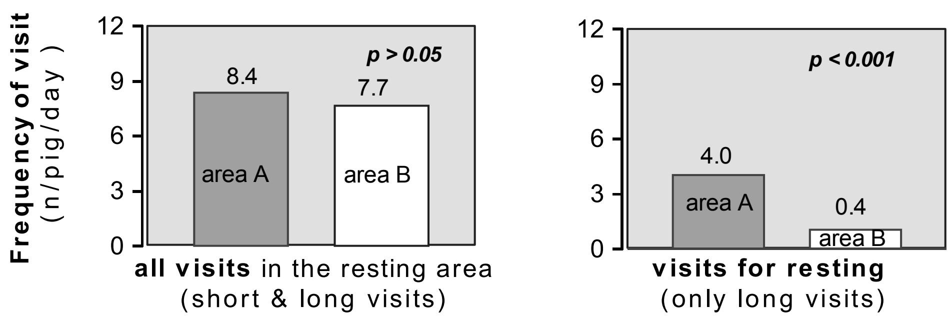

Figure 8. Average of number of visit in the resting areas A and B (before and after data classification) per animal and per day over the 4th fattening week (Wilkoxon Test)

When we analyze the frequency of visit before data classification (all visit in the resting area), no preference could be identified. In contrast the comparison between long visits (visits for resting) shows a clear preference for the lying area A.

Conclusion

In this paper we proposed a new method for evaluation of preference behaviour, using a large data set of records of animal behaviour obtained during 102 days in an experiment with 21 pigs. The basic approach assumes that the preference can be calculated as a function of time via the frequency of visits and duration of stay in accessible resting areas.

The results of this study show high individual variations of these characteristics. This raises the question of the relevance of these two characteristics in the description of the true preference. It is expected that only the long duration of stays characterize the preferred flooring system. For that reason, a method should be developed to classify this kind of visit. The aim of this classification was to use only the resting period (the long visits in the resting area) for further evaluations.

The application of this method showed that the log-transformed duration of stay in resting areas are distributed as two Gaussians. The bimodal distribution suggests that there are two classes of visits with different interval length. The first distribution shows the short time intervals (visit to exploration) and the second one represents the long time intervals (visit to resting). The intersection of both distributions is defined as resting criterion. In this case the resting criterion is 36.6 minutes.

Based on this resting criterion, we found that the characteristics of resting behaviour (resting duration and resting frequency) provide a better basis for the evaluation of preference behaviour. In the context of these investigations, the presented evaluation method is a useful tool to compare differently designed resting areas.

References

Börgermann, B., Rus, M. A., Kaufmann, O. 2007. Modelling of the preference behaviour of fattened pigs compared with different flooring systems. 8. Internationale Tagung Bau, Technik und Umwelt in der landwirtschaftlichen Nutztierhaltung, Bonn. S. 246-251.

Rus, M. A. 2010. Entwicklung einer Methode zur Bewertung des Präferenzverhaltens von Mastschweinen am Beispiel der Fußbodengestaltung (Development of an evaluation method of preference behaviour of fattening pigs concerning different floors); Dissertation, Humboldt-Universität zu Berlin.

Tolkamp, B.J., Allcroft, D.J., Austin, E.J, Nielsen B.L, Kyriazakis I. 1998. Satiety Splits Feeding Behaviour into Bouts. Journal of Theoretical Biology **194** (2). 235-250.

Tolkamp, B.J. und Kyriazakis, I. 1999. To split behaviour into bouts, log-transform the intervals. Animal Behaviour **57** (4). 807-817.

The Precision Livestock Farming (PLF): an innovative methodology for measuring the interest of piglets on environmental enrichments.

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Abstract

The scope of this study was to evaluate the preference and the time of interest of weaned pigs to two different types of the environmental enrichments. For this experiment the 28 piglets in two pens were monitored by a camera.
The enrichment materials were introduced to each pen for 3 days. All images were visually checked and labelled. The number and duration of interaction episodes with two environmental enrichments were determined. The video recordings of animals activity was measured using the Eyenamic software.
The study carried out allowed to explore the interest and preference of piglets to two environmental enrichments.

Keywords: piglets, environmental enrichments, PLF, camera images.

Introduction

Despite many years of genetic selection, natural behaviours as foraging, playing and exploration rest key motivational systems for pigs (Wood-Gush & Vestergaard, 1991, Van de Weerd & Day, 2009). Conditions on modern intensive farms are often considered as compromising with natural behaviours of pigs, which is shown by many authors as one of the the reasons of negative social behaviours, such as abnormal behaviours, e.g. tail and ear biting (Meunier-Salaun *et al.*, 1987, Fraser *et al.*, 1991, Van de Weerd *et al.*, 2006) and agression towards the penmates (Spicer & Aherne, 1987, Beattie *et al.*, 1996).
It is generally accepted that environmental enrichments, facilitating natural motivated behaviours of growing pigs, improve their welfare (Wood-Gush & Beilharz, 1983; Arey, 1993, Beattie, 2000). A number of positive effects of different environmental enrichments was shown in many scientific studies, among them are reduction of aggressive behavior (Grandin, 1989, Schaefer *et al.*,1990, Beattie *et al.*, 1996), reduction of belly nosing (Beattie *et al.*,1996, Rodarte *et al.*, 2004, Bench & Gonyou, 2006) and tail biting (Bøe, 1993, Petersen *et al.*, 1995, Zonderland *et al.*, 2008), production performance (Beattie *et al.*, 1996) and ease of handling (Day *et al.*, 2002). This positive results of environmental enrichments are considered as secondary welfare-relevant consequences. In barren conditions, risk of harmful social behaviours is high, as pigs tend to redirect their motivated behaviour towards inappropriate stimuli, as pen-mates (e.g. Fraser *et al.*, 1991, Peterson *et al.*, 1995, Beattie *et al.*, 2000, Kelly *et al.*, 2000). The result of different scientific studies have shown that the presence of environmental enrichments increased the time exploring them (Averos *et al.*, 2010), and

therefore decrease harmful social behaviours (Appleby and Wood-Gush, 1988, Blackshaw *et al.*, 1997, Van Weerd & Day, 2009).

In order to enhance animal welfare on farms in addition to minimum standards for protection of pigs the EC Directive (2001/93/EC) stipulates that: *"Pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals."* This general characterization leaves a room for continuous debates among scientists regarding environmental enrichments which could be effectively used on farm level. In some cases particulate substrates, suggested by the Directive 2001/93/EC and shown by many scientific studies (e.g. Fraser *et al.*, 1991, Van de Weerd *et al.*, 2003) as effective environmental enrichments couldn't be practically used, for example, in standard pens with partly or fully slatted floors, where the large amounts of substrate can block the liquid-slurry disposal systems. The existing challenge is that the effective environmental enrichment provided to the pigs should be not only enabling the expression of relevant natural behaviours and continuously keep their interest, but also be practical for the existing farming systems and cost-effective for the farmers. At present, the use of point-source enrichment objects, as an alternative to substrates is widespread on farms. Point-source objects are often referred to as 'toys' and generally limited in size, their use is often restricted to a single location in a pen (Van de Weerd & Day, 2009). Despite many scientific studies on effect of different types of point-source objects on the pigs, it is still not clear, which of them is more effective and if this type of environmental enrichments in general is sufficient to keep attention of pigs and to enable proper investigation and manipulating activities.

A number of studies on point-source objects shows that their material characteristics play crucial role in sustained interest and intensity of pigs' interactions with the object introduced to the pen. The most of the studied objects preferred by weaned and growing pigs could be characterized as 'chewable', 'deformable' and 'destructible' (Grandin, 1989, Feddes & Fraser, 1994, Van de Weerd *et al.*, 2003), which is probably linked to the foraging and exploration behaviours. Also, it was noticed by some authors that the combination of the enrichments with different characteristics is more interesting for pigs (Zonderland *et al.*, 2001, Van de Weerd *et al.*, 2003).

The important characteristics of the successful enrichment provided is also it's ability to keep continuous interest of the animals, otherwise the risk of redirected behaviour towards proper pen-mates is gradually increasing (e.g. Wood-Gush and Vestergaard, 1991; Fraser *et al.*, 1991, Bolhuis *et al.*, 2005). Therefore, it is important to control not only initial interest, but also the period of habituation to the novel enrichment. Studies on point-source objects show that habituation to certain of them can occur just a few days after introduction (Van de Weerd *et al.*, 2003, 2009), demonstrating that the duration of exploratory/playing behaviours decreases as pigs become more familiar with a novel enrichment.

The aim of the present study was to evaluate preference and interest of weaning pigs to environmental enrichments introduced to the pens, using Precision Livestock Farming (PLF) approach.

One of the objectives of Precision Livestock Farming (PLF) in the field of monitoring is to develop on-line tools for monitoring farm animals continuously during their life, in a fully automatic way. The objective is to measure criteria calculated on-line from collected data and without imposing additional stress to the animals. The aim of these technical tools is not to replace but to support the farmer who always remains the crucial factor in good animal management. Besides on-line automatic monitoring, PLF offers also interesting possibilities in automatic control for supporting the management of such complex biological production processes as feeding strategies, growth rate control, and activity control.

Materials and methods

Housing conditions and animals

The study was conducted in a swine weaning room located in Pianura Padana, Pavia province, Italy. The barn 760 cm long was containing six fully-slatted pens (190 cm x 250 cm) located in two rows of three on either side of an access area 80 cm wide (Fig.1).

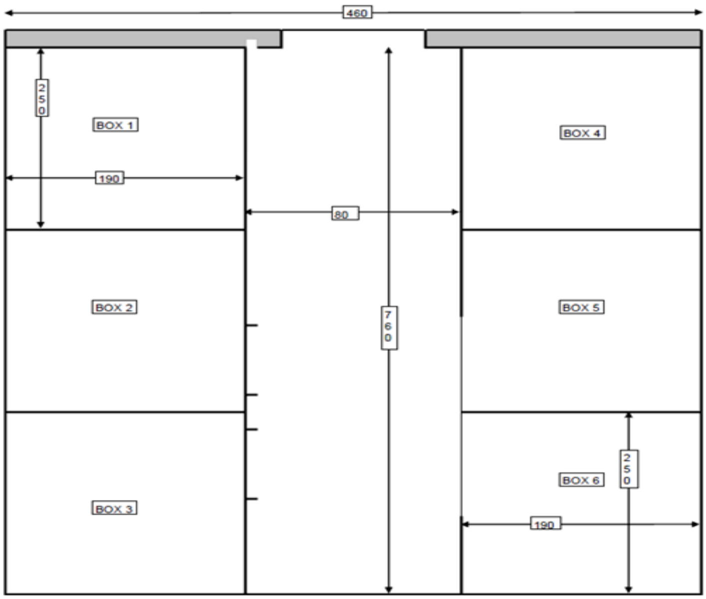

Figure 1. Top view of the weaning room

The study was conducted on 28 Dalland breed piglets during the weaning phase. The uniform groups of 14 growing piglets (50% male and 50% female) 55 days years old, weighing approximately 15 kg, were placed in two adjacent pens (pen A and B). The animals had *ad libitum* access to a commercial weaning pigs diet in pen A and diet, enriched with vitamins (A, D3, E) and amino acids (methionine, threonine, lysine) in pen B from a feed trough. Water was available ad libitum from drinking nipple. Lighting in the building was regulated by time, excepting the light, facilitating video registrations in experimental pens, switched on during 24 hours. There was no additional environmental enrichment in the pen before the experiments started.

Image recordings

Current study was based on video records from an infrared-sensitive CCD camera (VCB 35721RP, Sanyo Electric Co.LTD., Osaka, Japan). To get a top view of both pens, camera was mounted to the roof, 325 cm above the floor of the pen, with it’s lens pointing directly above the corridor separating the two pens. Camera was connected to PC with built-in frame grabber using the coax connection cable. Images were captured with a resolution of 768 x 586 pixels at a sample rate of 1 Hz, i.e. one frame per second.

<u>Behaviour monitoring</u>

The enrichment experiment was carried out during three days, twenty six days after the start of video recording (29 days total time of video recordings). On day 1 of experiment the enrichments, consisting of three woods and one chain were introduced to the pens A and B at 10:00 AM. The chain was fixed in horizontal position at piglet eye level in the angle of the pens, while the wooden blocks were placed randomly in the pens' floor .

During all video recording period, the Eyenamic software was running in real-time and video images from the camera were recorded simultaneously. The principle behind the Eyenamic algorithm (Bloemen *et al.*, 1997, Leroy *et al.*, 2006) was to develop a system that can robustly quantify activities of animals in practical field conditions, e.g. a pig pen.

The Figure 2 reports a picture of the experimental unit setup with the two pens.

Figure 2. The two pens (A and B) and the two observation zones, one per each pen

Each pen corresponded to a rectangular region in the image, within which activity was measured by Eyenamic algorithm and exploration/playing behaviour was labelled (Fig.2).

Every second the software automatically grabbed a monochrome image I*(x, y, t)* from the camera and calculated the difference of the intensity values with the previous image I*(x, y, t-1)*, taken a second earlier. From this difference image, the binary 'activity image' $I_a(x, y, t)$ was calculated, containing the pixels for which the intensity change exceeded a threshold:

$$\mathbf{I}_a(x,y,t) = \begin{cases} 1 & \text{if } \mathbf{I}(x,y,t) - \mathbf{I}(x,y,t-1) \quad \tau_1 \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

From the activity image $I_a(x, y, t)$ the activity index $a_i(t)$ for pen (Z_i) was calculated as the fraction of moving pixels with respect to the total number of pixels within the pen $\underline{Z_i}$:

$$a_i(t) = \frac{\sum_{(x,y)\in Z_i} \mathbf{I}_a(x,y,t)}{\sum_{(x,y)\in Z_i} 1} \tag{2}$$

The threshold τ_1 accounted for small intensity changes due to noise, e.g. electrical noise in the coax cabling and image acquisition circuits, small lighting variations, etc. The value of the threshold was set to 10% of the maximal intensity value, estimated by looking at the intensity variation of an ‘empty’ region, outside of the pig pen in the first 60 images, equivalent to one minute of recording.
An additional upper threshold τ_2 was applied to the activity index $a_i(t)$ to compensate for drastic intensity changes (e.g. when lights were switched on/off). In case of such an event, almost all pixels in the activity image I_a were ‘active’ and the activity index $a_i(t)$ was almost equal to 1 in the two pens. The threshold τ_2 was set to 0.5 of the maximal activity index. If this threshold was exceeded, i.e. more than half of the pen was active, the activity index was set to zero.
The pixel area sums in the nominator and denominator of equation (2) have an accuracy of one pixel which, using the camera calibration factor, was equivalent to an area of 2.9 cm^2.

Labelling procedure

After downloading recorded data in laboratory, the image files were visually checked and manually labelled, observing each frame (one frame per second) in order to detect pigs exploration/playing behaviour during 2 days (24 hours a day), observing the Day 1 and the Day 3 of the experiment. Labelling of video images was performed separately for each pen.
The aim of the continuous recording, was to create an exact record on the true duration of exploratory/playing behaviour, frequency and the time at which interaction episodes with each type of environmental enrichment started and stopped. For exploratory/playing behaviour patterns scores were assigned as follows:

- ’0’ no activity,
- ‘1’ interacting with chain,
- ‘2’ interacting with wooden block

Interaction episode was measured as (i) the length of time (sec) from first touch of environmental enrichment by pig or group of pigs to termination of action.

Statistical analysis

The variance analysis (Proc GLM, SAS 9.2, 2008) was performed on duration of exploration/playing episodes with two types of environmental enrichments, coming from the labelling procedure, to study the effect of the day, time of the day, and environmental enrichments on exploration/playing behaviour of piglets.
Frequency analysis (Proc FREQ, SAS 9.2, 2008) was performed to determine the number of playing episodes with two types of environmental enrichments (chain and wooden block), according to Lyons *et al*., 1995.

Results

No significant (P>0.19) difference in duration of interaction episodes with both environmental enrichments between the pens A and B was identified; therefore, in this case, both pens were taken as one experimental unit.

The mean duration time of interaction episodes (and S.E.M) with environmental enrichments is shown in Tab.1.

Table 1. Least Square Means of interaction episodes duration (sec) with two types of environmental enrichments in weaned piglets.

Enrichment type	LSMean ± SEM	P
Chain (1)	51.48±6.55	< 0.0001
Wooden blocks (2)	36.15±4.93	< 0.0001

The mean duration of interaction episodes was significantly (P < 0.0001) greater for the chain than for the wooden block (Tab. 1).
However, it was also determined, that the frequency of interaction episodes was 28.8 % higher for wooden blocks than for chain (Tab. 2).

Table 2. Mean interaction episodes frequencies in weaned piglets with different types of environmental enrichments (chain and wooden blocks). Data is expressed as mean frequency and percentage per type of environmental enrichment per whole labelling period.

Type of enrichment	Mean interaction frequency	Percentage %
Chain (1)	745	35.59
Wooden blocks (2)	1348	64.41

Analysis of the 24-h environmental enrichments use pattern from video records showed that mean duration of interaction episodes with chain as well as with wooden blocks decreased for Day 3 of experiment in both pens (Fig.3).

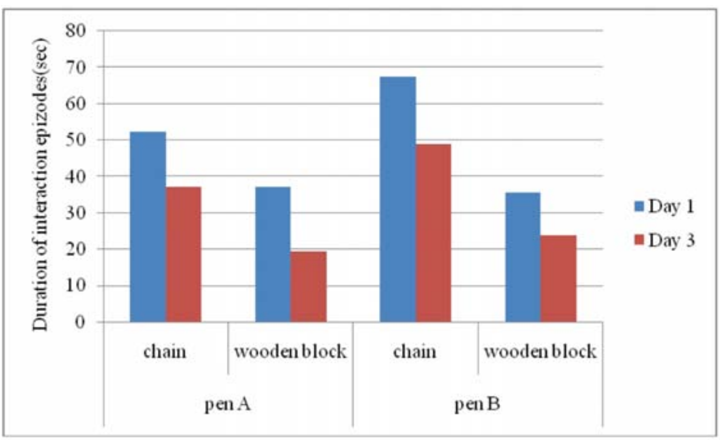

Figure 3. Effect of experimental day on duration of the playing episodes

Table 3 shows that the piglets from pen B were interacting with environmental enrichments 14.5 % more frequently than the piglets from pen A. They also tended to be more active, having greater mean activity index, which was calculated per 29 days of video recordings (Tab.3).

Table 3. Mean interaction episodes frequencies with environmental enrichments during the whole labelling period and mean activity index for 29 days of video recordings of weaned piglets in two pens (pen A and B).

Pen	Mean interaction	Percentage %	Activity Index Mean±SD
A	895	42.76	0.010±0.016
B	1198	57.24	0.015±0.019

The mean frequencies of interaction episodes for Day 1 and 3 were merged and compared with mean activity indexes, calculated for 29 days of video recording. There was found an effect of day time on interaction episodes (Fig.4). There was a drastic decline of interaction episodes frequency from 02:00 AM. to 07:00 AM, which is expected as the lights were turned off during the night. Activity indexes during this hours showed the lowest values (with a range from 0.005 to 0.008 units), since the animals were resting. The peaks of activity in pens were coinciding with the hours with most frequent interactions of piglets with both types of environmental enrichments.

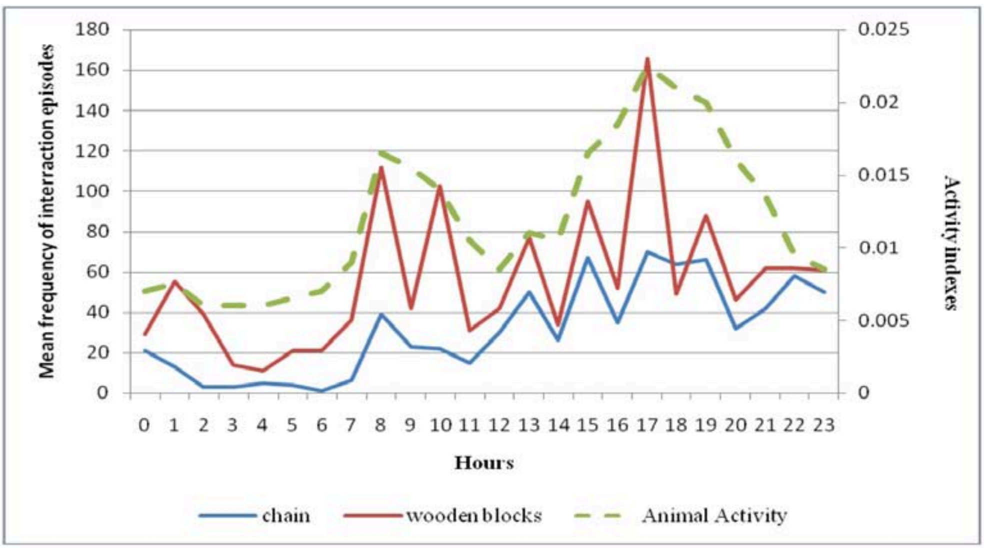

Figure 4. Effect of time of the day (24 h) on frequency of interaction episodes with different environmental enrichments (chain and wooden blocks) and animal activity determined by Eyenamic software.

Discussion

The importance of environmental enrichment material properties was shown in many scientific publications. Van de Weerd *et al.* (2003) discovered that environmental enrichments with “ingestible”, “odorous”, “chewable”, “deformable” and “destructible” characteristics capture and sustain interest of weaner and grower pigs. This characteristics are often associated to rootable substrates. For the point-source objects Zonderland *et al.* (2003) reported that “flexibility” and “destructibility” characteristics are independently contributing to the success of environmental enrichments.
According questionnaire done by Bracke *et al.* (2006), the majority of pig welfare scientists believes that a chain is not sufficient enrichment material for pigs. Pigs will play with chains, but they prefer to play with pliable objects when they are given a choice (Grandin, 1988). However in current study, long interactions with chain were observed, even if they were not as frequent as interactions with wooden blocks. This could be connected to “flexibility” characteristics of the chain, and the position of the chain, suspended in horizontal position on the level of pigs eye level, which allowed to bite and manipulate it easily. It was also found that pigs were playing more frequently with wooden blocks, but the duration of playing episodes was short. Grandin (1989) and Blackshaw *et al.* (1997) found that not fixed environmental enrichments, laying free on the pen floor were less attractive for the pigs than the fixed ones, as they become soiled with excreta. However, the destructibility features of wooden blocks, availability in different points of the pen and easiness to manipulate them could be a reason of increased frequency of interaction episodes. These results suggest that the combination of the point-sourced environmental enrichments with different characteristics could be an effective solution.
The results of experiment, indicating that the duration of interaction episodes with environmental enrichment is reduced with time is not surprising, as it is corresponding with results of other authors (e.g. Van de Weerd *et al.*, 2003, Zonderland *et al.*, 2003, Trickett *et al.*, 2009), who found the reduction of pigs’ interactions with environmental enrichments, when the novelty factor is gone and pigs become more acquainted with newly introduced enrichments.
The level of activity of piglets in one pen was higher than in other, which had implications also on quantity of interactions with environmental enrichments. We can suppose that it could be the result of the diet, enriched with antioxidants, however to explore the reason further experimentations should be done.
Also the period of the day was found influencing on the frequency of interactions of pigs with environmental enrichments. The activity indices calculated for 29 days showed the hours, when the pigs were mostly active during the day, and this picks of activity were corresponding with hours, when pigs were interacting more with environmental enrichments. This could be explained by a lot of factors, influencing on general distribution of pigs activity during the day, as photoperiod, feed assumption etc.

Conclusions

The present experiment was a preliminary study to assess the interest of the pigs to different types of environmental enrichments.The time consuming of labelling method didn’t allow the analysis more days in order to have more scientifically proved results. However, this method allowed to indentificate exact duration and frequency of interaction epizodes with environmental enrichments. This experimental study was performed according to PLF concepts and methods.

Piglets were interacting more frequently with wooden blocks, but the duration of interaction episodes was greater for chain. These results suggest, that the right combination of environmental enrichments with different characteristics could be more effective in terms of pigs welfare, involving pigs in more long and frequent interections with environmental enrichments, instead of performing negative behaviours towards their pen-mates.

In both pens, the number of interaction episodes with environmetal enrichments were strictly related to the activity index, calculated from 29 days of image recordings.

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References

Appleby, M.C., Wood-Gush, D.G.M., 1988. Effect of earth as an additional stimulus on the behaviour of confined piglets. Behav. Proc. **17** 83–91.

Arey, D.S. 1993. The effect of bedding on the behaviour and welfare of pigs. Anim. Welf. **2** 235–246.

Averos, X., Brossard, L., Dourmad, J.Y., de Greef, K., Edge, H.L., Edwards, S.A., Meunier-Salaun, M.C., 2010. Quantitative assessment of the effects of space allowance, group size and floor characteristics on the lying behaviour of growing–finishing pigs. Animal **4** 777–783.

Beattie, V.E., Walker, N., Sneddon, I.A. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. Anim.Welfare **4** 207–220.

Beattie, V. E., Walker, N., & Sneddon, A. 1996. An investigation of the effect of environmental enrichment and space allowance on the behavior and production of growing pigs. Applied Animal Behavior Science, **48** 151–158.

Beattie, V.E., Walker, N., Sneddon, I.A. 1998. Preference testing of substrates by growing pigs. Anim. Welf. **7** 27–34.

Beattie, V. E., O'Connell, N. E., & Moss, B. W. 2000. Influence of environmental enrichment on the behavior, performance and meat quality of domestic pigs. Livestock Production Science, **65** 71–79.

Bench, C.J., Gonyou, H.W. 2006. Effect of environmental enrichment at two stages of development on belly nosing in piglets weaned at fourteen days. J. Anim. Sci. **84** 3397–3403.

Blackshaw, J.K., Thomas, F.J., Lee, J.A. 1997. The effect of a fixed or free toy on the growth rate and aggressive behaviour of weaned pigs and the influence of hierarchy on initial investigation of the toys. Appl. Anim. Behav. Sci. **53** 203–212.

Bloemen, H., Berckmans, D., Aerts, J-M., Goedseels, V. 1997. Image analysis to measure activity of animals. Equine Veterinary Journal **23** 16-19

Boe, K.E. 1993. The effect of age at weaning and post-weaning environment on the behaviour of pigs. Acta Agric. Scand. Sect. A, Anim. Sci. Suppl. **43** 173–180.

Bolhuis, J.E., Schouten, W.G.P., Schrama, J.W., Wiegant, V.M. 2005. Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl. Anim. Behav. Sci. **93** 213–228.

Bracke, M.B.M., Zonderland, J.J., Lenskens, P., Schouten, W.G.P., Vermeer, H., Spoolder, H.A.M., Hendriks, H.J.M., Hopster, H. 2006. Formalised review of environmental enrichment for pigs in relation to political decision making. Appl. Anim. Behav. Sci. **98** 165–182

Day, J. E. L., Spoolder, H. A. M., Burfoot, A., Chamberlain, H. L., & Edwards, S. A. 2002. The separate and interactive effects of handling and environmental enrichment on the behavior and welfare of growing pigs. Applied Animal Behavior Science, **75** 177–192.

Feddes, J.J.R., Fraser, D. 1994. Non-nutritive chewing by pigs: implications for tail biting and behavioral enrichment. Trans. ASAE **37** 947–950.

Fraser, D., Phillips, P.A., Thompson, B.K., Tennessen, T. 1991. Effect of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. **30** 307–318.

Grandin, T., 1989. Effect of rearing environment and environmental enrichment on behavior and neural development in young pigs. Dissertation. University of Illinois, Urbana-Campaign, IL.

Kelly, H.R.C., Bruce, J.M., English, P.R., Fowler, V.R., Edwards, S.A. 2000. Behaviour of 3-week weaned pigs in strawflow, deep straw and flatdeck housing systems. Appl. Anim. Behav. Sci. **68** 269–280.

Leroy,T., Vranken, E., Van Brecht, A., Struelens, E., Sonck, B., Berckmans, D. 2006. A computer vision method for on-line behavioural quantification if individually caged poultry. Transactions of the ASABE **49** (3) 795-802

Lyons CAP, Bruce JM., Fowler VR 1995. A comparison of productivity and welfare of growing pigs in four intensive systems. Livestock Production Science 43,pp. 265–274.

Meunier-Salaun, M.C., Vantrimponte, M.N., Raab, A. and Dantzer, R. 1987. Effect of floor area restriction upon performance behaviour and physiology of growing-finishing pigs. J.Anim.Sci. **64**: 1371-1377

Petersen, V., Simonsen, H.B., Lawson, L.G. 1995. The effect of environmental stimulation on the development of behaviour in pigs. Appl. Anim. Behav. Sci. **45** 215–224.

Rodarte, L.F., Ducoing, A., Galindo, F., Romano, M.C., Valdez, R.A. 2004. The effect of environmental manipulation on behavior, salivary cortisol and growth of piglets weaned at 14 days of age. J. Appl. Anim. Welfare Sci. **7** (3) 171–179.

Schaefer, A.L., Salomons, M.O., Tong, A.K.W., Sather, A.P., Lepage, P. 1990. The effect of environment enrichment on aggression in newly weaned pigs. Appl. Anim. Behav. Sci. **27** 41–52.

Trickett, S.L., Guy, J.H., Edwards, S.A., 2009. The role of novelty in environmental enrichment for the weaned pig. Appl. Anim. Behav. Sci. **116** 45–51.

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Avery, P.J., Edwards, S.A., 2003. A systematic approach towards developing environmental enrichment for pigs. Appl. Anim. Behav. Sci. **84** 101–118

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Breuer, K., Edwards, S.A. 2006. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl. Anim. Behav. Sci. **99** 230–247.

Van de Weerd, H.A., Day, J.E.L., 2009. A review of environmental enrichment for pigs housed in intensive housing systems. Appl. Anim. Behav. Sci. **116** 1–20.

Wood-Gush, D.G.M., Beilharz, R.G. 1983. The enrichment of a bare environment for animals in confined conditions. Appl. Anim. Ethol. **10** 209–217.

Wood-Gush, D.G.M., Vestergaard, K. 1991. The seeking of novelty and its relation to play. Anim. Behav. **42** 599–606.

Zonderland, J.J., Vermeer, H.M., Ter Avest, A., Vereijken, P.F.G., Spoolder, H.A.M. 2003. Measuring a pig's preference for suspended toys by using an automated recording technique. In: Proceedings of the International Symposium of the C.I.G.R. Animal Welfare Considerations in Livestock Housing Systems, second Technical Section, pp.147–156.

Zonderland, J.J., Wolthuis-Fillerup, M., van Reene, C.G., Bracke, M.B.M., Kemp, B., den Hartog, L.A., Spoolder, H.A.M. 2008. Prevention and treatment of tail-biting in weaned piglets. Applied Animal Behaviour Science **110** 269-281.

Tail Biting in pigs – A review

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Abstract

One of the largest animal welfare problems in modern pig production is tail biting. This abnormal behaviour compromises the well-being of the animals, can seriously impair animal health and can cause considerable economic losses. Tail biting has a multifactorial origin and occurs mainly in fattening pigs. High stocking densities, poor environment and bad air quality are seen as important factors. However, little was done in practice to reach a deeper understanding of the internal and external motivators of this behavioural disorder which is not reported in sounders of wild boars. The aim of this review is to summarize the causes and the effects of tail biting in pigs and to present management strategies that are likely to reduce the incidence of this abnormal behaviour. In particular, management strategies by applying precision livestock farming (PLF) technologies to monitor and control the abnormal behaviour may be suitable to detect the occurrence of tail biting at an early stage so that counter measures can be taken.

Keywords: pigs, tail biting, abnormal behaviour, monitor.

Introduction

In commercial pig production, pigs are usually housed in large groups, similar-aged and similar-sized. Therefore, a common practice in pig production is to mix unfamiliar pigs in uniform weight groups, directly after weaning and at the beginning of the fattening period. After regrouping, pigs appear to experience social stress sufficient to cause a subsequent reduction in weight gain performance (Stookey & Gonyou, 1994), and it is usually followed by fights resulting in more wounded animals (McGlone & Curtis, 1985). Despite of the aggressive interactions, naturally noticed in pigs to establish the hierarchy within the group, there are some abnormal behaviours, different responses towards unfamiliar situations, that can be observed under stressing conditions. Such an abnormal behaviour affecting animal welfare and the economic efficiency of pig production, is tail biting. Although the syndrome has been recognized at least since the 19th century, at that time, it was not considered a major problem (Sambraus, 1985). Nowadays, this issue is as severe as 60 years ago and the frequency of reports appears to increase in all countries and in all housing systems. However, modified diagnostic methods and an altered attitude among the controlling staff might, at some extent, have influenced this result, making the diagnosis clearer than before (Schrøder-Petersen & Simonsen, 2001). Nowadays, there are four described categories of tail biting as pre-damage, damage, sudden-forceful and obsessive (Taylor *et al.*, 2010). Considering the large numbers of pigs fattened annually, tail biting represents a major economic and welfare problem for the pig industry and, as yet, no adequate solution to this problem has been found.

Causes

Tail biting is referred as "abnormal" behaviour since it is rarely reported under extensive, semi-natural or feral conditions (Walker & Bilkey, 2006). Intensive husbandry systems limit the expression of some behaviours which domestic species exhibit under less constrained conditions, for instance during farrowing, foraging and social interactions (Graves, 1984; Svendsen & Steen-Svendsen, 1997). Abnormal and maladaptive behaviours such as tail biting may arise in systems where natural behaviour is constrained (Moinard *et al.*, 2003). Tail-biting seems to result from the pigs natural tendency to root and chew on objects in their environment, during both foraging and exploratory activity and where tail biting occurs, it is often only a single animal which initially expresses the behaviour, in contrast to other non-biting penmates of similar breed, and with similar nutritional and housing provision (Van Putten, 1969; Stolba and Wood-Gush, 1989; Graves, 1984; Anon., 2006). As outdoor-kept pigs have less social discomfort, more space allowance and more objects to chew on, it seems reasonable to presume that outdoor pigs would not express tail-biting behaviour (Bilkei, 1994), although the same author presented a study where outdoor pigs did suffer from tail-biting (Walker & Bilkei, 2006). Even though the origin of tail biting is not fully understood, tail biting is considered to be an abnormal, pathological behaviour as it occurs mainly, but not exclusively, in pigs kept in barren environments (Anon., 2007). It is known that Tail Biting has a multifactorial origin, resulting from the interaction of various factors of the environment of the animals. In the table below it is possible to visualize some causes for tail biting found in different studies (adapted from Moinard *et al.*, 2003; Knoop, 2010; Anon., 2007). Some information is known about the time of day tail biting is likely to occur. Haske *et al.*, (1979) suggested tail and ear biting were more frequent before midday. Pigs are normally more active during daylight hours, possibly explaining this result (Fraser and Broom, 1990).

Table 1. – Risk factor for tail biting (TB).

Risk Factor	Characteristics
Gender	Males bite more than females;
Herd Size	Large herds increase TB;
Density	High stocking density increases TB;
Air temperature	High air temperature increases TB;
Age and weight	Probability of occuring TB increases with the age of the animals;
Floor	Compact floor in combination with straw tends to reduce TB;
Feed	Food quality, quantity and type of presentation can increase TB;
State of health	Respiratory problems increase 1.6 time the chance of occuring TB;
Enrichment	Toys can help to reduce TB when offered alternately;
Gases	High level of ammonia increases tail biting;
Genetics	Landrace is suggested to be more susceptible to tail bite.

Although the behavioural reaction of the bitten pig may help to precipitate increased biting, the availability of blood on the injured tail could also serve as an attraction. In particular, if certain pigs have a strong attraction to blood (e.g. duo to a mineral deficient diet), this can explain why the initial wound of a tail can trigger a sudden escalation of biting. Consideration of the diverse behaviour patterns that are grouped under the heading 'tail-biting' may reveal different etiologies of the problem, and may therefore indicate different ways in which they should be resolved.

Prevention - Tail docking and environmental enrichment

Tail docking is a routine management procedure in intensive piggeries. It is performed in the first days after the piglet is born and the commonly used tail-docking techniques include surgical tail docking (the tail is cut off using a sharp knife), heated docking iron (the tail is severed using a cautery iron (CAUT)) and rubber ring tail docking (a constrictive rubber ring is applied to the tail) (Sutherland *et al.*, 2008). For approximately 50 years it has been a largely successful practice to discourage tail biting by amputating the distal part of the tail. Ample evidence for the benefits of docking has been provided. One hypothesis why docking prevents tail biting, could be that the nerve regeneration, which follows docking, creates hypersensitivity and so pigs with docked tails will normally react more readily and more vigorously to assaults on their tails (Anon. 2007). Simonsen *et al.* (1991) found as possible evidence of increased sensitivity to pain, that the end of the amputated tail includes regressive changes of the peripheral nerves and formation of neuromas in some pigs. Chermat (2006) has observed that less than 5% of docked piglets (mild to severe docking) reacted to tail assaults (with agression or more than avoidance) when there was no lesion on the tail, whereas 70% showed a reaction when the tail presented a lesion. Therefore, even when the tail is docked, most pigs do not seem to react actively unless a lesion is present. Physiological indices of stress have shown increased responses of tail docking, including cortisol concentrations (Mellor & Holmes, 1988; Petrie *et al.*, 1996; Graham *et al.*, 1997; Kent *et al.*, 1998), haematological values (Schreiner & Ruegg, 2002) and haptoglobin concentrations (Eicher *et al.*, 2000). However, Prunier *et al.*, (2005) did not observe any clear changes in plasma profiles of cortisol and ACTH during the first 3 hours following docking in one-day old piglets. Therefore, it seems likely that tail-docking of day-old piglets does not induce a major physiological stress response, although these animals may be capable of showing such reaction. Behaviours, on the other hand, seem to change as a result to tail docking include eating (Eicher *et al.*, 2000), restlessness, foot stamping, head-turning, total active behaviour, time spent in abnormal postures (Graham *et al.*, 1997 and 2002; Kent *et al.*, 1998), vocalisation, tail wagging and tail jamming (Noonan *et al.*, 1994). There are several arguments against tail docking. One argument is the risk of infection, despite being a very rare sequel to docking (Haarbo *et al.*, 1966) and much more common in tail bitten animals (Hagen & Skulberg, 1960; Huey, 1996). Another argument offered by Colyer (1970) and Fraser and Broom (1990), is that the attention of frustrated potential biters may be redirected at other parts of the body of pen mates, such as ears and legs. This might lead us to another hypothesis for the preventive effects of docking, which is that if the pigs have only three to five centimetres of tail, then it is extremely difficult for the tail biter to get hold of the tail so it is possible that short-docked tails as less likely to be bitten (Jackisch *et al.*, 1996; Schrøder-Petersen & Simonsen, 2001; Moinard *et al.*, 2003). However, tail docking can be less welfare reducing for the animals than tail biting (Guise & Penny, 1998), possibly resulting in a slow and painful death for the bitten animals (Van Putten, 1969; Fritschen & Hogg, 1983). Tail docking is used as a supposedly curative solution on problematic farms and also the farmers' response to tail biting is to cut the tails shorter, however, it does not prevent tail biting completely (Moinard *et al.*, 2003; Anon., 2007).

According to EFSA (Anon., 2007) the most important risk factor for an outbreak of tail biting is the lack of straw or other environmental enrichment factors in intensive animal housing systems. For this reason, environmental enrichment has been recommended on pig farms. Preventive methods such as the provision of iron chains, car tyres, pieces of wood, ropes, salt blocks, supplementary food etc., have been tried. It is presumed that such stimuli occupy the pigs to some extent and thereby limit the attention of pen mates (Schrøder-Petersen & Simonsen, 2001). Feddes and Fraser (1994) suggest that the most effective toys for preventing tail biting are those which give the pigs an opportunity to perform destructive, non-nutritive chewing in which they alter, unravel or remove pieces from an object. Most of the “toys” used by farmers were not easily destructible, presumably so that they lasted longer and cost less. However, pigs often loose interest in these novel objects as soon as they become accustomed to them, leading to a low level of use and negligible behaviour. “Toys” would be more effective if they were more easily altered, attracting pigs’ attention towards them. Especially when no positive reinforcement is attached to the object, the preventive effect may be limited.

Economic Losses

Tail biting can reduce production results, increase on farm costs (e.g. labour and treatment costs) and lead to a variety of physical damage and carcass condemnation resulting in financial losses for the farmer and the abattoir (Zonderland, 2010). Badly bitten pigs can have reduced weight gains (England & Spurr, 1967, Wallgren & Lindahl, 1996), an increased incidence of condemnation of carcasses at slaughter in 61-67%, owing to the presence of abscesses or pyaemia in more than one site (Penny & Hill, 1974; Huey, 1996; Schrøder-Petersen & Simonsen, 2001). According to the European Food Safety Authority report, until 2006, the prevalence of injured tails were from 1-5% of the animals, and the number of cases of tail biting detected in farms were in the order of 30-70% (Anon., 2007). Estimates of farm prevalence range from under 1% to over 10% but individual farms may have figures as high as 20%, and over 60% of farms have been reported to have experienced this problem (Chambers *et al.*, 1995; Hunter *et al.*, 1999). Tail biting, in the worst instance can lead to cannibalism (van Putten, 1968) and it is also considered to be one of the greatest contributors to increased production costs and decreasing animal welfare, especially in the nursery and growing units (Fraser & Broom 1990; Anon. 2001). However, quantitative information on the economic consequences regarding tail damage for a pig farmer and the pig sector is scarce. For example, in a Swedish study, Keeling and Larsen (2004) recorded prevalence of 6,2 and 7,2%, whereas slaughterhouse records showed only 1,9%. Therefore, it is likely that abattoir records often note only severe cases associated with infection and condemnation (Anon., 2007). A Danish study involving 111 herds showed that tail damage, estimated by clinical examination of the herd on the farm, was two times more prevalent than detected by carcass inspection at the abattoirs (Busch *et al.* 2004). Moinard *et al.* (2003) estimated in 1999 that the cost of tail biting in the UK was over 4 million euro due to reduced weight gain, on-farm veterinary treatment, culling and carcass condemnation. A preliminary cost estimation of tail damage among pigs in the Netherlands indicates a financial loss of over 8 million euro for the pig sector (Zonderland, 2010). This calculation included similar criteria as Moinard *et al.* (2003) and was based on an average tail biting lesions prevalence of 2,12% (Smulders *et al.*, 2008) for weaned piglets as well as finishing pigs.

Solutions (PLF)

Tail biting is a substantial economic and welfare problem in growing and fattening pigs. A considerable amount of research has been done (Schrøder-Petersen & Simonsen, 2001). However, many applied ethologists feel their findings could be used more extensively in practice. A modelling technique using the available scientific information in a balanced way could facilitate the application of information to help reduce tail biting in pigs (Bracke *et al.*, 2004). The success and trust of animal welfare schemes relies solely on the validity, reliability and sensitivity of the measurement tool, and until today, no such tools combining several direct and indirect measurements have been subjected to rigorous evaluation (Scott *et al.*, 2001). A practical and robust tool must be based on relatively simple observations and records related to aspects of husbandry and welfare so that a skilled and trained researcher should be able to gather this information during a single visit. Although simple, such protocols combining several aspects should provide a detailed and valid picture of the welfare status of commercially kept animals. Performance records, behavioral, physiological and clinical parameters can be a good basis for assessing welfare at the animal level (Fraser, 1995; Gonyou, 1994) but they also indicated the difficult interpretation of these results and the limited value of performance measures for animal welfare (Meunier-Salaun *et al.*, 1987). However, once a valid animal-based tool is constructed, it can be used to determine on-farm risk factors concerning the provision of resources, as well as management, stockmanship and farm characteristics. For instance, Guarino *et al.* (2008) developed a tool for recognition of sick pig cough using sound analysis and algorithms have been tested to detect cough sounds and to classify the animals whether they were ill or not. Concerning tail biting, Bracke *et al.* (2004) validated a decision support system to help assess the extent to which a housing system is at risk. More recently, the University of Bristol in collaboration with the University of Newcastle developed a Husbandry Advisory Tool (HAT), which is a management tool to identify specific risks of tail biting present at pen level and to provide precise information to tailored advice to address these risks (Taylor, 2010), but no data related to the efficiency of this tool is available until the present moment.

References

Anon. 2006. Tail biting in pigs: Understanding the intractable problem. The Veterinary Journal **171** 198–199.

Anon. 2007. Scientific report on the risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. Annex to the EFSA Journal **611** 1–13.

Bilkei, G. 1994 Gesundheitsschäden der Schweine durch Fehler in der Haltung. In: Proceedings of the 2 Wochenseminar Grosstierpraxis. Veterina¨rverlag, Rothenburg/Fulda 111–121.

Bracke, M.B.M., Hulsegge, B., Keeling, L., Blokhuis, H.J. 2004 Decision support system with semantic model to assess the risk of tail biting in pigs 2. 'Validation'. Appl. Anim. Behav. Sci. **87** 45–54.

Busch, M.E., Wachmann, H., Nilsen, E.O., Petersen, H.H., Nilsen, J.P. 2004 Tail biting – can routine meat inspection data be used for classification of herds? Proceedings of the 18th IPVS Congress, Hamburg, Germany.

Chambers, C., Powell, L., Wilson, E., Green, L.E., 1995 A postal survey of tail biting in pigs in south west England. Vet. Rec. **11** 147–148.

Chermat, A. 2006 Le cannibalisme chez le porc charcutier : approches zootechnique, physiologique et comportementale. Thèse de docteur vétérinaire, Ecole Nationale Vétérinaire de Nantes, France.
Colyer, R. J. 1970 Tail biting in pigs. Agriculture **77** 215–218.
Day, J.E.L., Kyriazakis, Lawrence, A.B. 1995 The effect of food deprivation on the expression of foraging and exploratory behaviour in the growing pig. Appl. Anim. Behav. Sci. **42** 193–206.
Eicher, S.D., Morrow-Tesch, J.L., Albright, J.L., Dailey, J.W., Young, C.R. Stanker, L.H. 2000 Tail-docking influences on behavioral, immunological, and endocrine responses in dairy heifers. Journal of Dairy Science **83** 1456–1462.
England, D.C. Spurr, D.T. 1967 Effect of tail-biting on growth rate of swine, J. Anim. Sci. **26** 890–891.
Feddes, J. J., Fraser, D. 1994 Non-nutritive chewing by pigs: implications for tail biting and behavioural enrichment. Transactions of the American Society of Agricultural Engineers **37** 947–950.
Fraser D. 1995 Science, values and animal welfare: exploring the "inextricable connection". Animal Welfare **4** 103–117.
Fraser, D., Broom, D.M. 1990 Farm animal behaviour and welfare third edition. London, UK, 437p.
Fritschen, R., Hogg, A. 1983 Preventing tail biting in swine (anti-comfort syndrome). Historical Materials from University of Nebraska-Lincoln Extension 3p.
Gonyou HW. 1994 Why the study of animal behavior is associated with the animal welfare issue. J Anim Sci **72** 2171–2177.
Graham, M.J., Kent, J.E. Molony, V. 1997 Effects of four analgesic treatments on the behavioural and cortisol response of 3-week-old lambs to tail docking. Veterinary Journal **153** 87–97.
Graham, M.J., Kent, J.E. Molony, V. 2002 The influence of the site of application on the behavioural responses of lambs to tail docking by rubber ring. Veterinary Journal **164** 240–243.
Graves, H.B., 1984 Behaviour and Ecology of Wild and Feral Swine (Sus Scrofa). Journal of Animal Science **58** 482–492.
Guarino, M., Jans, P., Costa, A., Aerts, J.M., Berckmans, D. 2008 Field test of algorithm for automatic cough detection in pig houses. Computers and Electronics in Agriculture **62** (1) 22–28.
Guise, H.J., Penny, R.H.C. 1998 Tail biting and tail docking in pigs. Veterinary Record **142** 46.
Haarbo, K., Hemmingsen, I., Schmidt, P.E., Svendsen, P., Westergaard, J.M. 1966 Vulnera morsa caudae suum. Nordisk Veterinoer Medicin **18** 441–51.
Hagen, O., Skulberg, A. 1960 Halesår hos gris. Nordisk Veterinoer Medicin **12** 1–20.
Haske, C., Bogner, H., Peschke, W., 1979 Investigations on the behaviour of fattening pigs in different stall-housing systems in relation to tail and ear biting. Bayerische Landwirtschaftliches Jahrbuch, **56** 162–200.
Huey, R.J. 1996 Incidence, location and interrelationships between sites of abscesses recorded in pigs at a bacon factory in Northern Ireland. Veterinary Record **138** 511-514.
Hunter, E.J., Jones, T.A., Guise, H.J., Penny, R.H.C., Hoste, S., 1999 Tail biting in pigs. 1. The prevalence at six UK abattoris and the relationship of tail biting with docking. Pig J. **43** 18–32.
Keeling, L., Larsen, A. 2004 What are the characteristics of tail biting in pigs? Svenska djurhalsovardens fortbildningskonferens pa Billingen, Skovde, Sweden.
Kent, J.E., Molony, V., Graham, M.J. 1998 Comparison of methods for the reduction of acute pain produced by rubber ring castration or tail docking of week-old lambs. Veterinary Journal **155** 39–51.
Knoop, S. 2010 Literaturauswertung zum Thema Schwanzbeißen / Schwänze kupieren. Newsletter-Archiv: Schweinehaltung und Schweinezucht 1–8.
McGlone, J.J., Curtis, S.E. 1985 Behaviour and performance of weaning pigs in pens equipped with hide areas. J. Anim. Sci. **60** 20–24.
Mellor, D.J., Holmes, R.J. 1988 Rings versus knife for docking and castration of lambs. Australian Veterinary Journal **65** 403–404.
Meunier-Salaun, M.C., Vantrimponte, M.N., Raab, A., Dantzer, R. 1987 Effect of floor area restriction upon performance, behavior and physiology of growing–finishing pigs. J Anim Sci **64** 1371–1377.

Moinard, C., Mendl, M., Nicol, C.J., Green, L.E. 2003 A case control study of on-farm risk factors for tail biting in pigs. Applied Animal Behavioural Sciences **81** 333–335.

Noonan, G.J., Rand, J.S., Priest, J., Ainscow, J., Blackshaw, J.K. 1994 Behavioural observations of piglets undergoing tail docking, teeth clipping and ear notching. Applied Animal Behaviour Science **39** 203–213.

Penny, R.H.C., Hill, F.W.G. 1974 Observations of some conditions in pigs at abattoir with particular reference to tail biting. Veterinary Record **94** 174–180.

Petrie, N.J., Mellor, D.J., Stafford, K.J., Bruce, R.A., Ward, R.N. 1996 Cortisol response of calves to two methods of tail docking used with or without local anaesthetic. New Zealand Veterinary Journal **44** 4–8.

Sambraus, H.H. 1985 Mouth-based anomalous syndromes. World Animal Science, A5, Ethology of Farm Animals. A comprehensive Study of the Bhavioural Features of Common Farm Animals, 391–422.

Schrøder, D.L., Simonsen, H.B. 2001 Tail Biting in Pigs. The Veterinary Journal **162** 196–210.

Schreiner, D.A., Ruegg, P.L. 2002 Responses to tail docking in calves and heifers. Journal of Dairy Science **85** 3287–3296.

Scott, E.M., Nolan, A.M., Fitzpatrick, J.L. 2001 Conceptual and methodological issues related to welfare assessment: a framework for measurement. Acta Agric Scand A Anim **30** 5–10.

Simonsen, H.B., Klinken, L., Bindseil, B. 1991 Histopathology of intact and docked pig tails. British Veterinary Journal **147** 407–412.

Smulders, D., Hautekiet, V., Verbeke, G., Geers, R. 2008 Tail and ear biting lesions in pigs: an epidemiological study. Anim. Welf. **17** 61–69.

Statham, P., Green, L., Bichard, M., Mendl, M. 2009 Predicting tail-biting from behaviour of pigs prior to outbreaks. Applied Animal Behaviour Science **121** 157–164.

Stolba, A. and Wood-Gush, D.G.M., 1989 The behaviour of pigs in a semi-natural environment. Anim. Prod. **48** 419–425.

Stookey, J.M., Gonyou, H.W. 1994 The effects of regrouping on behavioral and production parameters in finishing swine. J. Anim. Sci. **72** 2804-2811.

Svendsen, J., Svendsen, L.S. 1997 Intensive (commercial) systems for breeding sows and piglets to weaning. Livestock Production Science **49** 165–179.

Sutherland, M. A., Bryer, P. J., Krebs, N., McGlone, J.J. 2008 Tail docking in pigs: acute physiological and behavioural responses. Animal **2**(2) 292–297.

Taylor, N.R., Main, D.C.J., Mendl, M., Edwards, S.A. 2010 Tail-biting: A new perspective. The Veterinary Journal **186** 137–147.

Taylor, N. 2010 Management tool for predicting tail biting. British Pig Executive (BPEX). http://ec.europa.eu/food/animal/welfare/seminars/docs/20101111_agenda_parma_nina_taylor.pdf

Van Putten, G., 1969 An investigation of tail-biting among fattening pigs. British Veterinary Journal **125** 511–517.

Walker, P.K., Bilkei, G. 2006 Tail-biting in outdoor pig production. The Veterinary Journal **171** 367–369.

Wallgren, P., Lindahl, E. 1996 The infl uence of tail biting on performance of fattening pigs. Acta Veterinaria Scandinavica **37** 453–460.

Zonderland, J.J. 2010 Talking tails – Quantifying the development of tail biting in pigs. 176p.

Section 8
Smart Farming

Precision Livestock Farming claims for Sustainable Dairy Production

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Abstract

The dairy production systems in Europe are confronted with societal discussions on increasing farm size, animal welfare, animal health, contribution to greenhouse gasses and the integration in the natural environment. These are all part of the sustainability discussion. Precision Livestock Farming claims to contribute substantially to the solutions in these discussion fields. To unravel this experts were asked to score the key daily cow related processes in dairy production (cow, feed, milk and manure) on expected cost reduction, profit increase, labour consequences, social farmers impact, environmental impact, time savings, product quality and societal impact.

Keywords: sustainability, dairy farming, impact, expert opinion

Introduction

Developments in livestock production take place in an uncertain environment. For the coming 15 years a worldwide increase of 40% is foreseen in the demand of proteins (meat and milk). To fulfil this need efficient production and reproduction of livestock is needed with adequate monitoring and control. However, in West European countries the economic and social environment has to deal with new constraints and ethical issues on animal welfare, animal disease, environment, food hygiene, sustainability and food quality management. Despite these constraints, much farmers still put a strong emphasis on growth and intensification of the production. This results in an intensified discussion on livestock production. Not mentioned often, but what can be seen as an underlying factor, is that consumers and society in general are afraid that farmers are not able anymore to pay enough attention to individual animals (Lokhorst & Ipema, 2010). This emphasis on individual animals is one of the keys of the Precision Livestock Farming (PLF) concept (Berckmans, 2008; Groot Koerkamp *et al.*, 2007; Wathes *et al.*, 2008). A short definition is given by Berckmans as the “Management of livestock farming by automatic real-time monitoring/controlling of production/reproduction, health and welfare of livestock”. Lokhorst and Ipema stress that PLF addresses two paradigm shifts. One from group to individual animal level and one going from management of uniformity to the management of biological variation between individual animals. The focus of PLF is on the operational management, so daily decisions are of interest. The PLF concept is fundamentally a basic way of thinking. Investments are done in data measurement (sensing), data handling, modelling and transformation into real time management actions that focus on individual animals that belong to a group. The practical implication is that this basic development can contribute to the areas of production efficiency and energy, animal welfare, animal health, product quality, food safety, environmental protection and regional development. So, it looks like PLF can contribute to a lot of discussions/issues. However, it becomes more difficult to identify the actual claims of PLF. In this paper the main question therefore is: 'What is the added value of PLF for sustainable dairy production'.

Method

Since PLF focuses on the operational decision support the dairy production process was analysed to answer the research question. Based on literature and expert knowledge of the authors the following critical processes were identified in the daily dairy process: feed and water, cow, milk, manure and greenhouse gasses (see also figure 2). These critical processes were decomposed into relevant sub processes. A sub process was relevant if the farmer or other service deliverer was able to influence the process. In other words, there should be a possibility for a 'Standard Operating Procedure' (SOP) to influence the input of the process and to control the output of a process. A Standard Operating Procedure is a set of written instructions that document a routine or repetitive activity to be followed. The basics of model based CIT control theory introduced by Berckmans (2004) were taken care of. The model is the animal that is complex, individually different and time-variant (CIT).
Sustainability and the added value were also decomposed. Inspired by the 'response-inducing sustainability evaluation (RISE) instrument' of Häni & Pikart-Müller (2008) who looked at sustainability at farm level, the following sustainability parameters were identified to study the added value of PLF in dairy production. Figure 1 shows an example of the summary polygon of the parameters.

Figure 1. Example of the summary polygon for the use of PLF on feed efficiency with observed sustainability parameters

A qualitative judgement was made by a group of 10 researchers of Wageningen UR Livestock Research. They all have experience with PLF research and have specific knowledge of the Dutch en West European market development in modern dairy production. The group can therefore be classified as experts, but not as balanced and totally independent. The items were scored on a scale form -3 till +3 where minus indicates a decrease from small to substantial and plus indicates an increase from small to substantial. Zero indicates in this case no effect. The final score per item was derived from the group discussion. The following parameters were used. *Cost reduction* means that amount of the input factors for the process, e.g. amount of feed, are reduced and therefore costs can be lowered. *Profits* indicates whether it is expected that the selling price of the product can be improved. *Labour* consequences are influenced when more or less labour is needed when PLF is used for the observed process. *Social* farmers impact is scored for the social impact for the farmers. Will use of PLF result in changes in quality of life for the farmer, more free time and interaction with other farmers. *Environmental* impact is scored for the consequences for the environment. Processes influence directly the product development, but also the 'by-products'. Examples are the amounts of manure, dust, and greenhouse gasses. *Time savings* is used to indicate whether PLF makes it possible to react quicker and more flexible. If a farmer can see a disease coming two days earlier he can react quicker and as a consequence the disease might be less harmful. Product *quality* is scored since PLF can influence the selection of input and output factors that will be under control. The intensity of the control can influence the product quality. *Societal* impact indicates whether the process-PLF combination will be acceptable for the society and will contribute to fill the gap between society and dairy production. From the description it is clear that the parameters chosen have a qualitative nature and that it will be difficult to compare them. However, to get more insight in were the added value of PLF will be in the improvement of the sustainability in dairy production the RISE instrument (Häni & Pikart-Müller, 2008) can be used.

Results

<u>Main cow related processes in dairy production</u>

A cow is able to transform a relative low value input, mainly forage and water, into high value products (figure 2). The dairy cow uses the in the gastrointestinal system absorbed elements and nutrients for maintenance of the elementary processes (e.g. breathing, thermoregulation, moving) and for synthesis of body tissue (growing), foetus and milk. The residual, the waste products of metabolism and other non-useful materials are excreted as manure (faeces, urine) and greenhouse gasses.

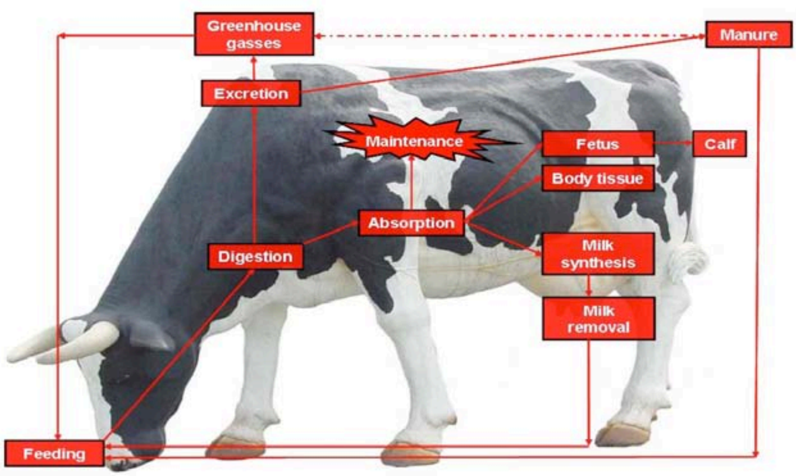

Figure 2. Scheme of the input-output cow related processes.

The results in this paper focus on the processes cow, feeding, milking, manure and their interdependence (Figure 2). First these processes are explained in some more detail and then the sustainability items 'cost reduction', 'profits', 'labour', 'social farmer impact', 'environment', 'time saving', 'product quality' and 'society' are presented and discussed.

Cow process

In the concept of precision dairy farming the individual cow is the key element. The cow consumes feed as source of fuel for all kind of internal and external body functions and processes. Most of the time the dairy cow is in gestation and lactation. This means that she is exposed to very exceptional physiological situations. In the expression of her daily behaviours she shows how to cope with these situations. In the reproduction cycle the endocrine system regulates the synthesis of different types of hormones. In certain stages of the reproduction cycle this can lead to a restless behaviour (oestrus, parturition). Also malfunction of certain body functions and processes (illnesses) can result in deviations in the daily behaviour pattern. Table 1 gives the sustainability scores for the sub-processes for the cow process. The identified sub processes are 'time budgeting', 'heat detection', 'pregnancy detection' and 'calving supporting'.

Table 1. Sustainability scores for the sub-processes of the cow process

Animal process	**Cost reduction**	**Profits**	**Labour**	**Social Farmer**	**Environment**	**Time saving**	**Quality**	**Society**	**Total**
Time budgeting	**3**	0	**2**	**2**	0	**1**	**1**	0	9
Heat detection	**3**	0	**2**	0	0	**3**	0	0	8
Pregnancy detection	**1**	0	**1**	0	0	**1**	0	0	3
Calving supporting	**2**	0	**1**	**2**	0	**1**	0	0	6
Total	*9*	*0*	*6*	*4*	*0*	*6*	*1*	*0*	*26*
Average	*2,25*	*0*	*1,5*	*1*	*0*	*1,5*	*0,25*	*0*	*6,5*

Results in Table 1 show that the expected biggest added value of PLF to the cow process can be expected for the items *cost reduction, labour, time saving* and *social farmer impact*. Also can be seen that improving *time budgeting, heat detection and calving supporting* will be beneficial for the farmer. On those sub-processes he can make the difference and he can integrate PLF is his daily management procedures and standing operation procedures. These sub-processes are, in order of relevance, explained in more detail in the following paragraphs.

Time budgeting

The amount of time an animal spends on lying, eating, rumination etc. is called time budget. Not only the total amount of time spent on an action is important, also the frequency an action is performed is important. When time budgets are available it's possible to have an early warning system for animal health. Detecting health problems in an early stage can reduce veterinarian and medicine costs. Animals can be treated preventive instead of curative. Also labour input can be reduced because less animals have to be treated and the treatment time is shortened. The amount of time saved can be used for other purposes like social contacts. Because of the individual approach, herd size isn't limitative anymore from a farm management point of view.

Oestrus detection

Before a cow can be inseminated it's important to know when she is in heat. However, signalling a cow in heat is not always easy because the time she is in heat and the way in heat is shown can differ per cow. To improve heat detection it is necessary to improve the algorithms used so false negative attentions can be reduced. When in heat detection improves, the number of re-inseminations can be decreased and, if present, a bull used for re-insemination isn't necessary anymore. Because the amount of inseminations is reduced, costs for labour, e.g. fetching cows, inseminations costs and also costs because of a shorter period between calves can be reduced as well.

Calving support

In most cases, a cow can give birth to a calf on her own without any help. However, to be sure no problems occur during calving, a farmer often checks the calving progress to be sure no professional help is needed. When the time budget of a cow is known, abnormalities in her behaviour, like the total time and frequency spending on lying and standing, can be an indication of the oncoming birth. Additional information like knowing her location in relation to the location of the herd can also be an extra indication of the oncoming birth. Knowing the exact time of birth as accurate as possible, the amount of necessary interventions of the veterinarian can be reduced so costs can also be reduced. Time is saved because less checks by the farmer are needed. This is also a big social advantage, especially during the night.

Pregnancy detection

A cow is pregnant, or not, when a veterinarian has examined her or whenever she is not in heat anymore after the last insemination. By combining additional individual management information, like the response in milk production on the concentrate intake (feed efficiency), it should be possible to know when a cow is pregnant in an earlier stage, so time is saved. Because it is not necessary anymore to have a veterinarian examining the cows, examination costs and labour for fetching cows can be decreased.

<u>Feeding process</u>

Dairy cows are ruminants in which feed intake and digestion consist of complicated processes. Feed for ruminants consists for a large part of forages, during certain periods supplemented with concentrates. An important nutrient source for ruminants present in forage, is fibre. In the first part of the gastrointestinal system, the rumen and the reticulum, fibre is primarily broken down into the three volatile fatty acids, acetic acid, propionic acid and butyric acid by microbes. Protein and non-structural carbohydrate (pectin, sugars, starches) are also fermented. Next, the degraded digestive substances together with the microbes are transported through the different parts of the gastrointestinal tract, where further digestion takes place and water, inorganic mineral elements and nutrients are absorbed into the blood stream. Experts have indicated that the process of feeding can be subdivided in the sub-processes that can be influenced by decisions/actions of the farmer. The sub-processes are ‘feeding efficiency’, ‘feeding location’, ‘feed utilization’, ‘feed spoilage’ and the sustainability scores can be seen in Table 1.

Table 2. Sustainability scores for the sub-processes of the feeding process.

Feeding process	Cost reduction	Profits	Labour	Social Farmer	Environ-ment	Time saving	Quality	Society	Total
Feed efficiency	**3**	0	0	0	**3**	0	**1**	0	7
Feeding location	**1**	0	0	0	**2**	0	0	**1**	4
Feed utilization	0	**1**	0	0	0	**1**	**1**	**-1**	2
Feed spoilage	**2**	0	0	0	**1**	0	**2**	0	5
Total	*6*	*1*	*0*	*0*	*6*	*1*	*4*	*0*	*18*
Average	*1.50*	*0.25*	*0.00*	*0.00*	*1.50*	*0.25*	*1.00*	*0.00*	*4.5*

Results in Table 2 show that the expected biggest added value of PLF to the feeding process can be expected for the items *cost reduction*, *environmental impact* and *product quality*. Also can be seen that improving *feed efficiency*, *minimising feed spoilage* and *managing of the feed location* will be beneficial for the farmer. On those sub-processes he can make the difference and he can integrate PLF is his daily management procedures and standing operation procedures. These sub-processes are, in order of relevance, explained in more detail in the following paragraphs.

Feeding efficiency

In common practice, cows are fed based on the “average cow”, which does not exists, present on the farm. This means that cows with the same milk production and the same roughage ratio get the same amount of concentrate. However, it is known that every cow has a different response in milk production on concentrate intake (André *et al.,* 2009; Maltz *et al.,* 2009). When all cows are fed individually, it is possible to strive for the highest profit from milk yield minus concentrate costs. Likewise, it should be possible to improve the mineral efficiency by adapting the amount of minerals like nitrogen and phosphate fed to the animal to the amounts in her milk. This gives possibilities to affect the environmental loads of dairy production.

Feed spoilage

From cultivation of grass, harvesting it as roughage to feeding of roughage, spoilage is inevitable. This varies from spoilage of fertilizer, spoilage during harvesting roughage, spoilage during grazing, preservation losses and feeding spoilage. When spoilage is minimized, costs for purchasing fertilizer, roughage and concentrates can be decreased. Monitoring the conservation process of the roughage can provide information about the quality of the roughage. Both trades contributes to a better environment.

Feeding location

The possibility of granting or refusing access to different feeding locations, including access to pasture, where different feeding components are provided, makes it possible to compose rations which are adjusted to the individual performances and needs of a cow, calve or heifer.

This makes it possible to save the amount of minerals used, not only minerals from the concentrates, but also minerals used in fertilizers and manure. Giving animals access to pasture for grazing is from a societies point of view eligible.

Feed utilization

Monitoring the rumen pH can provide information that is indicative for the functioning of the rumen. When the pH deviates from normal values, the composition of the feed ration needs attention. More extreme pH deviations indicate health problems like acidosis or ketosis. With information from a wireless rumen pH sensor it is possible to intervene in an early stage resulting in effects on the cow's health that are as low as possible.

A negative score is given here for societal aspects, because placing technology in an animal might be seen as an undesirable intervention.

Milk process

Milk is synthesized in the udder from nutrients brought up by the blood. The udder of a cow is made up of four mammary glands or quarters. Each quarter is a functioning entity of its own which operates independently and delivers the milk through its own teat. Generally, the rear quarters are slightly more developed and produce more milk than the front quarters. Milking is the act of collecting milk after proper stimulation of a cow to release milk from the udder. The first milking machines, applying vacuum for milk removal and a teatcup with liner in combination with a pulsator was an important invention for machine milking. The pulsator takes care of a regular opening and closing of the liner by cyclic connecting the pulsation chamber of the teat cup with vacuum or atmospheric pressure. The main purpose of pulsation (opening and closing the liner) is to minimize the development of circulatory impairment (congestion and oedema) during milking through which udder health and milk quality problems could be diminished. The most important source of income for a dairy farm are milk sales. Dairy farmers aim for selling as much as possible, high quality milk to the dairy. This requires high demands on the cow with respect to milk synthesis and milking ability. Table 2 gives the sustainability scores for the sub-processes for the milk process. The sub processes are 'milk synthesis' and 'milk removal'.

Table 3. Sustainability scores for the sub-processes of the milk process.

Milk process	**Cost reduction**	**Profits**	**Labour**	**Social Farmer**	**Environ-ment**	**Time saving**	**Quality**	**Society**	**Total**
Milk synthesis	**2**	0	0	0	0	0	**1**	**2**	5
Milk removal	**1**	0	0	0	**1**	**1**	**3**	**1**	7
Total	*3*	*0*	*0*	*0*	*1*	*1*	*4*	*3*	*12*
Average	*1.50*	*0.00*	*0.00*	*0.00*	*0.50*	*0.50*	*2.00*	*1.50*	*6*

Results in Table 3 show that the expected biggest added value of PLF to the milk process can be expected for the items *product quality, cost reduction* and *societal impact*. Also can be seen that improving *milk removal* and *milk synthesis* will be both beneficial for the farmer. On those sub-processes he can make the difference and he can integrate PLF is his daily management procedures and standing operation procedures. These sub-processes are, in order of relevance, explained in more detail in the following paragraphs.

Milk removal

Milk machine parameters are often the same for every cow and every quarter on a dairy farm. When these settings like vacuum level and pulsator ratio, can be adjusted per cow and quarter, less problems with udder health, like teat callosity or mastitis will occur. This results in an increase of the animal welfare. A lower use of medicines increases the quality of the milk and has a lower impact on the environment. It also decreases the amount of time needed for treating cows with medicines and uses less machine capacity. Therefore, costs will be lower because of the decrease in medicine use, less spoilage of milk and less labour time.

Milk synthesis

For the milk synthesis optimal circumstances like free access to cubicles, feeding rack, concentrate box, automatic milk system (AMS) is necessary. When we know what the time-budget and the ideal circumstances of an individual cow is during the day, it will be easier to fulfil its individual needs. An animal with less stress will need less, preventive, healthcare. Costs of healthcare will decrease, quality of life increases. Having respect for the individual needs of a cow will also contribute in the on-going discussion in society.

<u>Manure process</u>

Feed intakes are currently mainly estimated based on covering energy and protein requirements for maintenance, growth, reproduction and milk production. The consumed feed components are only partially effectively used. A lactating dairy cow uses dietary nitrogen (N) with an efficiency of about 30%. For dietary phosphorus (P) the efficiency is even lower. The remainder is excreted with the initial manure (faeces and urine). The manure production can be estimated from the consumed quantities of nitrogen (N), sodium (Na), potassium (K) and the produced amounts of milk fat and protein. However, part of N in the manure is lost to the atmosphere via volatilization.

The gaseous losses from barn and storage are affected by housing facility and management strategy of the farms. Table 4 gives the sustainability scores for the sub-processes for the manure process. The sub processes are ‘manure separation’, ‘manure measurement‘, and ‘cow radar’.

Table 4. Sustainability scores for the sub-processes of the manure process

Manure process	Cost reduction	Profits	Labour	Social Farmer	Environ-ment	Time saving	Quality	Society	Total
Manure separation	**1**	**2**	0	0	**3**	0	0	**-1**	5
Manure measurement	0	0	**1**	0	0	0	0	**3**	4
Cow radar	0	0	0	0	**2**	0	0	**3**	5
Total	*1*	*2*	*1*	*0*	*5*	*0*	*0*	*5*	*14*
Average	*0,33*	*0,67*	*0,33*	*0,00*	*1,67*	*0,00*	*0,00*	*1,67*	*4,67*

Results in Table 4 show that the expected biggest added value of PLF to the manure process can be expected for the items *environment* and *society* followed by *profit*. Also can be seen that improving *manure separation* and *cow radar* will be beneficial for the farmer. On those sub-processes he can make the difference and he can integrate PLF in his daily management procedures and standing operation procedures. These sub-processes are, in order of relevance, explained in more detail in the following paragraphs.

Manure separation

When manure is separated as close to the animal as possible, emissions of e.g. ammonia can be reduced as much as possible. When collected separately, the solid faeces and fluid urine part can be stored and processed separately. Because the solid fraction contains phosphate and the fluid part nitrogen, fertilization of pasture and crops is more balanced and more efficient, also less artificial fertilizer is needed. Fertilization is more accurate so there is a positive effect on the environment. Less artificial fertilizer is needed, so costs are reduced. However, when storing and separating the faeces with a device attached to an animal, it is expected that society will discuss the effect on animal welfare.

Cow radar

Dairy farms, and in particular cows, have a major contribution in the emissions of ammonia and other greenhouse gasses. Dairy farms are restricted in expanding based on location, environment and legislation, because of general assumptions of emissions per farm or per cow. When it is possible to display how much every animal emits, analogue with a weather radar map, total farm emissions can be calculated. A farmer can show how much his farm emits and prove the deviation with the general assumptions. These emissions can be monitored and farm specific plans can be made for reducing these emissions. Showing a decrease in emissions of greenhouse gasses is positive from a societies point of view.

Manure measurement

When the amount of manure excreted by an animal is individually measured, it is possible to get a more accurate impression of the cycle of nutrients in an individual animal. If all parts of the cycle are more in sight, it is possible to monitor the health of an animal more accurate. Based on this cycle, it is also possible to know what the individual "footprint" or the impact of an individual animal on the environment is. This is a positive contribution to the discussion in society on the Carbon footprint issue.

Concluding remarks

In this paper a method is introduced to score some sustainability aspects when the concept of Precision Livestock Farming is used in daily farm management on dairy farms. When daily operational management will focus on individual cows and being able to understand their 'language' and translate that in appropriate decision models and SOP's (Standing Operation Procedures) it can be recommended to focus on the main processes feeding, cow, milking and manure. In the context of this paper the scores are given by experts. According to the expert group opinion within these main processes the *time budgeting* (score 9 in Table 1), *heat detection* (score 8 in Table 1), *feed efficiency* (score 7 in table 2) and *milk removal* (score 7 in

Table 3) contributed most to the sustainability improvement for daily individual cow management.

References

André, G, E.J.B. Bleumer and G. van Duinkerken, 2009. Evaluation of an application for dynamic feeding of dairy cows, In: proceedings of the 4th ECPLF conference, edited by C. Lokhorst and P.J.G. Groot Koerkamp, Wageningen July 6-8th, 25-32.

Berckmans, 2004. Automatic on-line monitoring of animals by precision livestock farming. In: F. Madec (eds), Animal production in Europe: The way forward in a changing world, Saint Malo, pp 27-30.

Berckmans, D. 2008. Precision Livestock Farming (PLF)- preface. Computers and electronics in agriculture 62: 1-1.

Groot Koerkamp, P.W.G., A.P. Bos, and E.J. van Henten, 2007. Precision Livestock farming: creating order beyond control, In: 3rd International Congress on Precision Livestock Farming, Skiathos, Greece, 3-7 june 2007.

Häni, F.J. and Pikart-Müller, M. , 2008. RISE - Maßnahmenorientierte Nachhaltigkeitsanalyse landwirtschaftlicher Betriebe : weltweit anwendbares Instrument für standardisierte Nachhaltigkeitsevaluation sowie für nachhaltigkeitsbetonte Betriebsführung und Umfeldplanung. KTBL-Schrift 467, 94 p.

Lokhorst, C. and A.H. Ipema, 2010. Precision livestock farming for operational management support in livestock production chains. In: Towards effective food chains: models and applications, edited by Jacques Trienekens, Jan Top, Jack van der Vorst and Adrie Beulens, published by Wageningen Academic Publishers, p 293-308.

Maltz, E., A. Antler, I. Halachmi and Z. Schmilovitch, 2009. Precision concentrate rating to the dairy cow using on-line daily milk composition sensor, milk yield and body weight, In: proceedings of the 4th ECPLF conference, edited by C. Lokhorst and P.J.G. Groot Koerkamp, Wageningen July 6-8 th, 17-23.

Wathes, C.M., H.H. Kristensen, J.M. Aerts and D. Berckmans, 2008, Is precision livestock farming an engineers's daydream or nightmare, an animal's friends or foe, and a farmers' panacea or pitfall? Computers and Electronics in Agriculture 64: 2-10.

Practical and acceptable Precision Livestock Farming: results from BrightAnimal

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Abstract

The EU funded Coordination and Support Action "BrightAnimal" set out in 2009 to assess what has been achieved in Precision Livestock Farming and to highlight needs for future research in the area. The goal of BrightAnimal was to identify the *practical* and *acceptable* PLF. This has been performed with a multi-disciplinary, world-wide team of experts. After two years of investigation, we present here the result of our efforts in the form of a series of recommendations.

Keywords: Precision Livestock Farming, BrightAnimal, consumer, farmer

Introduction

Precision Livestock Farming (PLF) has in recent years found itself in the cross fire between engineering, natural sciences (especially biology), and of course livestock farming. Regular conferences on PLF and their proceedings (Cox, 2003, Cox, 2005, Cox, 2007, Cox, 2009) show that the science has now secured its place among general topics.
The European Commission, through Agenda 21 and other initiatives, is committed to improving sustainable development, especially within the member states and among its trading partners. Of course, food in general plays a vital role in sustainable development and livestock farming in particular.
The original hope was that PLF, by application of precision methods, would reduce resource needs and improve the efficiencies of livestock farming, improve animal health and welfare and reduce the gap between producers and consumers. In other words, that it would contribute to more sustainable animal production systems.
The question is whether this is true.
In a keynote speech (Groot Koerkamp 2007), Peter Groot Koerkamp concluded that the contribution of PLF on sustainable development of animal production systems is not yet known and that PLF at that time was "a collection of attempts to optimize the systems of today on specific one dimensional aspects, without reflecting on their possible structural limitations or failures."
There are two main factors why PLF has not achieved the expected results:

- PLF needs to be *acceptable*
- PLF needs to be *practical*

Livestock farming is influenced by a number of stakeholder groups which of course have different interests in PLF.

- Governments, through food laws and regulations
- Animal and human welfare interest groups (e.g. NGOs)

- The food industry through specification of desirable animal attributes
- The feed industry through the provision of feed and feed additives
- Service providers
- Consumers, through their purchasing patterns
- Farmers, many of which are small scale operations

Two of these stakeholder groups are key to influencing improvements in the management of livestock farming: consumers and farmers. BrightAnimal identified consumers as the main driving force of the food market. Their decisions very much drive the innovations on the farms, be it to meet their expectancy of low food prices by improving efficiency or by providing information to the consumer via labels, traceability or other means.
Farmers of course also have a major influence. They are the ones who actually have to make the decision to implement the PLF. Livestock farmers in Europe are still relatively small operators. As an arbitrary example we show in
Table the number of agricultural holdings in a number of European countries. It can be seen that although the percentages vary, in all of presented countries the highest number of holdings has less than 100 broilers. This is an important factor that must be taken into account.

Table 1. Number of agricultural holdings with broilers, by size of the holding in 2005 (source EUROSTAT)

	Total	**1-99**	**100-999**	**1000-2999**	**3000-4999**	**5000-9999**	**10000-49999**	**50000-99999**	**>=100000**
dk	360	190	10	0	0	0	60	70	20
de	9820	8340	450	60	20	30	590	240	90
gr	181770	176870	4130	30	20	180	450	50	20
it	43680	40770	1340	190	170	60	710	260	180
at	2740	2310	60	60	40	70	200	10	
pt	122820	121500	320	100	220	210	400	60	20
uk	1970	570	150	50	20	60	460	290	380
Totals	363160	350550	6460	490	490	610	2870	980	710
		97%	**2%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**

Precision livestock farming needs to take these two stakeholders groups into account when deciding what is acceptable and practical.
Consumers will decide what they are or are not willing to buy and these decisions will, in part, be based upon what methods farmers use in seeking to improve quality and reduce costs to the consumers. Governments and interest groups can assist in this process by assessing the proposed methods and by providing additional information. However, given the economics

behind Europe's food production, the main decisions will be made by consumers and their direct representatives, the retailers.
Of course, a vast variety of methods are available, but not all are really *practical*. Where consumers are concerned, the price premium they might or might not be willing to pay for meat or fish produced using certain techniques, will mostly benefit the retail end of the supply chain – and not the beginning where the major investment has been made. It is a simple fact that most consumers buy at retailers and that premiums for special foods remains only trickle down the supply chain.
At the same time, farmers spend more and more time away from their animals doing paperwork. In order to cope with the additional work, inferior monitoring systems are sometimes installed to "replace" the farmer.
This certainly cannot be the solution. Precision Livestock Farming needs to be *practical*.
Additionally when assessing technologies, methodologies and systems in PLF for farmers – especially with respect to developing the potential role and key target technologies – one must not forget to look beyond the boundaries of Europe. In particular, one should consider those countries which have experience in PLF, and those which have large animal populations, but perhaps less technology in place. What is acceptable and practical will of course depend on the country in question. Their viewpoints need to be taken into account, both to guarantee that Europe profits from international experience but at the same time avoids creating potential trade barriers. In a world of global food supply, it is essential to take into account the opinion of those beyond the European borders.

In April 2009, the EU-funded Coordination and Support Action (CSA) "*Multidisciplinary Approach to Practical and Acceptable Precision Livestock Farming for SMEs in Europe and world-wide*" (BrightAnimal) started. Its strategic objectives are shown in detail in Table ; summarising them one could say that the project wanted to evaluate the current Precision Livestock Farming (PLF) sector with a number of international experts and find out what could possibly be called *practical* and *acceptable* PLF for small and medium enterprises (SME) in Europe – and beyond.

Table 2. Strategic objectives of BrightAnimal

SO-1:	To evaluate, assess and coordinate existing research and to extract from this a framework for PLF in Europe and beyond, with special focus on SMEs.
SO-2:	To provide practical guidance to those most directly involved in PLF (mainly farmers) where the *practicality* and the *acceptability* of the proposed PLF measures for SMEs can be explicitly taken into account.
SO-3:	To create an international network of experts in the different areas of PLF to interact in a cross-disciplinary manner and further develop the framework.

During the course of the two-year project 13 international organisations contributed research, ideas and opinions. The organisations are listed in Table 2 and their geographic distribution shown in Figure . As can be seen, the project had a strong representation from Europe, but also from all other continents.

Table 3. The scientific partners of BrightAnimal

Scientific partners	Country
AIM UK	UK
FoodReg	ES
NOFIMA MARIN	NO
Bitland	DK/FO
Danmarks Tekniske Universitet	DK
Eesti Maaulikool	EE
Institute of Quality standards & Testing Technology for Agro-products, Chinese Academy of Agricultural Sciences	CN
Consumer Goods Council of South Africa	ZA
Kasetsart University	TH
Ministry of Agriculture and Agro-Based Industries Malaysia	MY
Empresa Brasileira de Pesquisa Agropecuaria	BR
Department of Primary Industries and Resources South Australia	AU
Aalborg Universitet	DK

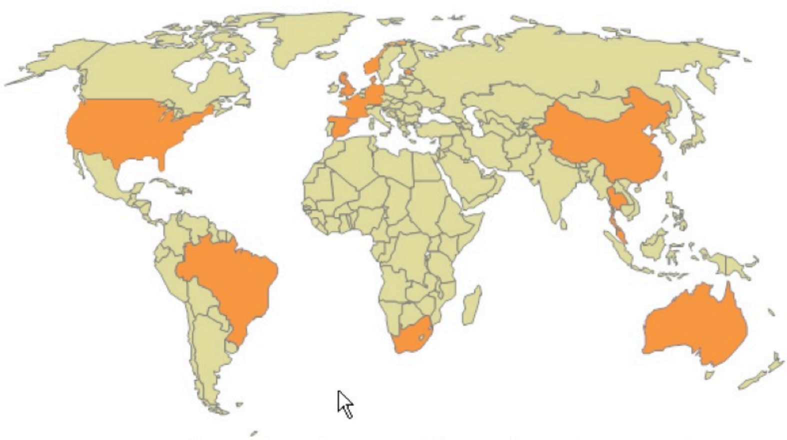

Figure 1. Geographical distribution of formal BrightAnimal partners

BrightAnimal hoped to contribute to the coordination of high quality research in a number of ways, mainly through

- Collecting, reviewing and analysing current research on technologies and systems relevant for PLF
- Creating a network and discussing key issues within that network
- Introducing the viewpoint of the international community into the European discussion
- Creating a framework for the assessment and the study of Precision Livestock Farming

- Creating high quality good practices which can serve as a model for the practical dissemination of high quality research
- Disseminating the results of this project

In particular, however, BrightAnimal produced three key outputs:

<u>Book on effective Precision Livestock Farming in Europe and beyond with special consideration of small and medium enterprises</u>

The book investigates current and near-future techniques in PLF, especially taking into account both the *practicality* for SMEs as well as their *acceptability*. Its aim is to assess Precision Livestock Farming from different viewpoints and arrive at recommendations; see section “Results and recommendations”.
The book has chapters on monitoring animal welfare health and behaviour, identification, sensory data collection and integrated systems development for PLF, Food Information Management and Advanced Traceability, Sustainability, Ethics and Societal impacts of PLF and Economic aspects of PLF.
The book elaborates on this basis a number of recommendations both for the industry as well as for research institutes and, additionally, policy makers.

The book will be available for download in May 2011. Please refer to www.brightanimal.eu for details.

<u>Good Precision Livestock Practices (GPLFP)</u>

As the second component, BrightAnimal wanted to produce detailed good precision livestock farming practices (GPLFP) for aquaculture fish, cattle, pigs and chicken.
However, due to the inability to do original research and the absence of suitable existing resources to produce such guides, we decided to convert our whole book into an editable resource for future research. Our project Wiki, together with an introductory leaflet for farmers can be accessed through our BrightAnimal website. Please refer to www.brightanimal.eu for details.

<u>The BrightAnimal demonstrator</u>

Together with the Harper Adams University College, BrightAnimal has built a demonstrator that can be visited on the college campus near Birmingham. By showcasing the Good Practices, interested parties can benefit from a highly practical look at PLF opportunities.
The demonstrator will focus initially on Harper Adams’ dairy unit and showcase existing commercial technology, such as precision feed mixing, behaviour monitoring and robotic feed push-up. The university college is negotiating currently further commercial systems to demonstrate and has plans to extend to beef, sheep, pigs and poultry in due course. Also on display are research technologies that are likely to see future commercial PLF application, such as feed intake monitoring. Harper Adams will allow virtual visitors in the future.

Work methodology

Figure 2. The BrightAnimal concept

The project was structured into 8 areas, called work packages.

- *1- Monitoring Animal Health, Environment, Behaviour and Welfare*
  This area concentrated on identifying relevant technologies from the area of monitoring in general. Most of its focus will be on the monitoring of animal health, behaviour and welfare through the different dimensions.
- *2- Identification, sensory data collection and integrated systems development for PLF*
  Animal identification systems and those for automated data capture have been assessed in this area. Existing and emerging Automatic Identification and Data Capture (AIDC) technologies have been reviewed.
- *3- Systems and Good Practises in PLF*
  This area studied Good Practises in PLF and elaborated *practical* and *acceptable* guidelines for farmers, based on the input of the other areas
- *4- Food Information Management and Advanced Traceability*
  This area represented the management of data collected on individual farms, its use for improving the efficiency of the farmer and its transport to relevant stakeholders, especially consumers.
- *5- Sustainability, Ethics and Societal impacts of PLF*
  This area represented the elements which come under the "needs to be acceptable" target of the project. It coordinated existing research on the ethical aspects of PLF in the broader sense, thereby establishing one dimension of the potential role of PLF in Europe. Societal and welfare impacts were an important area of study due to the relationship between PLF and intensification of farming systems.
- *6- Economical aspects of PLF*
  This area represents the elements which come under the "needs to be practical" target

of the project. It reviewed and coordinated research on the economical aspects of PLF and will try to distil from that a framework for the assessment of the economics of PLF technologies and systems.

In order to facilitate the discussion between the different stakeholders and their representatives, 8 public events were held in the course of the two year project. The project kicked off with a conference in Halifax with about 60 participants, held six workshops (Tartu, Copenhagen, Johannesburg) with 20-30 participants each and a final conference in Barcelona. Events were videotaped and presentations made available on the BrightAnimal website, www.brightanimal.eu.

Results and recommendations

Precision Livestock Farming was born in an attempt to help farmers cope with the challenges they are facing today. Modern livestock farming is expected to produce more and more to satisfy the growing intake of animal protein while they also have to cope with increasing animal health and welfare, reducing energy use and environmental foot print and coping with fewer and fewer suitable workers for their farms. PLF wanted to offer technology to assist farmers (e.g. surveillance systems to discover lameness) but also to improve the efficiency (optimise the feeding of the individual animal) and finally to reduce the labour cost or improve the flexibility at the farm (automatic milking systems).

Although Precision Livestock Farming is not actually a young field, it has not managed expectation very well. This has many reasons, not least of which is the complexity of animals – as compared to plants and precision agriculture. One probably has to accept that much more work is needed before PLF will become the standard way of livestock farming.

A major reason why PLF has not become more widely accepted is the relatively low adoption of PLF techniques in the field. There are many reasons for that, some of which are related to the suitability of the developed techniques and technologies, some are related to a lack of awareness, education and training of farmers and consumers, coupled with the pursuit of PLF more as an academic discipline than a practical farming development platform. Admittedly, in many areas of the world the main reason behind the lack of adoption is that labour is cheap and available – although skilled labour is in shortage almost everywhere. The need for PLF is best understood when labour is short and expensive. Another very important reason is that animal welfare is a very young consumer/retailer/legislative requirement and welfare-related PLF techniques are therefore still considered as being optional in most places.

The BrightAnimal group and its associates very much subscribe to the general idea of Precision Livestock Farming as a model for sustainable future farming. Therefore we believe that the field needs to restructure itself and in a way take itself more seriously. We have come up with a few recommendations that might provide some assistance in the process.

Marketing Precision Livestock Farming

The group around BrightAnimal firmly believes that the term "Precision Livestock Farming" is not well chosen for marketing the subject to farmers and consumers. We believe that the term reflects the fact that the field has had a very strong presence of engineers and less so of practitioners and indeed marketers. As a consequence, both farmers and consumers are not attracted to the field.

It is our impression that farmers think of "more time spent behind the computer rather than in the barn" when it comes to PLF. Although modern farmers in Europe – less in Asia and Africa – understand and appreciate the value of management systems, they miss spending more time with the animals. The term "precision" does not attract them.

Consumers are very much removed in their thinking from modern farming. Pictures of freely running animals on green grass very much dominate consumer thinking – when they don't look at the price tag. Technology and animals don't really go together in consumers' minds, unless there is a targeted effort to explain to consumers why technology may have beneficial effects, as happened with robotic organic milk farming in Denmark. Unsurprisingly enough, many of the related consumer groups and NGOs don't react very well to the term precision livestock farming.

As a consequence, we believe that a new name is essential for the implementation part of Precision Livestock Farming: a name that doesn't stress technology which anyway should only be a means to an end. We suggest using the term "**Smart Farming**" instead, respectively Smart Animal Farming in case there is a need to be more specific.

We believe that this term is catchy, short and not misleading and therefore constitutes a very good candidate for a marketable concept. Of course, the existing PLF community should be involved in the creation of this new term and marketing studies should validate that this is a term that farmers and consumers can relate to positively.

Essentials of Smart Farming

1. *Smart animal farming is the approach to farming that aims to achieve economically, environmentally and socially sustainable farming through the observation, interpretation and control of the smallest possible group of animals.*
2. Smart farming considers the bidirectional exchange of data essential and employs traceability for that purpose.
3. Smart farming is a discipline where farmers, engineers, biologist and economists work together for the best possible results.
4. Smart animal farming has profound respect for the individual animal and tries to detect its needs as timely as possible.

The need for a ménage à quatre: biologists, engineers, economists and... of course: farmers

The field that we will call Smart Farming from now on, has suffered from an imbalance in representation. The engineering side is dominating while the biological side is underrepresented. Economists have picked up this area very little and developments have been made without the benefit of involving the farmers (or consumers for that matter). As a result, one can find a range of research and products that

- Fail to match the real needs on farm
- Fail to arouse interest in farmers
- Have not been tested for economic viability

A good example for a broader approach is the Marie Curie Action BioBusiness where a clear emphasis has been made on bringing biologists and engineers together.

Making more of data: interpretation and control

Many of the research efforts that traditionally have been spent on Smart Farming relate to sensors rather than systems that interpret data from sensors and control the production process. A few counterexamples exist especially in climate control, but by far not enough.

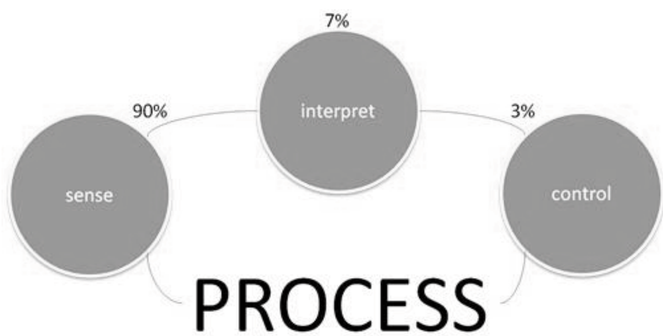

Figure 3. Rough estimate of research effort by category as presented in EC-PLF conferences

While sensors and sensing system such as image analysis and sound analysis systems are essential to Smart Farming, because they deliver the raw data stream, interpretation and control/actuators are probably of much stronger interest to the final users, i.e. the farmers.

While some commercial firms have realised this and provide systems that attempt to make a step in this direction, there is not enough research effort made in this area. Of course, the automation of interpretation and control is a very complex subject, but should therefore be so much more rewarding.

It should also be mentioned that not necessarily all steps in Smart Farming by definition need to be fully automated – Smart Farming is about *assisting farmers* to make good decisions, not about automatic farms.

Research funders are again called upon to emphasise the need for a balance between controlling, interpretation and sensing. We believe it makes sense to ask researchers to use a top down approach (i.e. from control to sensing), rather than a bottom up approach (from the sensor to control).

Catering to a need: creation of a service sector
Technology still works best in clean, cool and nicely ventilated environments. Farms are often far away from these optimum conditions. In addition to dealing with manure, high temperature ranges and gases, not all farms even in Europe have access to guaranteed electricity all the time. In addition, farmers are not necessarily very techno-friendly or savvy.

Technology in such conditions is likely to fail and many times farmers cannot be bothered to take care for the technology components.

In addition, much of the currently existing technology requires a larger amount of initial investment. In order to responsibly make that investment farmers have to understand and evaluate the need for and the value of a particular technology. At best, this is a very difficult task.

We believe that there is a great need for a service sector that

- Takes care of technology components
- Interprets data coming from sensors
- Dispatches advice to farmers
- Works on the basis of "technology as a service"
- Involve *users* in the development

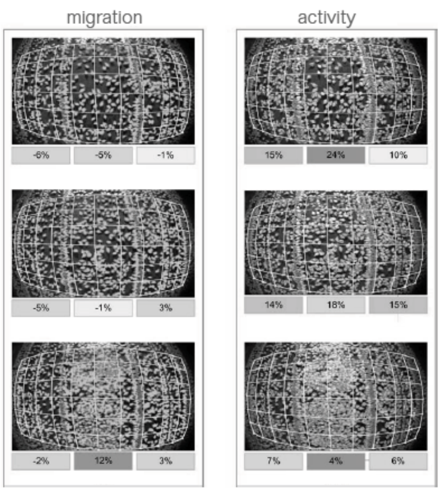

Figure 4. Pictures from eYeNamic taken from Fancom brochure; www.fancom.com

The product "eYeNamic" of the company Fancom is an example for such a service product. eYeNamic provides the basic service of assisting poultry farmers inspecting their animals at least twice a day as requested by EC directive 2007/43/EC laying down minimum rules for the protection of chickens kept for meat production[1]. Farmers pay an annual subscription fee and for that Fancom installs the hardware, maintains it and most importantly monitors the behaviour of the animals. Three cameras mounted in the ridge of the house continuously monitor the floor below.

Analysis software translates these images into an index for animal migration and activity in the house, both of which are valuable indicators of animal welfare.

However, the economical situation of most farmers does not make them a very good target for the service sector. Therefore some economical and social research is needed on how to build a viable service industry for Smart Farming.

[1] See http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2007:182:SOM:en:HTML

Shorten the distance to the consumer

Many consumers still associate meat production with production systems that are impossible to sustain at the price they are willing to pay for its products. In most countries the use of intensive farming practices is unavoidable to produce enough protein and at a price that is accessible for the majority of the population. Animal production as in the "good old times" is deemed to be the best possible way of raising animals – without clear scientific justification.

Consequently, consumers – with some exceptions – have a general aversion to the use of technology in animal farming and the animal product industry has made only timid attempts to educate consumers in these matters. To make an example, there would probably be few consumers who would object to video analysis to detect lameness in a much earlier stage or sound analysis of pig coughs to reduce the need for antibiotics.

We believe that the distance of consumers from actual production methods does not help the industry at all. The ignorance of consumers simply contributes to a general scepticism towards the food industry in general and animal production specifically.

Quite on the contrary, we believe that farmers are currently leaving out marketing opportunities for their products and their production. Based on an approximation of consumers and farmers, new models of interaction could be very beneficial for farmers – just as rural tourism turned out to be very successful. Such initiatives could include

- Social networks and farming – linking consumers and interested stakeholders through social networks with farmers
- Micro –investments for farmers from consumers (crowdsourcing)
- FarmCams – observation of farming practices by schools, NGOs and interested consumers
- Be a farmer for a day – let consumers "take care" of specific animals or animal houses

We believe that social scientists and marketing experts should study how to bring consumers gradually up to the reality of animal production. They should be educated how to appreciate controlled, animal centric production and motivated to look out for attributes that make modern production better for the animal.

Research funding bodies again have a key role in sponsoring the research, but animal producers' groups should also realise the potential of shifting their marketing towards a more realistic picture of animal production.

Make food production (more) transparent

The feed – animal – food production chain has missed, in most places and most animal production systems, the economic potential of exchanging data bi-directionally. We have seen only a few examples of bi-directional data exchange in the chain, for instance in modern salmon farming where ties between feed companies and grow-out producers are tight. The exchange of slaughter data (fish composition, size, form factor) and production data (illnesses, growth curves, environmental data) in these chains are seen as mutually beneficial both to enable short term decisions (advice on feeding, temporary change of feed composition) and longer term analysis (feed composition change due to statistical data from the whole customer base).

The exchange of data along the feed – animal – food chain is most important and beneficial when it is done on small groups or individual animals. The observation of growth parameters and the ability to feedback detailed slaughter data into the chain and link that data to feed intake unlocks an enormous optimisation potential. This is where traceability links into the Smart Farming approach.

Comparative analysis – i.e. how am I doing with respect to other farmers in specific geographical regions – could be highly beneficial for farmers. Slaughterhouses could use such data for supplier evaluation/scoring, increase of on-spec production and reduction of the risk to damage their reputation. The availability and the exchange of laboratory analysis data along the chain could reduce inefficiencies and increase the trust along the chain[2].

Finally, increase of availability of data in the chain can be used to construe a convincing picture for final consumers. The adherence to certain standards or practices (organic, welfare standards, Halal to name a few) could be demonstrated more convincingly than it is done today, thereby increasing the general acceptance of animal farming and raising the status of farmers and farm workers (with all the subsequent benefits that this would have).

Traceability is the exactly right tool to achieve more transparency in the feed – animal – food chain. However, standardisation and harmonisation is urgently needed, especially across borders. Practices like incompatible animal passports or identification systems are a serious blocking stone and prevent the unlocking of an important economic potential.

Here, more research is needed, but also the willingness to establish and stand behind a common infrastructure, a European traceability framework. This requires first of all lobbying and secondly marketing money to promote and implement such a framework. National efforts may serve as examples, but a true system needs to be transnational.

<u>Elaborate a holistic farm evaluation system and related standards</u>

Market differentiation for farmers is a very difficult task. Most farmers spend a lot of time and effort in making their production system especially efficient, well-run and animal friendly. However, they have no way to communicate this to their clients, NGOs, regulators or consumers.

In addition, the intricate inter-relationships between key indicators make it difficult for farmers to manage them manually. Concentrate feed for dairy cows, for example, has an impact on animal welfare, animal health, milk production efficiency (and therefore directly farmer satisfaction), economy and environmental load.

Isolated schemes exist that evaluate welfare, environmental impact or financial stability of an enterprise.

[2] For the implementation of this concept, multiple identification and the pathways concept, as part of object-connected ICT, are very relevant.

Figure 5. The 6 dimensions of farm decision making

However, we are not aware that there is any scheme that would

(a) Accept the complexity of farmers' decision making by making a holistic approach to farm management
(b) Express farmers' efforts in a compact way
(c) Assist farmers in obtaining or maintaining a certain level of production quality

Research is needed how to construct an evaluation/management system that would

- Allow farmers to manage specific aspects individually while maintaining an easy to understand overall "grade"
- Assist farmers in the management of his/her score by highlighting the interrelationship of certain production parameters
- Provide a realistic picture for buyers, consumers and legislators
- Promote European farming and provide a basis for objective market differentiation

In relation to this, there is also a need for more formal Good PLF (or Smart Farming) Practices, beyond what BrightAnimal can deliver. There is a need for standards in these areas, both relating to farming practices, technology use and documentation. Documentation of processes and traceability is probably both the easiest and the most essential area to standardise, because standardisation in this area does not require farming practises to change (which would be difficult to accomplish) and also because the recordings need to be understood and exchanged, and then a standard is essential. In particular standards are needed for defining the name and content of that which is being recorded, so that recordings made in one case can be directly compared to recordings made in another case, which in turn is a prerequisite for comparison, benchmarking and for building a database of experiences.

Awareness, education, training, communication and success stories

Perhaps the clearest deficit in current Precision Livestock Farming is the lack of communication, education and training, resulting in a lack of awareness in consumers and farmers, but also in practitioners.

It would be highly beneficial if Smart Farming and its academic variant Precision Farming became part of the tertiary education. There is a dire need to train experts in these fields and we believe that Smart Farming should be part of at least master studies, if not bachelor studies in the relevant fields.

Part of the communication strategies of Smart Farming should be the demonstration of all benefits including economic benefits for farmers (and other supply chain members). There is a need for validated success stories related to the use of Smart Farming technology and principles, for independent cost/benefit calculations and return on investment estimates, for a database of cases and technology applications to be built up. This will both increase the motivation of farmers and increase in the general the acceptance of smart farming technologies and principles.

Concluding remarks

BrightAnimal has produced a number of important results that will hopefully help reshape the sector and lead it to successful implementation. However, BrightAnimal could only go so far: as a Coordination and Support Action it could only collect and assess existing research efforts. Research and demonstration activities are not possible with this funding scheme.

After having spent two years discussing Precision Livestock Farming, we have come to the conclusion that the most important factor hindering a larger implementation of PLF in the field is *communication*. We firmly believe that there is a strong need for research and demonstration that packages existing technology and showcases it in a way that key stakeholders, especially farmers, understand.

We hope to have laid out the foundations of what Smart Farming should become; others will have to make a reality.

Acknowledgements

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References

Cox, S. 2003. Precision Livestock Farming, 2003 edited by S Cox, Wageningen Academic Publishers

Cox, S. 2005. Precision Livestock Farming, 2005 edited by S Cox, Wageningen Academic Publishers

Cox, S. 2007. Precision Livestock Farming, 2007 edited by S Cox, Wageningen Academic Publishers

Cox, S. 2009. Precision Livestock Farming, 2009 edited by S Cox, Wageningen Academic Publishers

Koerkamp, P.G. 2007. Precision Livestock Farming 2007 edited by S Cox, Wageningen Academic Publishers

Building support networks around an emerging technology using a focus on development: the example of automatic milking in Australia.

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Abstract

Automatic milking systems (AMS) have become a mature technology in some dairy production regions, particularly in Europe. In Australia there has been minimal uptake but in the last three years more than fifteen farms have installed AMS. Farmers investing in AMS face significant challenges in pre-purchase and post-installation decision-making and farming system adaptation, particularly within the context of predominantly grazing-based systems. This paper aims to report initial findings from a project being undertaken to help position the dairy industry for optimal private and public support of AMS farmers. The project uses a development-led approach to determine the needs of farmers, service providers, and other stakeholders. Early findings suggest that farmers may need different forms of support at three key decision points (pre-purchase, pre-installation, post-installation). Additionally there is a requirement for support in the greater service sector such as finance providers, milk company advisors, and technology retailers.

Keywords: automatic milking systems; capacity building; program development; decision-making

Introduction

The use of automatic milking systems (AMS) has seen rapid expansion in the last decade in Europe, and approximately 8,000 units were being used globally by 2007 (Svennersten-Sjaunja & Pettersson, 2008; de Koning, 2010). To date this trend has not been mirrored in Australia. Potential reasons behind the lower uptake in Australia compared to Europe are multifaceted and include differences in farming systems (predominantly grazing-based), larger average herd sizes with 215 cows/farm in Australia (Dairy Australia, 2008), farm financial constraints due to drought and milk price, fit of the technology with farmer attitudes about farming, and cost and availability of AMS technology and support. Factors impacting the uptake of AMS in the northern hemisphere have been explored by authors such as Ketelaar-de Lauwere (1999), Rodenburg (2002), Sonck (1995), and Svennersten-Sjaunja and Pettersson (2008).

The first commercial Australian AMS farm began operation in Australia in 2001 (Greenall *et al.*, 2004), however there were no new commercial installations until 2008. This has begun to change with a small number of AMS units installed in Australia in the past three years. Approximately fifteen AMS-farms were operational nationally at the time of writing, with several more installations expected. All units have been provided by one of two dairy technology retailers who face a strong challenge to install and support the technology in the context of geographically spread farms.

AMS represents a system-changing option for Australian farmers. As other authors have highlighted this technology requires significant management adaptation (Svennersten-Sjaunja & Pettersson, 2008; de Koning & Rodenburg, 2004). Installation of AMS potentially impacts the decision making margin of error inherent in dairy farm management. For example, if inadequate attention is paid to grazing management or animal health practices, then cow traffic and/or milking frequency can be impacted. The development of robust management practices on pasture-based AMS farms is seen to be of significant importance in the overall success of the AMS implementation (Donohue *et al.,* 2010; Kerrisk, 2009; Ketelaar-de Lauwere, 1999). de Koning and Rodenburg (2004) stated that 'a high level of management and realistic expectations are essential to successful adoption of automatic milking'.

Studies into the use of precision dairy technologies (including milk meters, activity sensors, conductivity sensors) in Australia indicated that support networks were disjointed and lacked key members who could span forms of knowledge and proprietary constraints (Eastwood *et al.,* 2009). The learning challenge faced by users of these technologies was highest during the first six months or up to the end of a full lactation with the systems. Also apparent in the precision dairy community studied by Eastwood *et al.* (2009) were issues around delineation of roles for private companies and industry organisations in providing learning support for precision dairy farmers. AMS potentially provides another example of a precision technology where the required learning support and knowledge transfer networks are not adequately facilitated by either retailers or industry service providers.

Overseas experience shows that reversion to conventional milking systems can occur where farmers enter such system-changing investments without adequate understanding of AMS characteristics (de Koning, 2010). Oudshoorn & de Boer (2005) stated that rejection of technologies such as AMS can occur due to not only economic reasons, but also ecological or societal concerns. Acceptance or rejection of technologies such as AMS can occur due to a mix of many factors including financial, life stage, farm type and attitudes (perceptions of technology, influence of peers, and relationship with risk) (Svennersten-Sjaunja & Pettersson, 2008; Kerrisk, 2009; de Koning, 2010).

Current arrangements around agricultural innovation systems tend to include an expectation that farmers are best-placed to manage on-farm adaptation of technology, and therefore there is minimal funding of development and knowledge brokering capacity (Klerkx & Leeuwis, 2009). The initial installation and adaptation process of precision dairy technologies in Australia is managed by the farmer in conjunction with the technology retailer however past research has shown the limitations associated with relying on privately delivered adaptation support (Eastwood *et al.,* 2009). The potential involvement of public or industry funds in delivering technology support warrants a development approach focussed on 'taking more time' to get ongoing investment in capacity development right.

This paper outlines a development program, which was instigated not only to support current AMS farmers in Australia, but also to determine the support potentially required by later adopters of a technology, which shapes as being highly important in the future of Australian dairy farming. The aim of this paper is to outline a potential framework for developing support capacity around a high challenge and system changing technology such as AMS. The research presented here provides initial reflections from an evolving development project run by the Department of Primary Industries in Victoria, Australia.

Method

Using a development focussed model for extension design

Technology extension programs are often characterised by a pre-determination of how to deliver a 'product' to users (Guerin & Guerin, 1994; Pannell *et al.,* 2006). The technology-transfer model focuses on extending research results or technology products to the target market, with an under-emphasis on the development stage of the research, development and extension (RD&E) cycle (in this context 'development' can be defined as the process of arranging knowledge and systems regarding delivery of support). Examples of technology-transfer can be situations where research is conducted based on industry priorities, the results of which are then extended to users. A weakness of this approach is that research results, achieved in controlled environments, may not reflect the complex issues that exist in commercial application. Alternatively a new technology may have unforeseen or unintended consequences when attempting to use it inside a farming system. The lower than expected adoption rates of precision farming technologies globally (Bewley, 2010; Kutter *et al.,* 2009) could be seen as an example of the outcome of neglecting development in the RD&E process. Potential issues also arise when extension programs are designed to 'deliver' research products to farmers, without measured consideration and piloting of the actual need and scope of the extension demand.

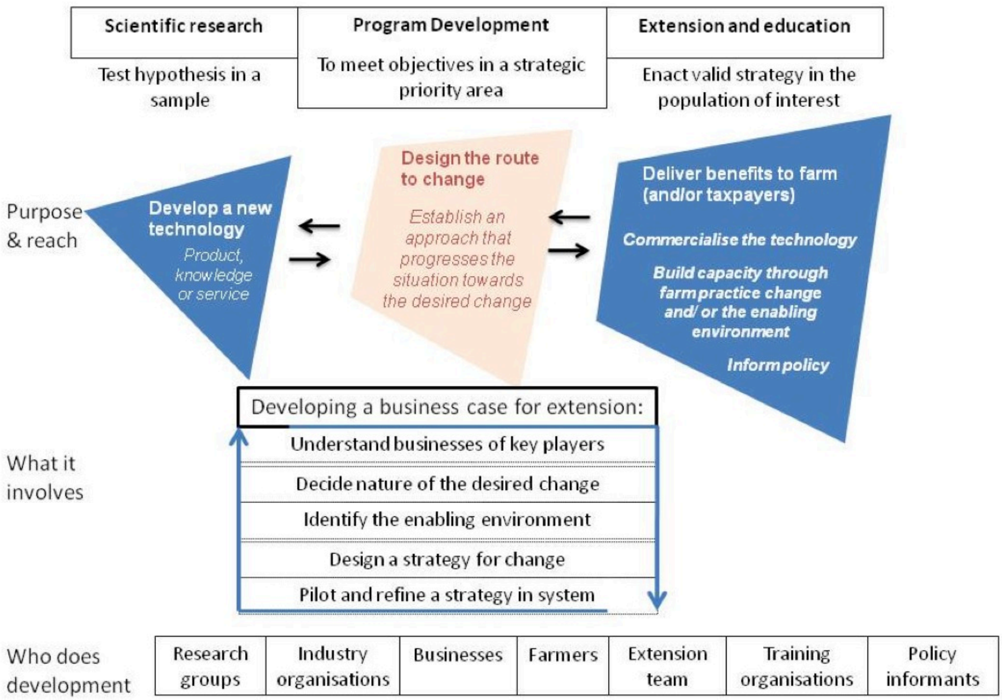

Figure 1. The development-led innovation model

The development-led innovation model of Brightling and Nettle (2010) aims to 'integrate RD&E systems and co-develop new technologies or knowledge through strong linkages between players' (Fig. 1). They see that such an approach is required to reduce reliance on technology-push that focuses on research and its universal relevance. The model outlines an approach to innovation which follows three main steps: locate program activities on the RD&E continuum, establish a dynamic program development team, and work through the program development steps of:

i. Understanding the businesses of key players
ii. Deciding the nature of the desired change
iii. Designing a 'route to change' strategy
iv. Identifying features of the enabling environment
v. Piloting the approach in the target audience
vi. Making the business case for extension/education

<u>Creating an AMS knowledge network – an example of program development</u>

The AMS development project discussed in this paper was set up as an 'action-pilot' with a dual focus. The first aim was to *begin* developing some support capacity across Australia for farmers making the decision to invest in AMS. The wider aim was to pilot 'a capacity development model for the Australian dairy industry to support the integration of AMS into farm systems'. Through this approach the pilot project will describe the best way industry can support farmers to:

1. Determine if AMS is a logical fit for their system,
2. Identify and plan for key system changes prior to installing AMS, and
3. Optimise their farm business after AMS has been installed.

The project began in mid-2010 and involved three main spheres of activity: a guiding development group, a regional advisory group, and a national capacity building network. The roles, members and main activities associated with each group are outlined in Table 1 below.

Table 1. Roles, members, and activities of groups in the AMS development project

	Role of group	**Members**	**Activities**
Development group	- Plan and adjust development project activities	Extension and research personnel	Occasional meetings (3-4 per year)
Regional advisory group	- Providing feedback from the service sector; - Input around AMS market segments; - Develop hypothetical advisory network maps around AMS market segments	Finance, AMS retailers, dairy company field officers, farmers and consultants	Workshops as required (2-3 across life of project)
Advisor network	- Build capacity of a core of independent AMS advisors nationally; - Pilot a capacity building approach for AMS advisors	National extension officers, AMS researchers Guest input from AMS farmers, service providers	Four two-day workshops throughout the project, including visits to commercial AMS farms and research farms.

<u>Describing the development-led innovation process in an AMS context</u>
At the time of writing, the project was underway. Therefore, this discussion focuses on some early reflections against the development-led innovation framework described above. The project design followed the three steps suggested by Brightling and Nettle (2010) in their model.

a. Locate program activities on the RD&E continuum
AMS represents a proven technology globally, and examples of its use in Australia to date have shown it to be a feasible option. However, there are some critical questions around its integration into pasture based farming systems. Research from the New South Wales based 'FutureDairy' project had developed management guidelines for the technology (Kerrisk, 2009), but little was understood about the enabling environment for the technology. Uncertainty existed as to how the technology might be adopted in Australia, the roles of private industry vs. industry/state based extension and education, how farmers might go about making investment decisions and what kind of support was warranted.

The project was located on the RD&E continuum at a point where primary research into the technology had been conducted, but an understanding of the farming systems context, and potential farming systems change, was required before design of further research and extension is undertaken. It is a developmental context as the outcome from the work is a business case for future investment in service delivery and capability development.

b. Establish a dynamic program development team

A core group of development personnel was engaged from within the Department of Primary Industries Victoria (DPIV) team, and this group was convened to undertake the detailed work of the development. A University researcher was also added to this team. Experts in AMS from both Australia and New Zealand (NZ) were then co-opted to provide specific input into the project development when required. The development group was designed to be as flexible as possible, meeting when and if required and having an open agenda to react to changes in the development environment. Other groups which fed into the development team were designed to be targeted in their mandate, for example aimed at addressing key questions (regional advisory group) or providing a platform for ongoing engagement (advisor network).

c. Developing a business case for extension

Program development involves five iterative steps which are not necessarily sequential but build toward the development of a business case. The steps are considered to be a guide rather than a recipe for success, and provide a potential pathway towards the end-point of a business case for further research and extension in the area, which in this case is building AMS support capacity.

i. Understanding the businesses of key players

This step is aimed at positioning the innovation in the context of the main communities of interest and potential users. The two key groups in the context of this project were farmers and service personnel. Understanding and positioning Australian farmers in respect to their possible approach to AMS investment and management is being undertaken using a market analysis technique adapted from Waters *et al.* (2009). Four case study typologies were derived through adaptation of previous attitudinal analysis of Australian dairy farmers (ibid.). Potential size of the future AMS market has also been estimated through industry statistics on intentions for upgrading milking equipment.

To understand the service sector around AMS a regional advisory group has been engaged (see Table 1). Around this group research activity is planned to develop social network maps of the service sector and to review international experience of AMS adoption and support networks over the last two decades. The regional advisory group will be used to validate findings from this research, and to refine support needs for the service sector.

ii. Deciding the nature of the desired change

The project development hinged around building an understanding of what change was required in the AMS support capacity space. This was an important feature of the development-led approach, minimal predetermined assumptions were made regarding the form of research and extension which might be required to support AMS farmers. The project development team started out by describing the key questions farmers could be asking around

AMS. This then led to broad development questions that needed to be answered. These questions, and associated approaches to capacity building, will be negotiated throughout the project with the development team, co-opted experts, regional advisory group, and the advisor network.

iii. Designing a 'route to change' strategy
The route to change needs to consider the potential roles of people involved and aim for simplicity on implementation. A business plan for future investment in capacity development is the primary output of the project. This will describe the enabling environment that will be most conducive to effective integration of AMS in Australia and how industry/government could invest to support sustainable change.

iv. Identifying features of the enabling environment
In this step the level of capacity required by the people and systems involved is ascertained. This is a primary objective of the project, and the guiding questions are aimed at building an understanding around the approach farmers might take to investing in AMS, the information they may be sourcing and who it is they will seek out to help them make a decision.

v. Piloting the approach in the target audience
In designing the project the development team were conscious of the recent expansion in AMS installations (an increase from 4 units to over 50 in 2 years) and the subsequent potential demand for advisory support in the near-term. Counter-balancing this was uncertainty over whether the recent AMS uptake was indicative of a trend, or more of a spike brought on by short-term government incentives and a milk price spike. Recent data also suggested that only 3 percent of dairy farmers were considering AMS investment (Mackinnon *et al.*, 2010) with only a proportion of these expected to actually install the technology.

With the considerations above in mind a pilot capacity building program was included in the project. The approach involved assembling extension staff from the main dairy regions of Australia and one from NZ. The aim of this group was to rapidly build the industry's capability to support farmer decision making in the short term through a series of workshops and training exercises. It is not expected that participants in this process will become AMS experts, rather that they will know enough of the issues and challenges associated with AMS that they can support farmers to ask the right questions.

vi. Making the business case for extension/education
The final step is the creation of a business case detailing how to move forward with an extension or education program. The business case should outline the 'route to change' and describe the delivery method including structures for evaluation and measures of return on investment. The interim project outcomes indicate that a business case for AMS capability development needs to focus on several key areas including: positioning of advisory capacity and information needs, private/public roles and responsibilities, specific and ongoing knowledge sharing structures.

Preliminary results and discussion

The project was continuing at the time of writing, and this paper presents an interim review of the outcomes. The focus of the project was to build towards creation of the business case described above.

Positioning of advisory capacity and information needs

The development process has identified five main areas where farmers might require advisory support in the AMS purchase, installation and implementation process:

- Managing voluntary movement & cow traffic (farm layout and voluntary movement)
- Animal husbandry in AMS systems (animal husbandry pre-installation and post installation – including reproduction, udder health and related milk quality, lameness)
- Making AMS technology work for you (regulations, milking tasks, maintenance of machinery and infrastructure, labour)
- Profitable feeding for AMS systems (managing supplement/concentrate use, managing home grown feed under voluntary movement)
- Making wise AMS investment decisions (finances, enterprise growth)

The next aim for the project will be to determine the specific features of these topic areas that are required by farmers and the relevant service sector. Additional factors to consider are: the form of knowledge delivery (web-based, one-on-one, guidelines, workshops); who should deliver the information (independent extension personnel, technicians, consultants); and where is the knowledge AMS-specific as opposed to more general farm management support.

Public/private roles

AMS technology is a commercial product, and as seen globally the AMS space in Australia is highly competitive and technology retailers place value on their proprietary knowledge around on-farm use and support structures. Additionally there is an ongoing debate around the role of public or industry-funded programs in supporting agricultural R&D (Klerkx & Leeuwis, 2008). A key aspect of the business case will be to address the positioning of private and public AMS support. The regional advisory group will have a major role to play in the determination of this balance.

Knowledge sharing structures

An important feature of ongoing innovation systems is a demand-driven knowledge creation and sharing structure (Eastwood *et al.,* 2009). An integrated private/public extension approach would need to consider a structure could be created and maintained to not only share knowledge of AMS farming systems held by technology retailers and the service sector, but also that of current AMS farmers.

Conclusion

A framework for building AMS capacity has been set up to determine the needs of farmers and other stakeholders around AMS adaptation and learning in Australia. The framework has aimed to avoid a pre-determination of the industry needs around AMS support capacity.

Engagement has involved interested parties in the AMS domain to enable a targeted and integrated route-to-change. The interim results from this approach show that farmers may need different forms of support at three key decision points (pre-purchase, pre-installation, post-installation). Additionally there is a requirement for support in the greater service sector such as finance providers, milk company advisors, and technology retailers. The development-led innovation approach adopted for this project will enable the creation of a business case for AMS support in Australia which is positioned to strike a balance between private and public responsibilities. Through a conscious focus on development it is hoped the business case will provide a more targeted, efficient, and effective path forward for AMS extension than if an extension program had been derived from assumptions of farmer needs.

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References

Bewley, J. 2010. Precision Dairy Farming: Advanced Analysis Solutions for Future Profitability. Paper presented at the The First North American Conference on Precision Dairy Management, Toronto, Canada.

Brightling, P. and Nettle, R., 2010. Development-led innovation: A new model for operationalising RD&E. Accessed 25 October 2010: http://www.dairyaustralia.com.au/Our-Dairy-Industry/Dairy-Moving-Forward.aspx

Dairy Australia, 2008. Australian Dairy Industry in Focus 2008. Dairy Australia, Melbourne.

de Koning, K. and Rodenburg, J. 2004. Automatic milking: State of the art in Europe and North America. Proceedings of Automatic Milking - A Better Understanding. Lelystad, the Netherlands. Wageningen Academic Publishers, Wageningen, The Netherlands.

de Koning, K. 2010. Automatic milking – Common practice on dairy farms. Paper presented at the The first North American Conference on Precision Dairy Management, Toronto, Canada.

Donohue, R. H., Kerrisk, K. L., Garcia, S. C., Dickeson, D. A. and Thomson, P. C. 2010. Evaluation of two training programs aimed to improve early lactation performance of heifers in a pasture-based automated milking system. Animal Production Science 50(10): 939-945.

Eastwood, C.R., Chapman, D.F. and Paine, M.S., 2009. Farmers as co-developers of innovative precision farming systems. In, Bregt, A., Wolfert, S., Wien, J.E., & Lokhorst, C. eds. EFITA (European Federation of Information Technology in Agriculture) Conference '09 - 7th EFITA Conference. Wageningen, The Netherlands 6-8 July 2009. Wageningen Academic Publishers: The Netherlands.

Guerin, L. J. and Guerin, T. F. 1994. Constraints to the adoption of innovations in agricultural research and environmental management: a review. Australian Journal of Experimental Agriculture, 34, 549-571.

Kerrisk, K. 2009. Management guidelines for pasture-based AMS farms. Dairy Australia. Accessed (25/11/10) http://www.futuredairy.com.au/home.php.

Ketelaar-de Lauwere, C. C., Ipema, A. H., van Ouwerkerk, E. N. J., Hendriks, M. M. W. B., Metz, J. H. M., Noordhuizen, J. P. T. M., and Schouten, W. G. P. (1999). Voluntary automatic milking in combination with grazing of dairy cows: Milking frequency and effects on behaviour. Applied Animal Behaviour Science 64(2), 91-109.

Klerkx, L. and Leeuwis, C. 2008. Institutionalizing end-user demand steering in agricultural R&D: Farmer levy funding of R&D in The Netherlands. Research Policy, 37(3), 460-472.

Klerkx, L. and Leeuwis, C. 2009. Shaping Collective Functions in Privatized Agricultural Knowledge and Information Systems: The Positioning and Embedding of a Network Broker in the Dutch Dairy Sector. The Journal of Agricultural Education and Extension, 15(1), 81 - 105.

Kutter, T., Tiemann, S., Siebert, R. and Fountas, S. 2009. The role of communication and co-operation in the adoption of precision farming. Precision Agriculture-Online First, 1-16. http://www.springerlink.com/content/c1x617pw33k53265/ (Accessed 25/11/10)

Greenall, R. K., Warren, E. and Warren, M. 2004. Integrating Automatic Milking Installations (AMIs) into Grazing Systems - Lessons from Australia. Proceedings of Automatic Milking - A Better Understanding. Lelystad, the Netherlands. Wageningen Academic Publishers, Wageningen, The Netherlands.

Mackinnon, D., Oliver, M. and Ashton, D. 2010. Australian dairy industry: technology and management practices, 2008–09. ABARE–BRS research report 10.11, Canberra, Australia.

Oudshoorn F.W. and de Boer I.H.M. 2005. Survey of the sustainability aspects of Automatic Milking Systems (AMS) in organic dairy production. In: S. Cox (Eds.), Precision Livestock Farming ’05, (pp. 193-199). Wageningen: Wageningen Academic Publishers.

Pannell, D. J., Marshall, G. R., Barr, N., Curtis, A., Vanclay, F. and Wilkinson, R. 2006. Understanding and promoting adoption of conservation practices by rural landholders. Australian Journal of Experimental Agriculture, 46, 1407-1424.

Rodenburg, J. (2002). Robotic milkers: What, where... and how much!!?? Paper presented at the Ohio Dairy Management Conference, December 16 and 17, 2002.

Sonck, B. R. (1996). Labour organisation on robotic milking dairy farms. PhD dissertation. Wageningen Agricultural University. 201pp.

Svennersten-Sjaunja, K.M. and Pettersson, G. 2008. Pros and cons of automatic milking in Europe. Journal of Animal Science 86 (Suppl.1):37-46.

Waters, W., Thomson, D. and Nettle, R. 2009. Derived attitudinal farmer segments: A method for understanding and working with the diversity of Australian dairy farmers. Extension Farming Systems Journal, vol. 5, no. 2

Identifying on adoptable diagnostic technique and modifiable risk factors for clinical peste des petits ruminants (PPR) from S. A. Quaderi Teaching Veterinary Hospital (SAQTVH) of Chittagong Veterinary and Animal Sciences University (CVASU), Bangladesh

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Abstract

Application of hospital register data in Bangladesh is very rare. In this study, SAQTVH register data was used to describe the clinical features and epidemiology of PPR virus infection. Initially, the clinical diagnostic protocol was validated and followed for the diagnosis of the PPR patient in SAQTVH of CVASU by antigen detection technique. The Cohen's kappa statistics was applied to check the agreement between two diagnostic protocols. A very good agreement was found between to diagnostic protocol. To identify the risk indicators, binomial probability test were used where a test proportion of 0.50 and a significant level of $p<0.05$ was used.

Keywords: Adoptable, modifiable, risk factors, PPR, probability.

Introduction

Peste des petits ruminant (PPR) is a highly viral contagion of goat and sheep (1, 2). The causal agent of the disease is peste des petits ruminant virus (PPRV) that is a morbillivirus of the paramimyxoviridae family (3). In non protected animals the morbidity rate is 90-100% and in severe outbreaks mortality can reach up to 100% (4, 5). The disease was first described in early 1940s in West Africa (6). Recent distribution of the disease is very wide in respect to geographical areas. Increased number of the endemic county over the time period indicates that the disease is widely distributed and spreading in equatorial Africa, the Arabian Peninsula, and part of Indian subcontinent (7).

PPRV infection almost always shows significant clinical signs and findings in clinical phase of the infection on which a proper diagnosis can be made. This febrile disease is clinically characterized by high fever, pneumonia, mucopurulent ocular and nasal discharge, necrosis and ulceration of the oral mucosa, profuse diarrhea and dehydration (3-5). Clinical findings in PPR is unequivocal and may be sufficient for the diagnosis PPR in endemic areas and virus isolation and histopathology is essentially suggested for previously unaffected areas and areas where the disease is sporadic (8).

Bangladesh faced the first outbreaks of peste des petits ruminants (PPR) in the year 1993, a serious outbreak had been occurred in the border belt of the south eastern districts of Bangladesh (7, 9, 10). The outbreak which was resembled to Rinderpest was confirmed later by the reference virology laboratory of Pirbright, UK as PPR (9). Since 1993, following the first outbreaks recorded in Bangladesh PPR became endemic and remains as a major disease problem in the goat population in Bangladesh. Although PPR is prevalent in Bangladesh from about two decades very little information is known about the epidemiology of this disease in Bangladesh (11). More over, the country is facing a significant economic loss every year due to the high morbidity and case fatality rate that is not estimated yet.

S. A. Quaderi Teaching Veterinary Hospital (SAQTVH) of Chittagong Veterinary and Animal Sciences University (CVASU) is a general veterinary hospital and referral centre for the Chittagong metropolitan city and rest of the Chittagong district in Bangladesh. Significant number of out patients of SAQTVH, CVASU is goat of different breeds with different diseases and disorders of which PPR is one of the common diseases (12). Diagnosis of the patients at SAQTVH, CVASU is mainly done by anamnesis, signalment, clinical findings and if required by laboratory findings. Individual patients in this hospital are registered with unique patient identification number. Each clinical case is recorded in the prescribed case register with animal history, population history, clinical sign, clinical findings, laboratory findings and presumptive or confirmatory diagnosis.

A questionnaire based case control study was conducted on patients presented at veterinary hospital to elucidate the association between the PPR infection and possible determinants. Risk factors investigated included demographic and managemental attributes. An unconditional binary logistic regression was applied for using backward elimination procedure to asses the possible associations. Three factors remained statistically significant in the final model: Black Bengal breed (OR 4.694 [95 per cent CI 1.164 – 18.292]), communal grazing (OR 4.240 [95 per cent CI 1.029 to 17.473]) and introduction of new goats in the herd (OR 5.267 [95 per cent CI 1.167 to 23.853]).

Materials and methods

<u>Sample:</u>

The study was conducted over fifty (50) weeks in the year 2009 at S. A. Quaderi Teaching Veterinary Hospital (SAQTVH), Chittagong, Bangladesh, on goat patients of various age and sex that were bring to the veterinary hospital over the study period. The animals were examined clinically and any animals with clinical signs and symptoms resemble to peste des petits ruminants were sampled by swabbing from oral mucosa for antigen detection. Therefore, tissue sample from oral mucosa was selected as for detection of PPRV infected goats.

<u>Antigen detection</u>

PPRV antigen can be detected by immuno capture ELISA, where monoclonal antibody directed against non-overlapping antigenic domain on the nucleocapsid (N) to detect N protein of the virus from infected animals (15). This is a good tool for a rapid and confirmatory diagnosis of PPRV. Recently, Sil and others described another antigen detection technique where they directed monoclonal antibody against non-overlapping antigenic domain on the haemagglutnin (H) protein of PPR virus (16). The method described by the Sil and others was followed to detect the PPR specific H antigen in our study.

Validation of the clinical diagnosis

The clinical diagnosis protocol used for diagnosing the PPR at SAQTVH, CVASU was validated with the antigen detection technique described as enzyme immuno slide assay (EISA) on 100 goats in a different setup. Agreement between the two methods was evaluated using Cohen's Kappa statistics (13). Samples from field specimen on acetone fixed slide can be confirmed by monoclonal antibodies directed against haemagglutnin protein of PPRV (14). This study followed the standard protocol of EISA that is commonly in practice for diagnosing PPR in Bangladesh. Cohen's kappa was applied to check the agreement between two diagnostic protocols.

Population parameters and Clinical presentations of PPR cases

This study carefully reviewed the clinical case sheets and summarized possible risk indicators and their categories. Then this study retrieved the data from the patient register to describe the variations in the frequency of the PPR cases according to the categories. Application of binomial probability test saw the variations between the categories. A test proportion of 0.50 and a significant level of $p<0.05$ for the binomial probability test were considered. Overall frequency of the presentation of clinical signs and symptoms was described as frequency distribution with the percentages.

Definition of case and control

The sequence of steps leading to detection of case and control are depicted in Figure 1. A total number of 100 patients were sampled during the study period suspected as PPR. Suspected samples tested positive for antigen detection of PPR virus were enrolled as cases (n=50). The samples tested negative were considered as controls of our study (n=50). Selection of 25 cases and 25 controls (1:1) were tested randomly animals for the current study.

Questionnaire and Risk factors

Development of a questionnaire was used to address the various demographic and managemental issues that were potential risk factors for PPRV infection. The questionnaire included question about 7 potential risk factors. All the cases and controls were examined for any difference in demographic and managemental attributes that included age, sex, breed, grazing pattern, live animal market and introduction of new animals in the herd. Vaccination history was excluded because of the lack of proper vaccination record and chance of recall bias. Questionnaire was filled in for each suspected patient whilst samples were collected for antigen detection.

Statistical analysis

Evaluation of differences in exposure to demographic and managemental factors in case versus control using X^2 test of homogeneity with a significant level p>0.05 and computed OR with 95% confidence interval. All the variables whose associated p-value were <0.2 in univariable analysis were included in multivariable analysis. For multivariable analysis we used unconditional binary Logistic regression to test the independence of association. We estimated odds ratio (OR) and p value with 95% confidence interval. Collinearity was assessed among all covariates to be considered for inclusion in the final model. We also checked the possibilities for the interaction and confounding among variables. A final model was fitted by using a backward elimination procedure. Significance of risk factors was assessed by using the likelihood ratio test based on p ≤0.05. All the statistical analyses were performed in SPSS 13.0 for windows (SPSS Inc., USA).

Results

Results of the diagnosis of same goats by both clinical protocol and cEISA are presented in table 1.

A good agreement (kappa=0.801, CI [0.635–0.966]) was observed between clinical diagnostic protocol and cEISA. From January to December 2009, a total of 100 PPR case were presented. Among them 38 (38%) were female and 62 (62%) were male. The age distribution of the cases was: 70 (70 %) goats of 1-12 months of age group , 21 (21.0%) goats of 12-24 months of age group and 9(9%) of them was of more than 24 month age group. The patient characteristics and the binomial test results are presented in table 2.

The chi-square value for the overall likelihood ratio test for the final model was 17.98 (p=0.0004) and the Hosmer and Lemeshow statistics for goodness of fit of the final model was 6.596 (df=5, p=0.252) which is considered to be acceptable (17). No interaction and confounding were observed during model building procedure.

Table 1. Agreement between two diagnostic protocols.

		cEISA			Cohen's Kappa (CI)
		+	-	Total	
CLINICAL DIAGNOSIS	+	35	5	40	
	-	3	57	60	0.747 (0.513-0.980)
	Total	38	62	100	

Table 2. Possible risk indicators for the PPRV infection.

Risk indicators		N=100 Observed Proportion	Test Prop.	‡P
Sex	Male	38 (0.38)	0.50	<0.005
	Female	62 (0.62)		
Age	1 year ≤	30 (0.30)	0.50	<0.005
	1 year ≥	70 (0.70)		
Flock size	Small	58 (0.58)	0.50	0.006
	Large	42 (0.42)		
Grazing	Free grazing	85 (0.85)	0.50	<0.005
	Confined	15 (0.15)		
Breed	Black Bengal and Cross	56 (0.56)	0.50	0.042
	Jamnapari and sheep	44 (0.44)		
New introduction	Yes	79 (0.79)	0.50	<0.005
	No	21 (0.21)		

‡ asymptomatic significant (two tailed) based on 'z' approximation.

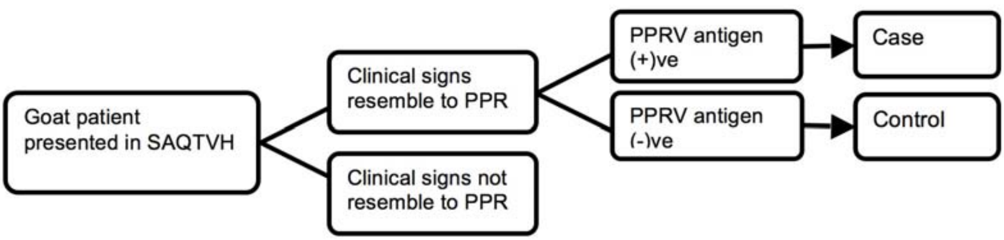

Figure 1. Scenario tree for selection of case and control in the current study.

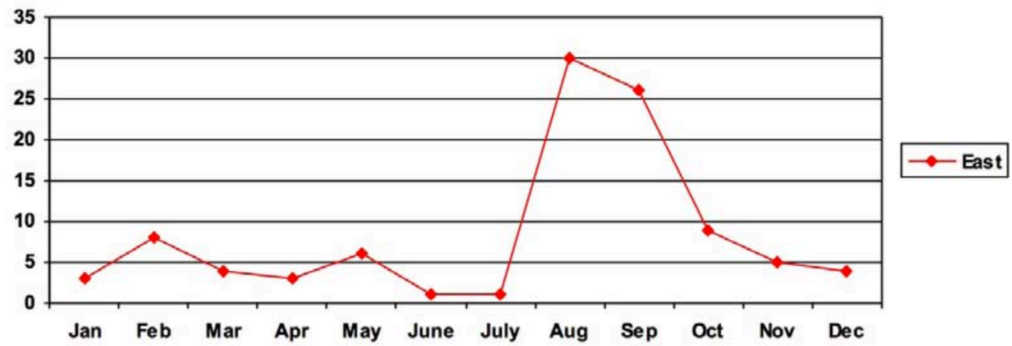

Figure 2. Temporality of the PPR cases: The epidemic curve and over all linear trend line of the recorded PPR cases at SAQTVH, CVASU

Discussion

Diagnosis of the PPR case in most instances was based on clinical history and clinical examination at SAQTTH, CVASU. No prior validation study for the clinical diagnostic protocol was performed before. Although the clinical signs sought sufficient in the diagnosis of PPR in the endemic areas (8) but still this study can not ignore the chance of error due to the observer. Hence, we checked the agreement of the clinical diagnosis with EISA technique applying the kappa statistics. The kappa value obtained (kappa=0.801) in our validation process shows a higher degree of agreement which supports the accuracy of the clinical diagnosis. The kappa value (k) was interpreted by a previously described classification (16): <0.2 = slight agreement, 0.2-0.4 = fair agreement, 0.4-0.6 = moderate agreement, 0.6-0.8 = substantial or good agreement, and >0.8 = almost perfect agreement.

Our risk indicator analysis by binomial test describes the significant differences of frequency of PPR patients between sex, age group, flock size, grazing pattern, breed and history of new introduction. These factors are not necessarily the determinant for the PPR infection but certainly candidate for the factors to be considered for inclusion in the analysis for the risk factors of PPR virus infection. The classical clinical features of the PPRV infection described earlier as high fever, pneumonia, mucopurulent ocular and nasal discharge, necrosis and ulceration of the oral mucosa, profuse diarrhoea and dehydration (3-5). Our observation revealed the same clinical features among the PPR patients presented at SAQTVH, CVASU.

The observed temporal pattern consisting of the three distinct epidemic peaks. Epidemic peaks were observed between the month of August and September around the 'Manasha Puja', a festival of the Hindu Religion. This finding provides some interesting insights into the epidemic. The festival is known for sacrificing huge number of goats by the believers. To meet the demands of the increase number of the goats a huge supply comes from India by legal and illegal trade. The goats imported from India are probably contributing to the epidemic peaks. It is reported that the PPRV is in epidemic state in India in the month of August and September (17, 18). Besides, temporal autocorrelation function confirmed fixed annual cyclic pattern of the epidemic of PPRV in Chittagong region. This is another important finding from our study. Based on this finding we can formulate the mass vaccination schedule for PPRV in this region.

From the case-control study it found the Black Bangle goat breed is about four and half times more susceptible to PPR infection than the other exotic and cross bred goats. The higher prevalence (19) of PPR infection noticed in Black Bengal breed. The susceptibility of the Black Bengal goat to PPRV infection needs to investigate in more depth.

Besides, the animals under the communal grazing found about four times more vulnerable to PPR infection then those reared under confined stall feeding or gidding. The transmission of the virus is well documented via direct contact. The direct contact between the susceptible and infected animals or by aerosol way is the common route of transmission (19, 20). The communal grazing allows the susceptible animal to come in contact with the infected animal and increase the chance of transmissibility.
Another important epidemiological finding is the introduction of the new animal in the increases the risk of PPRV infection about five times. The newly introduced animals are mostly purchased from the local market. A well known source of the goat supply in the local market is the Indian markets. In India PPR is prevalent year round (21, 22). We thus advocate the separate shelter for the newly purchased goat at least a week after purchase. As incubation period of the PPR virus is little less than a week.

Black Bengal goats are very important economic animal for Bangladesh. Most of the goat owner are poor and mostly rear their goats by communal grazing. Based on the results of our study we suggest mass vaccination in black Bengal goats to prevent PPRV infection as suggested in India (21). Selection of the proper vaccine and vaccination schedule is prerequisite for mass vaccination. We also suggest the vaccine efficacy trial for the selected vaccine.

This present study is an example of the use of veterinary hospital register data for the descriptive clinical and epidemiological studies for the understanding the frequency and pattern of the infectious diseases in a particular region of a country. We can use the results of the study for further formulation of the future analytical study that can explore more details of the epidemiology of the PPRV in Bangladesh.

Acknowledgements

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References

Amjad H, Qamar ul I, Forsyth M, Barrett T, Rossiter PB. Peste des petits ruminants in goats in Pakistan. The Veterinary record 1996; 139(5): 118-9.

Roeder PL, Abraham G, Kenfe G, Barrett T. Peste des petits ruminants in Ethiopian goats. Tropical animal health and production 1994; 26(2): 69-73.

Gibbs EPJ, Taylor WP, Bryant J. Classification of peste des petits ruminants virus as the fourth member of genus Morbillivirus. Intervirology 1979; 11: 268-74.

Radostits OM, Gay CC, Blood DC, Hinchcliff KW. Veterinary Medicine. 9th ed. London: W.B. Saunders Company Ltd., 2000.

Lefevre PC, Diallo A. Peste des petits ruminants. Revue scientifique et technique (International Office of Epizootics) 1990; 9(4): 935-81.

Gargadennec L, Lalanne A. La peste des petits ruminants. Bulletin des Services Zoo Techniques et des Epizooties de I' Afrique Occidental Francaise 1942; 5: 16-21.

Dhar P, Sreenivasa BP, Barrett T, Corteyn M, Singh RP, Bandyopadhyay SK. Recent epidemiology of peste des petits ruminants virus (PPRV). Veterinary Microbiology 2002; 88(2): 153-9.

Scott GR. Peste des petits ruminants. In virus infection in ruminants Amsterdam: Elsevier, 1990.

Debnath NC. : an overview In: Proceedings of BSVER, Symposium on eradication of Rinderpest and related diseases. Dhaka, 1995: 9-13.

Sil BK, ed. Peste des petits ruminant, A brief introduction its diagnosis and control. Dhaka: BLRI, 2000

Chowdhury EH, Bhyian AR, Parvin R, *et al.* Epidemiology, pathology and sensitive tools for the diagnosis of PPR in Bangladesh. In: FAO/IAEA International Symposium on Sustainable Improvement of Animal Production and Health, Vienna, Austria, 8-11 June, 2009: 295-6.

Chowdhury MYE, Faruque MR, Ahmed SSU, Azizunnesa, Chowdhury S. Occurence of diseases and disorders of goat recorded at veterinary teaching hospital of Chittagong Veterinary and Animal Sciences University in Bangladesh. International Journal of Animal and Fisheries Science 2008; 1(5): 90-3.

Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Meas 1960; 20 :37–46

Sil BK, Taimur MJFA, Hossain KM, *et al.* Development of Mab-based enzyme immuno slide assey for the rapid detection and accurate field diagnosis of peste des petits ruminant virus. Bangladesh Journal of Livestock Research 2001; 7: 48-63.

Diggle PJ, Chetwynd AG, Haggkvist R, Morris SE. Second-order analysis of space-time clustering. Stat Methods Med Res 1995; 4(2): 124-36.

Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33(1): 159-74.

Taylor WP, Diallo A, Gopalakrishna S, *et al.* Peste des petits ruminants has been widely present in southern India since, if not before, the late 1980s. Preventive veterinary medicine 2002; 52(3-4): 305-12.

Kumar A, Singh SV, Rana R, Vaid RK, Misri J, Vihan VS. PPR outbreaks in goats; epidemiological and therapeautic studies. Indian J Anim Sci 2001; 68: 38-40

Jana D, Ghosh M. Incidence of an explosive outbreak of peste des petits ruminants (PPR) in Black Bengal goats in Bankura district of West Bengal. Indian Veterinary Journal 2002; 79: 739-40.

Scott GR, ed. Peste des petits ruminants and Rinderpest. 3 ed. Great Britain: Blackwell and Science, 2000.

Rajak KK, Sreenivasa BP, Hosamani M, *et al.* Experimental studies on immunosuppressive effects of peste des petits ruminants (PPR) virus in goats. Comparative immunology, microbiology and infectious diseases 2005; 28(4): 287-96.

Taylor WP, Diallo A, Gopalakrishna S, *et al.* Peste des petits ruminants has been widely present in southern India since, if not before, the late 1980s. Preventive veterinary medicine 2002; 52(3-4): 305-12.

Pictures: PPR affected goat and sheep

Section 9
Poultry

Choosing the most appropriate bedding material for broiler production using multicriterial analysis

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Abstract

This study aimed to select the most appropriate bedding material for use in broiler production and it was based on data from a research which studied the effect of bedding materials in broiler carcass quality, using six distinct types of bedding material. The analytical hierarchy process was applied by adopting selected criteria in accordance to the most important characteristics required by broiler producers. Weights were given to the criteria and a pair wise comparison was done. Results showed that wood shaving was the best alternative (28.3%), followed by rice husk (24.3%) and by chopped Napier grass (*Pennisetum pupureum*) (13.3%).

Keywords: multicriterial analysis, analytic hierarchy process, alternative bedding material.

Introduction

Bedding acquisition and litter management are a great struggle for broilers' producers. The sustainability of broiler industry requires bedding material to be environmentally friendly, and the replacement of built-up litter needs to be at low cost in order to be implemented by farmers (Mayne *et al.*, 2007; Bilgili *et al.*, 2009, Freitas *et al.*, 2009b). This action requires the availability of alternative bedding sources. Managing litter moisture becomes more challenging in built-up litter, especially during the last weeks of production. Among the important factors contributing to this moisture cycle in the rearing environment there are: short downtimes between flocks, partial-house brooding, evaporative cooling systems, and poor drinker management (Bilgili *et al.*, 2009). The incidence of breast burns and blisters, leg abnormalities, and foot pad lesions are reported in literature as partial result of bad litter conditions (Hester *et al.*, 1987; Benabdewelil & Ayach, 1996).

Amongst the available multi-attribute approaches, the analytic hierarchy process (AHP) has the capabilities in combining different types of criteria in a multi-level decision structure to obtain a single score for each alternative to rank the alternatives. Several studies are published on distinct scenarios and arrays of AHP, with the conclusions indicating the suitability of this analysis in the selection of criteria (Ananda & Herath, 2003; Omkarprasad & Sushil, 2006).

The purpose of this study was to develop a system for selecting the most appropriate bedding material for rearing broiler chicken, considering all restrictions at producers' level, and using the multi criteria analysis.

Materials and Methods

This research was done in two parts. Part 1: data on six distinct bedding materials were collected, evaluating the outputs of broiler's carcass quality, litter ammonia emission and litter caking. Part 2: AHP process was used for determining which the most appropriate bedding material was considering all data recorded in Part 1.

Experimental design of Part 1

The research was done in the experimental broiler's housing 50m long, 10m wide and height of 3m. The total rearing area was divided into 56 boxes each one with 4.5 m^2. Each box had a bell type drinker and a manual feeder. The housing had lateral curtains in order to manage de air income and the inside environment was controlled using forced ventilation by positive pressure fans (6 of 746 J s^{-1}) and two lines of fogging (1 valve every 2 m, 0.42 MPa). The initial heating was done using 0.9 MJ for each box. Twenty hours of lighting was used during the birds' growth from incandescent lamps of 0.014 MJ, resulting in average 22 lx. Random experimental design was adopted in a factorial arrangement (6 x 2) being six types of bedding and two genders with five repetitions per treatment. The bedding materials were: wood shavings, rice husk, chopped Napier grass (*Pennisetum pupureum)*, 50% of sugarcane bagasse (*Saccharum L.*) plus 50% wood shavings, 50% of sugarcane bagasse (*Saccharum L.*) plus 50% rice husk, and plain sugarcane bagasse (*Saccharum L.*) and the genders were male and female Ross ®308 broilers. The total of 3240 one day old chicklings was reared, being 54 birds in each box in a stocking density of 15 bird m^{-2}. The broilers had the normal commercial growth procedure.

The following parameters of the distinct type of beddings were measured: caking, temperature, humidity, pH, ammonia emission and capability of proliferation of pathogenic microorganisms. Caking was assessed in three points in each box at 21, 35 and 42 days of growth. Bedding temperature and humidity were recorded at 21, 35 and 42 days old. Temperature was measured using infrared thermometer. The final humidity was calculated as the values between the wet and the dried samples (at 65°C for 72 h) weighted before and after the procedure. Values of pH were obtained using a solution of bedding sample and deionized water reading from a digital pH meter. Ammonia emission was assessed for evaluating rearing ambient quality using the methodology of Oliveira *et al.* (2004). Broilers performance was recorded (feed ration consumption, weight gain, mortality and feed conversion) and evaluated weekly. Welfare conditions were assessed by using recorded values of the surface temperature measurements, lesion area of foot pad dermatitis, breast lesion, claw lesion and back bruises. Rearing ambient maximum and minimum air relative humidity and temperature were registered daily at 8:00 AM.

The statistical analysis was done using ANOVA, and Tukey test was applied to the average results. Data were analyzed using the software SAS (1988) and considered to be statistically significant when $P < 0.05$. The output of this experiment gave the background for the AHP analysis.

Part 2 - Analytical hierarchy process (AHP)
Five steps were needed to apply AHP: (a) structuring the selection problem (b) identifying the technological options (c) identifying the applied criteria (d) developing the weighting schemes, and (e) ranking management or technological options. The fundamental challenge was to find out the attributes that producers genuinely consider; and the objective hierarchies should be constructed attending this classification (Keeney, 1992). The attributes were selected based on two distinct set of data, first from the results of Part 1 and previous research results (Benabdewelil & Ayach, 1996; Grimes *et al.*, 2002; Oliveira *et al.*, 2004), and second on the criteria the producers generally use to purchase bedding material. Even though in theory there are several solutions for proper bedding materials, those are often represented as non-feasible choices due to some technical restrictions (Mayne *et al.*, 2007; Bilgili *et al.*, 2009). The selection of the criteria was based on the results of the field experiment from Part 1. The selected criteria were chosen based also on data from current literature (Mayne *et al.*, 2007; Bilgili *et al.*, 2009) and the scheme of the system was designed using three distinct levels (Figure1).

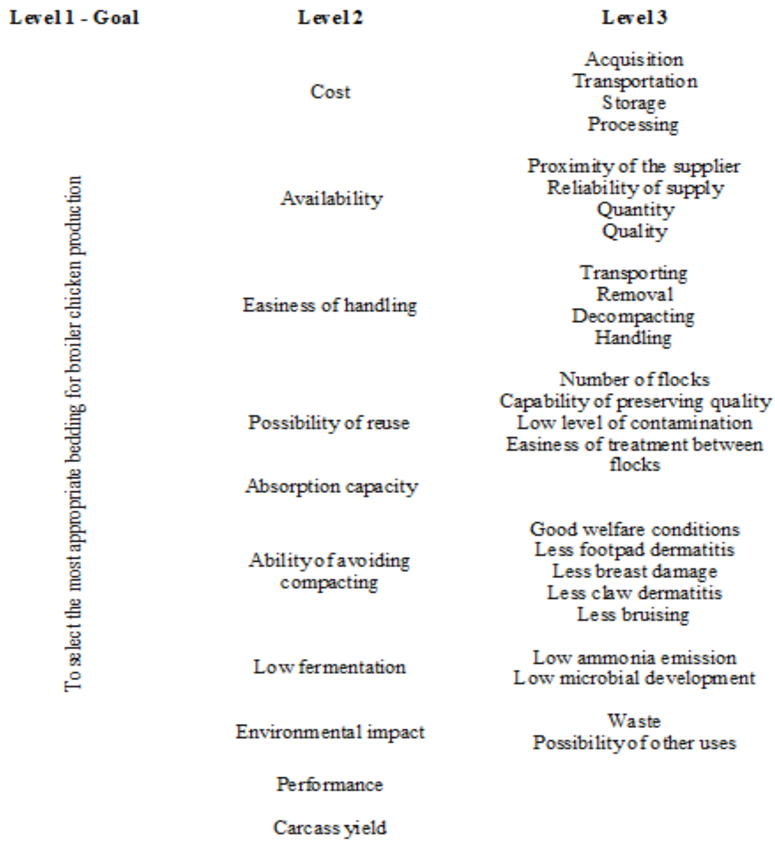

Figure 1. Scheme of the chosen criteria for the goal of selecting the most appropriate bedding material for broiler chicken production.

AHP derives ratio scales from paired comparisons of criteria, and allows for some small inconsistencies in judgments. Inputs can be actual measurements, but also subjective opinions. As a result, ratio scales (weightings) and a consistency index will be calculated. For decision making with multiple inputs from different stakeholders, the geometric mean of individual inputs is used. Mathematically the method is based on the solution of an Eigen value problem. The results of the pair-wise comparisons are arranged in a matrix. The first normalized Eigen vector of the matrix gives the ratio scale (weighting), the largest Eigen value determines the consistency ratio.

The adopted weight scale of importance was defined according to Satty's scale of importance (Satty, 1977) using the 1–9 scale for pairwise comparison. In the application of the AHP approach, a pairwise comparison matrix is formed in which rows and columns are allocated to the components belonging to the same parent component in the decision hierarchy. The weight of component *i* compared to component *j* with regard to the parent component is determined using Saaty's scale , and assigned to the (*i, j*) *th* position of the pairwise comparison matrix (Saaty, 1980) chosen to support comparisons within a limited range, but with sufficient sensitivity. Once the pairwise comparison matrix is formed, weights of components are calculated by solving for the eigenvector of the pairwise comparison matrix, where, $w_{i,j}$ is the weight of importance and it represents the weight the criteria *i* is more important than *j*.

The pairwise comparisons yield a reciprocal (*n, n*) of a matrix *A*, where $a_{ii} = 1$ (diagonal elements) and $a_{ji} = 1/a_{ij}$. *A* is consistent if and only if $\lambda_{max} = n$. However, the inequality $\lambda_{max} > n$ always exists. Therefore, the average of the remaining eigenvalues can be used as a "consistency index" (CI, Eq 1) which is the difference between λ_{max} and *n* divided by the normalizing factor $(n - 1)$.

$$CI = (\lambda_{max} - n)/(n - 1) \tag{1}$$

The CI of the studied problem is compared with the average RI obtained from associated random matrices of order *n* to measure the error due to inconsistency (Saaty, 1977, Saaty, 1980). A consistency ratio (CR = CI/RI) value ≤ 0.1 should be maintained for the matrix to be consistent; otherwise the pairwise comparisons should be revised. Homogeneity of factors within each group, smaller number of factors in the group, and better understanding of the decision problem would improve the consistency index.

The weights for each criterion in levels 2 and 3 were given based on the results of the field experiment in Part 1, and using the field experience of the researchers who worked in the trial. Each criterion was pair-wise compared and the local weight was calculated as the geometrical mean of each matrix line, representing the local weights. The global weight represents the weight related to the specific criterion, taking into account the related weights given to all items which compose that level, and pairwise compared. In each aspect, such as comparing criteria or alternatives under each criterion, a decision maker gives intuitive judgment as pairwise comparisons.

Computational analysis was done using the web based software AHPProject (2010).

Results and Discussion

Global weight results for the criteria used for selecting broiler chicken bedding material show the largest value for "possibility of reuse" (17%), followed by easiness of handling" (16%) and "cost" (14%), as shown in Table 1. Considering those criteria and the tested alternatives of bedding material it can be seen (Table 1) that wood shaving is the alternative that offered higher possibility of reuse (38.1%), followed by rice husk (28.3%) and by 50% of sugarcane bagasse plus 50% rice husk (16.8%). The criteria "easiness of handling" was higher for the wood shavings (37.1%) followed by rice husk (30.7%) and 50% of sugarcane bagasse plus 50% rice husk (13.1%). The criteria "cost" presented higher value (22.5%) for the material Chopped Napier grass (*Pennisetum pupureum*) followed (20.4%) by the Plain sugarcane bagasse (*Saccharum* L.), and in third place (16.1%) 50% of sugarcane bagasse plus 50% wood shavings. The values of the criteria's weight increase as favorable is the criteria towards the alternative, then the high values of cost obtained for the materials means that those alternatives are the less expensive ones. Attention needs to be called upon the fact that not all broiler producers have Napier grass planted at the farm, but when having it would be the best solution cost wise.

Table 1. Global weights of each criterion on level 2 and local weight of each criterion for each alternative.

	Cost	Availability	Easiness of handling	Possibility of reuse	Absorption capacity	Ability of avoiding compacting	Low fermentation	Environmental impact	Performance	Carcass yield
Global weight (%)	14.0	12.0	16.0	17.0	8.0	6.0	5.0	3.0	11.0	0.7
Alternative	**Local weight (%)**									
Wood shaving	13.0	17.8	37.1	38.1	42.0	41.5	30.1	32.2	16.7	16.7
Rice husk	15.0	30.9	30.7	28.3	26.0	28.2	24.0	21.6	16.7	16.7
Chopped Napier grass (*Pennisetum pupureum)*	22.5	5.9	11.7	12.8	12.7	10.2	9.3	4.8	16.7	16.7
50% of sugarcane bagasse plus 50% wood shaving	16.1	16.1	8.6	8.3	8.4	7.5	15.9	17.4	16.7	16.7
50% of sugarcane bagasse plus 50% rice husk	13.1	16.8	13.1	16.8	7.5	7.4	6.7	7.5	12.9	16.7
Plain sugarcane bagasse (*Saccharum* L.)	20.4	12.5	4.5	5.2	4.1	5.0	7.6	7.5	16.7	16.7

Even though broiler producers aim for good performance and carcass yield all criteria represented little in the overall decision weight, agreeing with the results presented by Bilgili *et al*. (2009). The authors evaluated commercial and alternative bedding materials and found that they had little influence on the live performance of broilers in three successive trials. Dermatitis incidence and severity varied significantly among the bedding materials and were related to high litter moisture and caking scores. From the standpoint of foot pad dermatitis etiology, the ability of the bedding to absorb and quickly release moisture may be the most important characteristics of the material (Hester *et al.*, 1987; Benabdewelil and Ayach, 1996). Concerning moisture content it is reported that wet litter conditions increased volatilization of ammonia from the litter, and that ammonia emissions from wood shavings were 19% greater than from the bedding material of wheat straw around drinkers, leading to greater caking observed when wheat straw was used (Tasistro *et al.*, 2007).

Important percentage of harvested area during 2006 in Brazil corresponds to sugarcane, rice and grass used in beef cattle planted pastures (Table 3). Napier grass is within the categories of grass used in cattle grazing and it is the smallest harvested area among those materials for use in broiler bedding presented in this present study. Associated to the low regional availability and considering that this product is not residual from other agricultural activity, and it also presents high nutritional values for cattle production (Fontes *et al.*, 2005; NRC, 1996), Napier grass may not be the most attractive material to be used for broiler chicken bedding in the cost component.

Table 2. Brazilian estimated percentage of harvested area related to the products of sugar cane, rice and forage grass divided by the country's regions, and the broiler chicken production.

Regions	Harvested area (%)			Brazilian broiler chicken production (million head)
	Forage grass	Sugar cane	Rice	
North	0.00	1.05	20.06	18.962
Northeast	3.06	9.00	5.93	97.063
Southeast	0.42	45.6	0.80	281.828
South	0.14	2.26	6.35	493.673
Midwest	0.07	5.51	1.94	102.779
Brazil	0.91	11.36	4.91	994.305

Source: IBGE (2010).

Regarding the sugarcane and rice production in the country it can be confirmed that the availability of the products varies between the regions (Table 2). In the Southern region a large percentage the planted area (nearly 45%) is for sugarcane leading to large production of bagasse in this region. In the Northern region large areas of rice are planted generating large quantities of this product. However, as the sugarcane rice is a seasonal crop and its accessibility varies along the year as well as its availability for broiler' producers. Sugarcane bagasse has high nutrition value for beef cattle production (Leme *et al.*, 2003) and also high energy value (Cortez & Gómez, 1998); in addition to be used for generating energy by burning dried bagasse, which goes into the energy supply matrix of the ethanol and sugar industries. Therefore, nowadays the bagasse presents large restrictions to be used as broiler bedding in Brazil, as it competes with economical energy generation.

Rice husk is found in large volume in some regions of the country where is it used for broiler chicken bedding; however, it is reported to result in lower flock performance when compared to wood shavings. Beside that the cost of rice husk uses to be higher than wood shavings in some broiler producer regions (Table 2), where rice crops are not grown intensively. Wood dust is mainly a byproduct of wood furniture industry and it is available basically in all counties in Brazil. However, renewable forests of soft wood (*Eucaliptus*) are being planted for providing wood shavings for broiler bedding. Both wood shavings and dust do not have high energy value, and it is sometimes considered as waste, which in most regions it is an indication of a low cost broiler bedding material. Broiler chicken performance and well being were found to be improved when the birds are reared on wood shavings (Neme *et al*., 2000).

Final ranking of alternatives is presented in Figure 2. Most studies comparing broiler bedding materials have reported that when birds are reared on alternative beddings their performance is equal to or less than that of birds reared on wood shavings (Grimes *et al.* 2002). According to Tasistro *et al.* (2007) bird mortality was not affected by the use of non-conventional bedding materials, but broiler weight gain when wheat straw was used was significantly lower than with wood shavings.

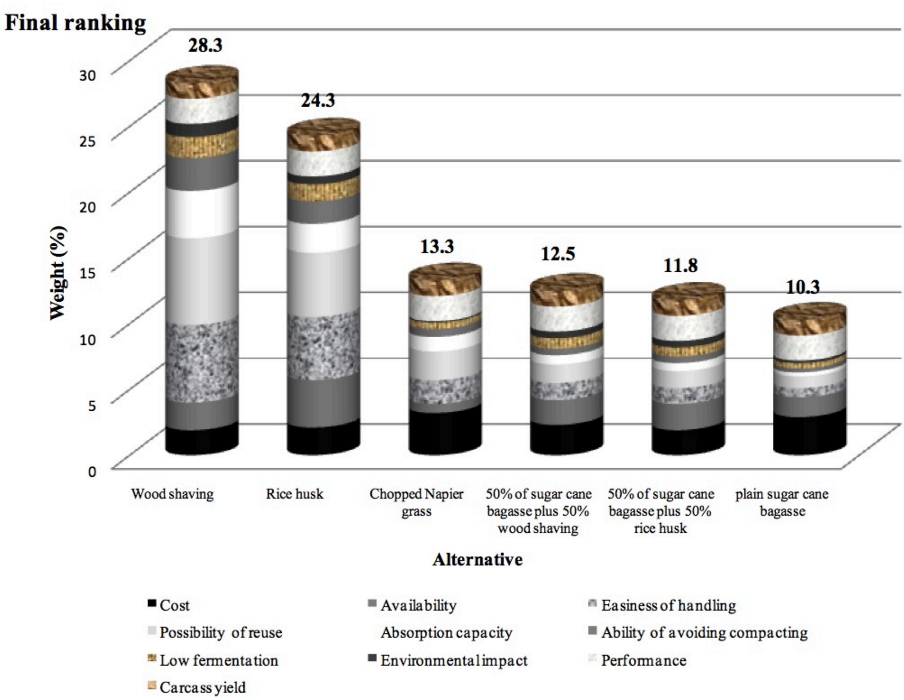

Figure 2. Final ranking and local weights for each tested alternative

13.3 12.5 11.8 10.3

Conclusions

An alternative, economical source of broiler chicken bedding may be needed to meet future demand. Favorable environmentally friendly ways of recycling or reducing litter waste are currently needed. However, with known data under Brazilian conditions and using multicriterial analysis, wood shaving appeared yet to be the best selection of broiler bedding material.

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References

AHPProject. 2010. Available at: http://ahpproject.com [Accessed 03.04.2010].

Ananda, J., Herath G. 2003. The use of Analytic Hierarchy Process to incorporate stakeholder preferences into regional forest planning. Forest Policy and Economics **5** 13-26.

Benabdewelil, K., Ayach, A. 1996. Evaluation of alternative litter materials for poultry. Journal of Applied Poultry Research **5** 203-209.

Bilgili, S.F., Hess, J.B., Blake, J.P., Macklin, K.S., Saenmahayak, B., Sibley, J.L. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research **18** 583–589.

Cortez, L.A.B, Gómez, E.O. 1998. A method for exergy analysis of sugarcane bagasse boilers. Brazilian Journal of Chemical Engineering **15** 1-6.

Fontes, C.A.A., Oliveira, R.C., Erbesdobler, E.D., Queiroz, D.S., Lombardi, C.T. 2005. Net energy content for maintenance and weight gain of elephant grass and changes on body composition of grazing steers during the rainy season (Abstract in English). Brazilian Journal of Animal Science **34** 1711-1720.

Frame, D.D., Buckner, R.E., Anderson, G.L. 2002. Pelletized newspaper bedding for turkeys and its effect on brooding performance. Journal of Applied Poultry Research **11** 229–232.

Grimes, J.L., Carter, T.A., Gernat, A.E., Godwin, J.L. 2007. A novel bedding material made from cotton waste, gypsum, and old newsprint for rearing turkeys. Journal of Applied Poultry Research **16** 598–604.

Grimes, J.L., Smith, J., Williams, C.M. 2002. Some alternative litter materials used for growing broilers and turkeys. World's Poultry Science Journal **58** 515–525.

Hester, P.Y., Sutton, A.L., Elkin, R.G. 1987. Effect of light intensity, litter source, and litter management on the incidence of leg abnormalities and performance of male turkeys. Poultry Science **66** 666–675.

Instituto Brasileiro de Geografia e Estatística [IBGE]. 2010. Banco de Dados Agregados: Sistema IBGE de Recuperação Automática [SIDRA]. Available at: http://www.sidra.ibge.gov.br/ [Accessed 26.04.2010].

Keeney, R.L. 1992. Value-focused thinking: A path to creative decision analysis. Harvard University Press, Cambridge, Ma, USA.

Leme, P.R., Silva, S.L., Pereira, A.S.C., Putrino, S.M., Lanna, D.P.D., Nogueira Filho, J.C.M. 2003. Levels of sugarcane bagasse in diets with high concentrate for Nelore steers in feedlot (Abstract in English). Brazilian Journal of Animal Science **31** 1786-1791.

Mayne, R.K., Else, R.W., Hocking, P.M. 2007. High litter moisture is sufficient to cause footpad dermatitis in growing turkeys. British Poultry Science **48** 538–545.

National Research Council [NRC]. 1996. Nutrient requirements of beef cattle. pp 242. 7.ed. Washington, D.C., USA.
Neme, R., Sakomura, N.K., Oliveira, M.D.S, Longo, F.A., Figueiredo, N.A. 2000. Addition of calcium sulfate in three types of litter about the fixation of nitrogen and on broiler performance (Abstract in English) Ciência Rural **30** 687-692.
Oliveira, M.C., Ferreira, H.A., Cancherini, L.C. 2004. Efeito de condicionadores químicos sobre a qualidade da cama de frango (Abstract in English). Arquivo Brasileiro de Medicina Veterinária e Zootecnia **56** 536-541.
Omkarprasad, S.V., Sushil, K. 2006. Analytic hierarchy process: An overview of applications. European Journal of Operational Research **169** 1-29.
Saaty, T.L. 1977. A scaling method for priorities in hierarchical structures, Journal of Mathematical Psychology **15** 234-281.
Saaty, T.L. 1980. The analytic hierarchy process. McGraw-Hill Press, New York, USA.
SAS Institute. 1988. SAS/STAT users guide for personal computers, release 6.03. SAS Institute, Inc., Cary, NC.
Tasistro, A.S., Ritz, C.W., Kissel, D.E. 2007. Ammonia emissions from broiler litter: response to bedding materials and acidifiers. British Poultry Science **48** 399-405.

Spreadsheet modelling to compute the air exchange rate in commercial broiler barns

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Abstract

A spreadsheet model was developed and exploited to create a user friendly tool that estimates air exchange rates of commercial broiler barns. For that purpose, the carbon dioxide (CO_2) balance is used. All required input data of the CO_2 balance method can be entered into the system. For a better clarity, a flow chart was designed to show the connection between the mathematical equations and the associated input data. Microsoft Excel® was used to develop the spreadsheet by implementing the flow chart and the mathematical model to show the results of the input settings easily. Input data of practical CO_2 concentration measurements in a broiler barn were used to validate the practical functionality of the model. The result of the CO_2 balance was compared with data, detected by measurement ventilators in the forced ventilated broiler barn. A good correlation (R^2 = 0.92) was found between the calculated (CO_2 balance method) and the measured (measurement ventilators) values.

Keywords: spreadsheet modelling; air exchange rate; broiler; emissions

Introduction

Ventilation rate in animal houses is a key parameter for environmental control in intensive livestock production. Ventilation is important to maintain a certain internal air temperature to keep pace with the animals' physical growth. The intensive rearing of broilers for meat production is a specialised farming system where the indoor environment must be controlled. Thus, a proper determination of ventilation rates is required (Wathes & Charles, 1994). Quantification of ventilation rates is also necessary to specify airborne emissions from animal buildings. To estimate gas emission from livestock production facilities, the difference of inside and outside gas concentrations and the air exchange rate of the building are needed (Phillips *et al*., 1998). The major purpose of a ventilation system is to create an environment in which the animal health is maintained and the productivity is satisfactory (Charles, 1994). An accurately measurement of ventilation rates is complicated, especially in naturally-ventilated barns. There are several methods for determining ventilation rates. According to Phillips *et al.* (2001), they can be classified in two main groups; indirect and direct measurement methods. Indirect methods rely on mass balance of a tracer gas in the air. The principle of this balance is to monitor the inlet and outlet concentration of a tracer gas of an animal barn (Pedersen *et al*., 1998; Blanes & Pedersen, 2005). The gas involved (tracer gas) could be an artificially produced gas if the rate of production is known. In broiler barns, carbon dioxide (CO_2) is considered to be produced mainly from the broilers' metabolism. In addition, a certain portion of CO_2 is released by manure. Van Quwerkerk and Pedersen (1994) considered that 4% of total CO_2 production occur from manure. Therefore, CO_2 concentration from manure was neglected in the mass balance model. The CO_2 balance represents a method for estimating air exchange rate

in broiler barns. Various studies focused on the approach of mass balances for determining ventilation rates from agricultural housings (e.g. Seedorf *et al.*, 1998, Teye & Hautala, 2007, Calvet *et al.*, 2010).
The purpose of this study was to create a useful tool to calculate easily the air exchange rate in a commercial broiler barn by applying the CO_2 balance method. Therefore, we used a Microsoft Excel® spreadsheet model. The reason for implementing the model using a spreadsheet makes it more accessible to users who are not familiar with models (Ragsdale, 2001). The spreadsheet is a widely used model for managing different issues. For instance, Duru *et al.* (2007) developed a management tool for dairy farms.
In the first part of this paper we summarise the model and the indicators needed. Then in a second part the model is used as a research tool and the exchange rates of CO_2 balance method and measured ventilation rate are compared.

Material and methods

Carbon dioxide balance
In this balance the difference between incoming and outgoing fluxes in a building is defined as emission rate. To determine these incoming and outgoing fluxes, two factors are needed: mass concentration and airflow rate (DIN 18 910-1, 2004).
Additionally, the produced CO_2 by the animals has to be considered. The CO_2 content inside a broiler barn is generated by the animals. The supply of CO_2 by the animals increase over time with bird growth, respiration rate and activity. Within the calculation of the balance of the air exchange rate (V in $m^3\ h^{-1}$) the hourly CO_2 concentrations were used. The balance of the air exchange rate is using the assumption of a tracer gas with following equation:

$$V = \frac{Q_{CO_{2,a}} * N}{C_{CO_2,in} - C_{CO_2,out}} \qquad (1)$$

where $Q_{CO2,a}$ ($g\ h^{-1}$) represents the CO_2 production from one broiler and N is the number of broilers. Further, $C_{CO2,in}$ ($g\ m^{-3}$) defines the concentrations of CO_2 inside the barn, whereas $C_{CO2,out}$ ($g\ m^{-3}$) is the concentrations of CO_2 outside the barn.

The CO_2 mass flow ($g\ h^{-1}$) for one animal is estimated as followed (Müller, 2001):

$$Q_{CO_2,a} = \rho_{CO_2} * V_{CO_2,a} \qquad (2)$$

where ρ_{CO2} ($g\ l^{-1}$) is the density of CO_2 and $V_{CO2,a}$ ($l\ h^{-1}$) is the CO_2 volume flow of one broiler.
The CO_2 production of one broiler represents a physiological function of the total heat production of broiler (φ_{tot} in W). According to the report of CIGR (1984) is 100 W of total heat production from an animal equivalent to 16.3 $l\ h^{-1}$ CO_2 production ($F_{CO2,a}$). Following equation arise, whereas the total heat production of the broiler has to be considered with corrections ($\Phi_{tot,cor}$ in W).

$$V_{CO_2,a} = F_{CO_{2,a}} * \phi_{tot,cor} \qquad (3)$$

The total heat production of one broiler ($\varphi_{tot,cor}$) depends on the inside air temperature (T). Therefore, according to the report of CIGR (1984) a factor F_T is multiplied by the total heat production of one broiler (φ_{tot}) with m as broiler weight in kg.

$$\phi_{tot,cor} = \phi_{tot} * F_T \tag{4}$$

$$F_T = 4*10^{-5}(20-T)^3 + 1 \tag{5}$$

$$\phi_{tot} = 10 * m^{0.75} \tag{6}$$

<u>Spreadsheet model</u>

A tool was developed by integrating the mathematical Equations 1-6 with required input data for calculating the air exchange rate of a commercial broiler barn. Owing to a better understanding, Figure 1 shows a flow chart which connects the mathematical equations and the associated input data. Subsequently, Microsoft Excel® was used to implement this flow chart into an electronic mathematical model to show the results of the input settings automatically. In total, seven variables of input data are necessary to calculate the air exchange rate by using the CO_2 balance method.

The objective of making a CO_2 balance model is to create a user friendly tool that estimates an expected air exchange rate of a commercial broiler barn. Moreover, by deciding some parameters, this tool can help to define sensitive factors which affect the air exchange rate. Hence, by monitoring and varying input data it can be used to assess environmental impact potentials.

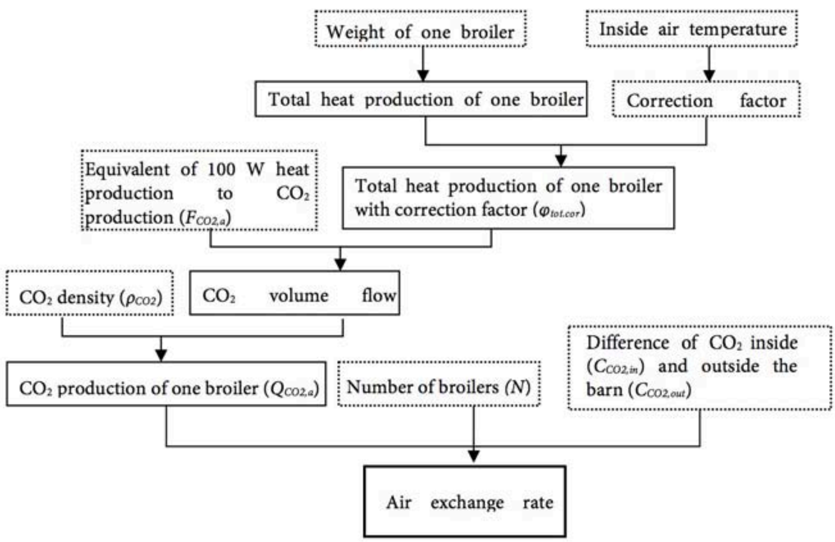

Figure 1. Flow chart of the mathematical model for calculating the air exchange rate of a commercial broiler barn. The dotted and solid edgings show the input data and the calculated data, respectively.

Practical measurements

Practical Measurements were carried out in a broiler barn of a farm located near to Berlin (Germany). Owing to the experimental setup, the measurements were performed during 34 days of one growing cycle between 25 March and 27 April 2005.

The farm covers an area of about six hectares. The farm consists of twelve broiler barns. In total, 382,200 broilers are raised during a growing cycle. The measurements took place in a barn with 30,000 broilers (length 88 m, width 15 m, height 4.5 m). The operation of the fans is controlled by the temperature inside the broiler barns, which ranged between 22 and 34 °C during the growing cycle. There are seven to eight broiler growing cycles per year within the broilers kept to an age of 36-37 d with market weights of approximately 1.5-1.8 kg. The broiler weight measurements were managed by a control and management system of the stable. Thereby, the weights of the broilers were conducted by using automatically scales which are situated at several location at ground floor level.

Inside the broiler barn the CO_2 concentration ($C_{CO2,in}$) was recorded at six measurement points close to the exhaust air outlets with a photoacoustic field gas monitor. For comparing, the CO_2 balance with real measured data, the air-volumetric flow rate (q) was detected by measurement ventilators. The inside air temperature (T) was sampled close to the exhaust air outlets. From these datasets hourly means were calculated. The outside CO_2 concentration ($C_{CO2,out}$) was considered with a constant factor of 650 mg m^{-3}. All the specifications of the techniques applied, are listed in Table 1.

Table 1. Summary of the variables and the characteristics of used instruments.

Variable	Manufacturer	Units	Measurement Height [m]	Temporal resolution	Accuracy	Detection limit
Inside concentration of CO_2 ($C_{CO2,in}$)	Photoacoustic field gas monitor Type: 1312, INNOVA AirTech Instruments, Ballerup, Denmark	mg m^{-3}	4	1 min at each of 6 points	<1%	0.2
Air-volumetric flow rate (q)	Measurement ventilators, Type: MVP63, Hotraco Group, Hegelsom, The Netherlands	m^3 h^{-1}	4	every 10 min at 9 points	-	-
Inside temperature (T)	Temperature pobe, Type: N2000, Comark Instruments, Hitchin, UK	°C	4	every 10 min at 9 points		

Results and discussion

Spreadsheet model

Figure 2 shows the window of the spreadsheet to calculate the air exchange rate of a commercial broiler barn by applying the CO_2 balance method. All required input data, in total seven variables, are marked with a black colour. The resulting calculated data out of the input data are presented with a grey background. Within this window all data, needed for the CO_2 balance method, will be merged and displayed.

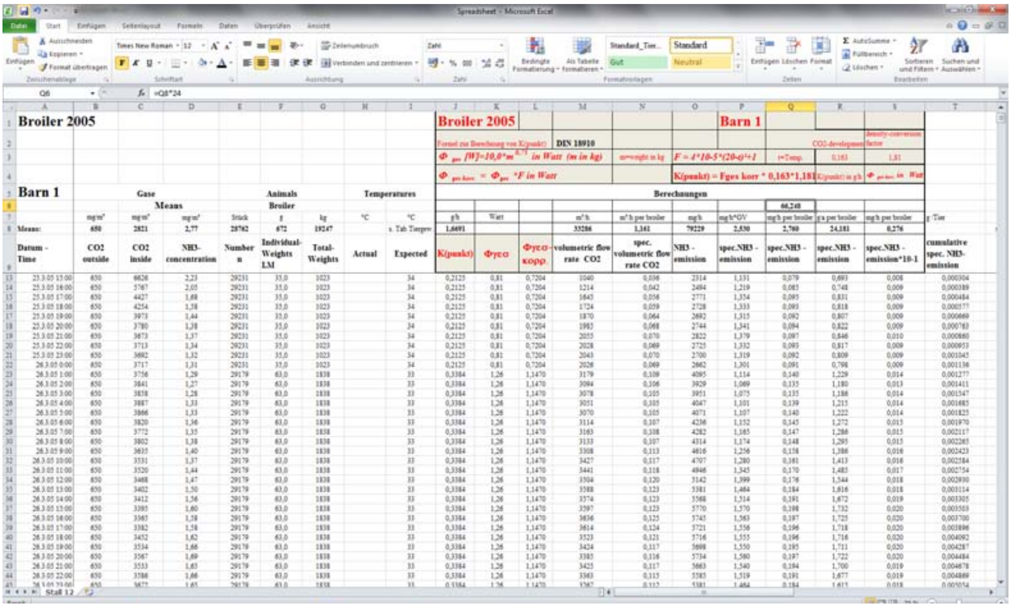

Figure 2. Overview of a spreadsheet with required input data (black) and calculated data (grey background).

The graphical result of the spreadsheet for calculating the air exchange rate is represented by Figure 3. Thereby, the time-series of the air exchange rate (*V*) rose over the entire growing cycle up to a maximum of 250.000 m^3 h^{-1}. More and more ventilation became necessary as the cycle progressed, since a certain internal air temperature had to be maintained to keep pace with the broilers' physical growth. Diurnal variation in the production of metabolic heat and CO_2 in general are important to consider in respect to the accuracy of the CO_2 balance method (Pedersen *et al.*, 1998). The occurring variations within the time-series of the air exchange rate, calculated by the CO_2 balance, pointed to an influence of *T*. Thereby, *T* was affected by the operation of the ventilation system. Over the entire growing cycle, *T* ranged between 22 and 34°C, necessary to maintain certain inside air temperatures depending in the age of the broilers' physical growth. More and more ventilation became necessary as the cycle progressed. Nevertheless, the air exchange rate during day 25-30 showed comparable low

values. Because of the lack of simultaneous measurements of CO_2 production and activity, it is not possible to determine an explanation for the patterns of the air exchange rate.
In general, the spreadsheet model came out as a useful tool to support the user in calculating the air exchange rate. In addition, this knowledge provides the user with information about the emission rate into the atmosphere. It is possible to provide reliable information on the extent to which the broiler farm acts as a source of air pollution in the surrounding environment.

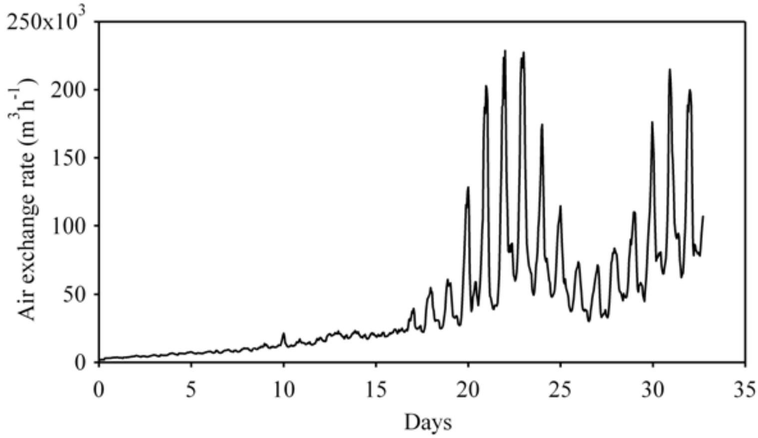

Figure 3. Times-series of the air exchange rate calculated by the CO_2 balance.

<u>Comparison of CO_2 balance and measured air exchange rate</u>

Figure 4 depicts the air exchange rates, measured by the ventilators and compared with the values of the CO_2 balance method, together with the result of the linear regression analysis. Overall, a high correlation between the calculated and measured air exchange rate is observed, with $R^2 = 0.92$. The slope with 0.73 showed that the air exchange rate measured by ventilators was underestimated. This meant that by using the CO_2 balance method, higher air exchange rates were achieved. Further, visually distinctions occurred regarding low or high ventilation rates. For $q > 100$ m^3 h^{-1} the variations were more scattered. This fact pointed to a dilution of CO_2 content in the air inside the stable. As a consequence, the difference of $C_{CO2,in}$ and $C_{CO2,out}$ was getting smaller. The deviations of measured and calculated air-volumetric flow rates were higher for $q > 100$ m^3 h^{-1}.

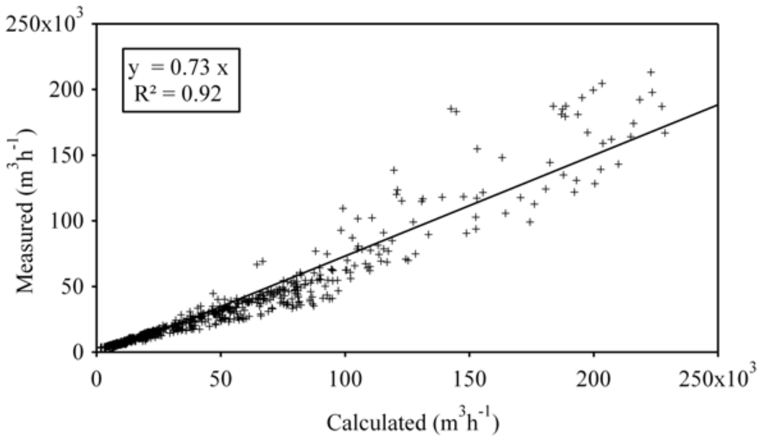

Figure 4. Scatter plot of the air exchange rate calculated by the CO_2 balance and measured by ventilators.

By comparing the time-series (Figure 5) of the differences between measured (ventilators) and calculated (CO_2 balance) air exchange rates, mainly negative values were detected. That implies an overestimation of the values arose from the CO_2 balance method. This fact is consistent with the result of the linear regression in Figure 4 with a slope <1 for measured air exchange rates by measurement ventilators. A possible explanation for the overestimate of the air exchange rate by applying the CO_2 balance method can be found in the assumption of a constant CO_2 outside concentration. For future investigation on this research aspect, a parallel observation of the CO_2 outside concentration with high time resolution should be attempted.

After the first 15 days, more and more ventilation became necessary as the cycle progressed, since a certain internal air temperature had to be maintained to keep pace with the broilers' physical growth and because CO_2 concentrations rose as the birds grew in size. Later on, more variation of the difference occurred (Fig. 5), due to the higher ventilation rates.

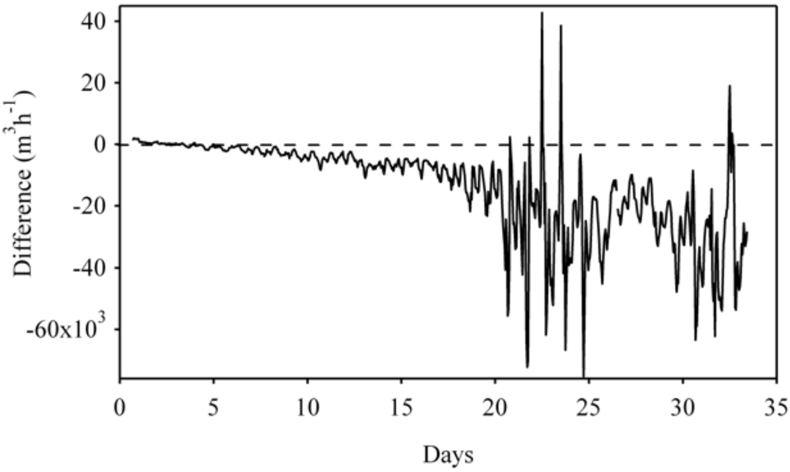

Figure 5. Times-series of the difference of air exchange rate measured by the CO_2 balance and measured by ventilators.

Conclusions

A user friendly tool of estimating air exchange rate of commercial broiler barns was attempted to design. For that reason, a Microsoft Excel® spreadsheet model was developed. The indirect CO_2 balance method was used to calculate the air exchange rate. This CO_2 balance method was developed as a chart flow and was adapted in a mathematical spreadsheet model in order to simplify the practical implementation. Consequently, the spreadsheet model can be used to make the calculations for the CO_2 balance method and to get automatically the results from the input settings. Following input data were required: number and weight of broilers, difference of CO_2 concentration inside and outside of the barn, CO_2 density and inside air temperature. In general, the spreadsheet model represents a practical tool in specifying sensitive factors which affect the air exchange rate in a commercial broiler barn. Moreover, an assessment of environmental impact potentials is feasible by monitoring and varying input data. Concerning the comparison of exchange rates of CO_2 balance method and measured ventilation rate, a high correlation with $R^2 = 0.92$ was achieved. The applied CO_2 balance method overestimated the air exchange rate. Future improvements of the CO_2 balance method should focus on a proper determination of CO_2 outside concentrations.

References

Blanes, V. and Pedersen, S. 2005. Ventilation flow in pig houses measured and calculated by carbon dioxide, moisture and heat balance equations. Biosystems Engineering **92** 483-493.

Calvet, S., Cambra-López, M., Blanes-Vidal, V., Estellés, F. and Torres, A. G. 2010. Ventilation rates in mechanically-ventilated commercial poultry buildings in Southern Europe: Measurement system development and uncertainty analysis. Biosystems Engineering **106** 423-432.

Charles, D. R. 1994. Comparative climatic requirements. In: Livestock Housing (Wathes, C. M., Charles D. R., eds), CAB International.

CIGR, 1984. Climatization of animals houses / Working group on climatization of animal houses, CIGR and UFBIU. Scotland GB, 1984. available under: http://www.cigr.org/documents/CIGR-Workinggroupreport1984.pdf

DIN 18 910-1. 2004. Thermal insulation for closed livestock buildings – Thermal insulation and ventilation forced - Part 1: Principles for planning and design for closed ventilated livestock buildings. Beuth-Verlag.

Duru, M., Bergez, J. E., Delaby, L., Justes, E., Theau, J. P. and Viégas, J. 2007. A spreadsheet model for developing field indicators and grazing management tools to meet environmental and production targets for dairy farms. Journal of Environmental Management **82** 207-220.

Müller, H.-J. 2001. Methods of balancing for determining air-volumetric flow rates in free ventilated stables. In: Measuring methods for ammonia emissions. Bd. KTBLSchrift 401 (KTBL ed.). Darmstadt, 122 – 137.

Pedersen, S., Takai, H., Johnsen, J. O., Metz, J. H. M., Groot Koerkamp, P. W. G., Uenk, G. H., Phillips, V. R., Holden, M. R., Sneath, R. W., Short, J. L., White, R. P., Hartung, J., Seedorf, J., Schröder, M., Linkert, K. H. and Wathes, C. M. 1998. A comparison of three balance methods for calculating ventilation rates in livestock buildings. .Journal of Agricultural Research **70** 25-37.

Phillips, V. R., Holden, M. R., Sneath, R. W., Short, J. L., White, R. P., Hartung, J., Seedorf, J., Schröder, M., Linkert, K. H., Pedersen, S., Takai, H., Johnsen, J. O., Groot Koerkamp, P. W. G, Uenk, G. H., Scholtens, R., Metz, J. H. M. and Wathes, C. M. 1998. The development of robust methods for measuring concentrations and emission rates of gaseous and particulate air pollutions in livestock buildings. Journal of Agricultural Research **70** 11-24.

Phillips, V. R., Lee, D. S., Scholtens, R., Garland, J. A. and Sneath, R.W. 2001. A review of methods for measuring emission rates of ammonia from livestock buildings and slurry on manurestores, part 2: monitoring flux rates, concentrations and airflow rates. Journal of Agricultural Engineering Research **78** 1-14.

Ragsdale C. T. 2001. Teaching Management Science With Spreadsheets: From Decision Models to Decision Support. INFORMS Transactions on Education **1** 68-76.

Seedorf, J., Hartung, J., Schröder, K. H., Linkert, K. H., Pedersen, S., Takai, H., Johnsen, J. O., Metz, J. H. M., Groot Koerkamp, P. W. G, Uenk, G. H., Phillips, V. R., Holden, M. R., Sneath, R. W., Short, J. L., Scholtens, R., White, R. P. and Wathes, C. M. 1998. A Survey of ventilation rates in livestock buildings in northern Europe. Journal of Agricultural Engineering Research **70** 39-47.

Teye, F. K. and Hautala, M. 2007. Measuring ventilation rates in dairy buildings. International Journal of Ventilation **6** 247-256.

van Quwerkerk, E.N.J. and Pedersen, S. 1994. Application of the carbon dioxide mass balance method to evaluate ventilation rates in livestock buildings. Proceedings of XII CIGR World congress on Agricultural Engineering, Milan, Italy, Vol. 1: 516-552.

Wathes, C. M. and Charles, D. R. 1994. Livestock Housing. Wallingford (UK): CAB International.

Development of walking index for broilers from 17 to 24 days old

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Abstract

This research had the objective of developing a model which describes the way that a flock of broilers from 17 to 24 days old walked in the region around the feeder, for better understanding their feeding behavior. The model takes into consideration the area occupied by the birds, their age and environmental variables such as ambient temperature, relative humidity and light intensity. Results showed that almost all variables contribute to reducing the movement, except the illuminance, but the ambient temperature is the one that mostly affect the response variable which was the movement of the birds, followed by age, relative humidity and the amount of area occupied by the broilers.

Keywords: animal behavior, birds' movement, housing occupied area, ambient variables.

Introduction

Broiler chickens need ideal conditions of temperature, hygiene/health, humidity, space, litter quality, etc. in order to express their genetic potential. The birds also need to have access to feed and feed them properly. Several studies are found in current literature regarding the behavior in broiler chickens, specially related to aggression, feeding, hierarchic posture and locomotion disorders as function of the rearing environment (Rutz, 1994; Cahaner *et al.*, 1995; Pagel e Dawkins, 1997; Macari e Furlan, 2001; Bokker *et al.*, 2004; Curto, 2007; Kristensen *et al.*, 2007; Aydin *et al.*, 2010). However, little is known with respect to the movement of the birds around the feeding area, as monitoring specific flock movement pattern in this area is a potential way for representing feeding preferences at commercial farm. This research aimed to propose an algorithm that describes the walking index of broiler chickens from 17 to 24 d old in the feeding area, as function of the ambient variables, age of birds, area occupied by the broilers and light intensity.

Material and methods

<u>Birds and husbandry</u>
The study was carried out in conventional Brazilian commercial broiler housing with 100m of length and 8.5m of width rearing 14 thousand broilers of Ross® genetic strain using a flock density of 16 birds m^{-2} located in latitude South 22° 26,398' and longitude West 47° 32,553', with altitude 635m with dry winter and wet summer. The study was carried out on Southern hemisphere winter of 2009. Manual feeders were used in the initial phases and after the third week tubular and automatic feeders were used. Drinkers were bell type. For environmental

control axial fans were used associated to foggers. The building was side opened with polypropylene wall curtains (93 g m^{-2}). The floor was made with whole concrete covered with new pine shavings as bedding substrate (Figures 1 a and b).

Experimental procedure

Direct video footage was made using a tripod supporting the video camera (Sony DCR-TRV330®) and giving a view from the top. In the center of this area there was a tubular feeder. The video image area corresponded to an area of floor of approximately 1.0m x 1.5m. This feeder did not have a partition grid over the trough, representing unlimited access to the feedstuff. Data recording was on days 17 to 24 of growth, which corresponded to the steepest part of the growth curve (Goliomytis *et al.*, 2003). Recording consisted of 55 min of video footage done twice a day, in the morning period (within 8:30h to 10:30h) and the in the afternoon (within 14:00 h to16:00 h). To avoid abnormal behavior of broilers towards the set up of the camera the first 10 min of video footage was neglected during the analysis of behaviors, resuming the total recording in 45 min each sampling. Data were digitalized to extension VOB (DVD/video) for allowing the images to be visualized in a computer monitor.

a **b**

Figure 1. Outdoor (a) and indoor (b) view of the studied broiler housing.

Birds' behavior recording

The area covered by the video camera and recorded was divided into 48 quadrants and marked in a transparent film which was put over the monitor (Figure 3).

A total of 168 frames were analyzed. There were 14 frames per video footage, in two videos per day during six days. The number of birds in the frame was recorded and the following factors were observed during the video footage analysis: (a) the total of birds present each frame; (b) the area occupied (local stocking density) which was determined as the percentage of the total number of quadrants (total of 48) which were occupied by the flock in each frame; and (c) the amount of birds in the flock that walked within 15s interval. The bird was considered in movement when it walked from a quadrant to the next or to further distance, and it was expressed as percentage of the total birds which were in the frame and were moving. Considering the schematic representation it was considered movement when the bird moved from the place $X_n Y_n$ to any adjacent position.

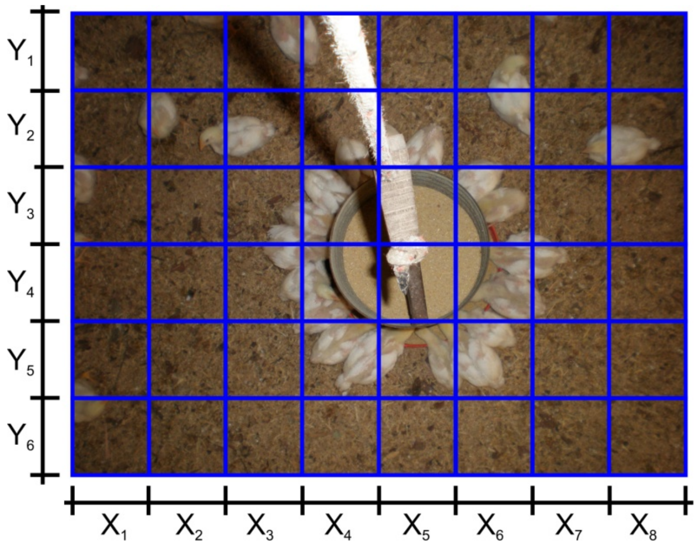

Figure 3. Schematic representation of the quadrants used for analyzing the video footage and each frame.

<u>Ambient variables recorded</u>
Ambient data inside housing were recorded using data logger HOBO® H8 (dry bulb temperature, relative humidity and light intensity) set for registering each 30s.

<u>Statistical analysis</u>
Data evaluation started with an exploratory analysis for establishing relationships between variables, using the multivariable analysis Principal Components Analysis. Between the identified principal variables Pearson correlation was applied, and a regression model was proposed to establish a functional relationship between the birds' movements and the other variables (age, temperature, occupied area and relative humidity). Data were processed using the statistical software MINITAB® 15.1 (Minitab, 2005).

Results and Discussion

The Principal Components Analysis was applied with the objective of making visible possible associations between variables of a group of data, reducing the number of variables which are related to the study (Figure 4).
The result is shown in a vectorial way where the lines with small length means low correlation explain much, and the vector with high length and small angle are highly associated (Salgado, 2006). The variables inter relations found in Figure 4 presented 76.7% of the total variability, which validates the visual findings. From Figure 4 it was found the following associations:

- The walking movement of the broilers (%) is inversely associated to age and to the area occupied (vectors with an angle of ~180º. This means that the movement of the birds tends to decrease with the increase of both age and the floor occupied area;

- Age and occupied area are strongly and positively associated, meaning that the area occupied by the birds increase as they grow;
- Air temperature presents moderate negative association with the birds' movement;
- Air relative humidity and light intensity presented low association to the birds' movement; and
- Air relative humidity presents strong association with light intensity.

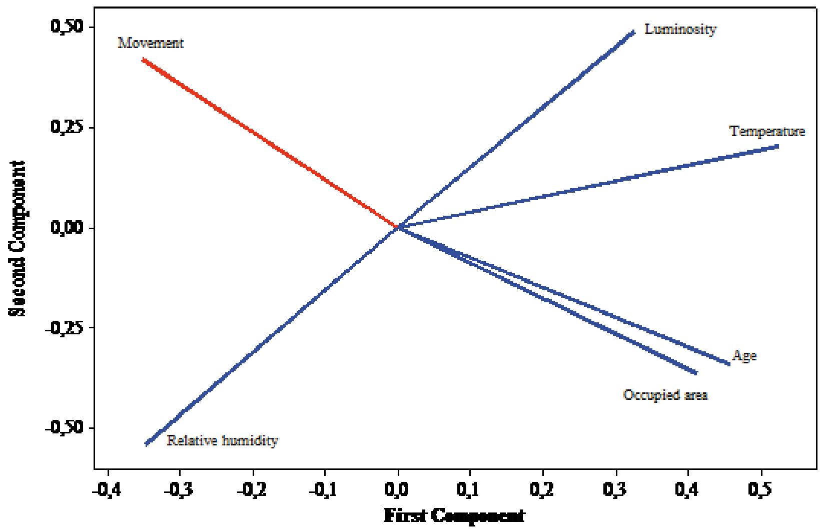

Figure 4. Graph of the Principal Components Analysis for searching the relationship between the movement of the birds and other variables that were involved in the trial.

After these results the degree of linear association was tested using Pearson's coefficient. In general the correlations were positive (p-value < 0.001), specially the correlation between age and occupied area and birds' movement and occupied area (Table 1).

Table 1. Main correlations found between the studied variables.

	Age	**Occupied area**	**Ambient temperature**
Occupied area	0.665		0.365
Birds' movement	-0.557	-0.525	-0.332

Pearson Correlation; p-value < 0.001 for all correlations.

After the correlations were measured a regression analysis model was proposed considering the birds' walking movement as function of the variables age, occupied area, ambient temperature and relative humidity. As light intensity was not significant it was not used in the model. Outliers were taken away from the model due to discrepancies. Residual analysis was added to establish a linear correlation between variables. The final model is shown in Equation 1.

$$MOV (\%) = 135 – 1.18 Age- 0.213 OA (\%) – 1.74 T (°C) – 0.706 RH(\%) \quad (1)$$

Where age is the birds' age, OA is the occupied area, T is the ambient temperature and RH is the air relative humidity.

The model showed an R^2 = 51.5% indicating that the used variables were moderately sufficient to explain birds' movement under that specific conditions. In this model ambient temperature was the variable that influenced most in the birds' movement, followed by the birds' age, air relative humidity and occupied area (local stocking density). Using the equation it is found that an increase of 1°C in ambient temperature results in a decrease of 1.75% in the movement of the birds. The increase of one day in the broilers' age results in the decrease of 1.18% in the birds' movement. The increase of 1% in the occupied area decreases 0.2% in the birds' movement, and finally, the increase of 1% in the air relative humidity provokes the decrease of 0.7% of the birds' movement inside housing.

Studies suggest that genetic strains with high growth characteristic are greatly influenced by increase in ambient temperature and relative humidity, mainly found in tropical countries (Cahaner *et al.*, 1995; Macari e Furlan, 2001). Current literature also points that birds tend to decrease feed consumption and motor activities when ambient temperature increases significantly (Rutz, 1994; Curto, 2007). Therefore, this may be an important variable which limits broilers movement inside housing under tropical conditions such as Brazil. Medeiros *et al.* (2005) found that thermal comfort inside the aviary maintain the birds at rest and normally dispersed on the floor and the threshold of environmental variables recommended by the authors are: ambient temperature near 26 °C, relative humidity close to 70%, and air speed 1.5 m s^{-1}. According to Neves *et al.* (2010) a small variation on the environmental variables may influence broilers' feed behavior.

Aydin *et al.* (2010) developed a model to investigate the activity levels of broiler chickens regarding to gait score using an automatic image monitoring system under laboratory conditions. This technique could allow the researches to study behavior analysis of different gait score groups. In the present study it is also expected that the developed model could help researches and farmers for a better understanding of the influence of the environment conditions on birds' behavioral activities using a video monitoring tool.

Light intensity is known as one variable that influences broilers' movement, and inside open buildings the amount of light may vary from 5 to 100.000 lx (Prescott & Wathes, 1999; Théry, 2001). The recommended value of light intensity is within the limit of 20 lx (FAWC, 1992). Kristensen *et al.* (2007) found that age and time of the day are the variables that mostly affect broilers behavior. In this study results showed that there was no effect of light intensity in the broilers' movement, although the value of light intensity varied from 21.5 l to 2399,5 lx, with an average value of 362 lx of natural daylight.

Conclusions

The present model establishes a connection between the flock density in the feeder area, ambient temperature and relative humidity, and points out that these variables are moderately sufficient for explaining the birds' walking index inside the housing. Further studies need to be carried out within the total production cycle and using extreme values of the ambient data for helping understanding better these relationships. The improvement of this model could be apply to feed a real time automatic system with a video camera for monitoring of the flock conditions, considering some drawbacks, such as heat stress, gait disorders and feeding behavior. This tool allows the farmers to take more assertive management decisions.

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References

Aydin, A., Cangar, O., Eren Ozcan, S., Bahr, C., Berckmans, D. 2010. Application of a fully automatic analysis tool to assess the activity of broiler chickens with different gait scores. Computers and Electronics in Agriculture **73**, pp. 194–199.

Bokkers, E.A.M., Koene, P., Rodenburg, T.B., Zimmerman, P.H., Spruijt, B.M. 2004. Working for food under conditions of varying motivation in broilers. Animal Behaviour **68**, n.1, pp. 105-113.

Cahaner A, Pinchasov Y, Nir I. 1995. Effects of dietary protein under high ambient temperature on body weight, breast meat yield and abdominal fat deposition on broiler stock differing in growth rate and fatness. Poultry Science **74**, pp. 968-975.

Curto, F. P. F.; Nääs, I. A.; Pereira, D. F.; Salgado, D. D. 2007. Estimativa do padrão de preferência térmica de matrizes pesadas (frango de corte) (abstract in English). Revista Brasileira de Engenharia Agrícola e Ambiental **11**, n.2, pp. 211-216.

FAWC - Farm Animal. Welfare Council, 1992. Report on the welfare of broiler chickens. Ministry of Agriculture, Fisheries and Food, p. 9, paragraph 35-38.

Goliomytis, M., Panopoulou, E. and Rogdakis, E. 2003. Growth Curves for Body Weight and Major Component Parts, Feed Consumption, and Mortality of Male Broiler Chickens Raised to Maturity. Poultry Science **82**, pp. 1061-1068.

Kristensen H.H., Prescott N.B., Perry G.C., Ladewig J., Ersbøll A.K., Overvad K.C., Wathes C.M. 2007. The behavior of broiler chickens in different light sources and illuminances. Applied Animal Behaviour Science **103**, pp. 75-89.

Macari, M.; Furlan, R. L. Ambience in poultry production in tropical climate. In: Silva, I.J.O (Ed). Ambience in poultry production in tropical climate: Series Agricultural Engineering Rural Constructions. v: 1. SBEA:Piracicaba/SP, 2001. p. 31-87.

Medeiros, C.M., Baêta, F.C., Oliveira, R.F.M., Tinôco, I. F.F., Albino, L. F. T., Cecon, P. R. 2005. Effects of temperature, relative humidity and air velocity on broiler chickens. Engineering in Agriculture **13**, n.4, pp. 277-286.

Minitab. Version 15.1.0.0. Inc. 2005.

Neves D.P., Nääs I.A., Vercellino R.A., Moura D.J. 2010. Do Broilers Prefer to Eat from a Certain Type of Feeder? Brazilian Journal of Poultry Science **12**, n. 3, PP. 179-187.

Pagel, M.; Dawkins, M. S. 1997. Peck orders and group size in laying hens: future contracts for non-aggression. Behavioural Processes **40**, pp. 13-25.

Prescott, N. B., Watches, C. M. 1999. Reflective properties of domestic fowl (Gallus g. domesticus), the fabric of their housing and the characteristics of the light environment in the environmentally controlled poultry houses. Brazilian Poultry Science **40**, pp. 185-193.

Rutz, F. Physiological aspects governing the thermal comfort of birds. In: Conference APINCO, 1994. Santos/SP. Proceedings... Campinas: FACTA, 1994. p. 99-110.

Salgado, D. D. 2006. Statistical model to predict the welfare of broiler breeders based on data from the environment and behavior analysis. 128p. Thesis (Masters) - School of Agriculture Engineering, University of Campinas, Campinas.

Thery, M. 2001. Forest light and its influence on habit selection. Plant Ecology **153**, pp. 251-261.

Active Control of Chickens' Activity Index in a Small Chamber

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Controlling activity in broiler chickens may provide an inexpensive tool with the potential to improve broiler welfare.
The objective of this paper is to examine the possibility to control the activity index of chickens in a small chamber via controlling the micro-environmental variable temperature around the chickens. A small ventilated test chamber (0.70×0.65×0.4 meters) equipped with outlet fan and a heater in the inlet was used. In this study dynamic mathematical modelling was used to predict the activity index of broilers in relation to variations in the inlet temperature and ventilation rate. Step inputs in ventilation rate and inlet air temperature were applied and temperatures at 30 sensor locations (5×6 grid) were recorded. The chamber was populated with seven broiler chickens (age 6 days). The equipment used for activity measurement consisted of a digital CCD camera that was mounted 1.30 meters above the floor of the chamber and connected to a PC with built in IEEE1394 FireWire interface. The lens was pointed downwards to get a top view image of the chamber. Images were captured with a resolution of 640 by 480 pixels and a 1 Hz frame rate. Software was developed to measure the real time activity level of all chickens visible in the camera image in. Before the experiments, the chamber visible in the camera images was divided in four zones. Every second, the algorithm logged the camera image and the activity index for each zone, defined as the fraction of the floor space in the chamber that was covered or uncovered by animals in the camera image during a one second period. The dynamic variation of activity index of chickens was compared to the two-dimensional temperature spatial profile inside the chamber. A model-based predictive controller was designed for active control of chicken activity index.

Keyword: Model-based controller, Broiler activity index, dynamic modelling

Introduction

The increasing human population density all over the world is leading to an increase in meat consumption. Chicken meat accounts for almost 30% of the demand of meat today, so it cannot be neglected. Numerous reasons for the preference of poultry meat to pork or veal can be given, but the main reasons for eating poultry are its calorific and nutritional values, together with an easy preparation (M. Nowak and T. Trziszka, 2010).
Several studies have focussed upon ways of increasing activity early in growing, although reducing activity is sometimes desirable, for example during depopulation. Rearing broilers in bright red light early in life increased activity and decreased leg disorders compared with broilers reared in dim blue light (Praitno et al., 1997), whilst environmental complexity has been reported to either increase activity (Bokkers and Koene, 2003) or have no effect upon activity or gait score (Bizeray et al., 2002c). High light intensity increased activity of broiler chickens and decreased leg problems and mortality without affecting production (Cherry and Barwick, 1962 and Newberry et al., 1988).

Controlling activity via aspects of the environment requires predictions of how the animals respond to different levels as well as variations in environmental stimuli. The responses are likely to involve both steady-state and dynamic components, and both traditional statistical analysis and dynamic modelling can be used to describe them. Methods of dynamic modelling are generally described as either mechanistic or data-based, depending on their approach and objective. Mechanistic models are often used to understand a biological system and their complexity often reflects a biological system. In contrast, data-based models do not make any prior assumptions about the biological system and since they are generally much simpler than mechanistic models, they are more appropriate for control purposes. Combined methods have also been developed, e.g. data-based mechanistic modelling, in which models are determined from the data alone but are then interpreted on the basis of biological understanding of the system (Young, 1993). By using this technique, it may be possible to control the activity of the chickens by predicting (modelling) their dynamic responses to changes in an input stimulus, in this case step-wise variations in light intensity (Aerts et al., 2000). However, before implementing a control system at farm level, it is vital to determine a suitable target for activity, based upon the behaviour and welfare of broilers.

Automated image analysis techniques were used in different studies to determine the activity of chickens such as that used by Kristensens et al. (2006). In which they suggested in their study that a combination of step-wise variations in light intensity and the dynamic data-based modelling technique could provide additional information on ethological mechanisms controlling broiler activity. This is encouraging for predicting and controlling activity, which could improve the welfare of broiler chickens on the farm.

The main objective of this paper is to model the effect of step-wise increasing in inlet-temperature and ventilation rate on the dynamic activity of chickens. The resulted models will be a base for model-based controller to control the chickens' activity.

Material and methods

Test chamber

The research work presented in this paper is based on the analysis of data from planned experiments in a small scale tested instrumented chamber in the Laboratory of Measure, Model and Manage Bioresponses (M3-BIORES) at the Katholieke Universiteit Leuven. The test chamber represented in the figure 1, has an inner dimension of length = 0.71 m, width = 0.62 m, and height = 0.385 m and is equipped with an electrical heater with maximum capacity of 224 W.

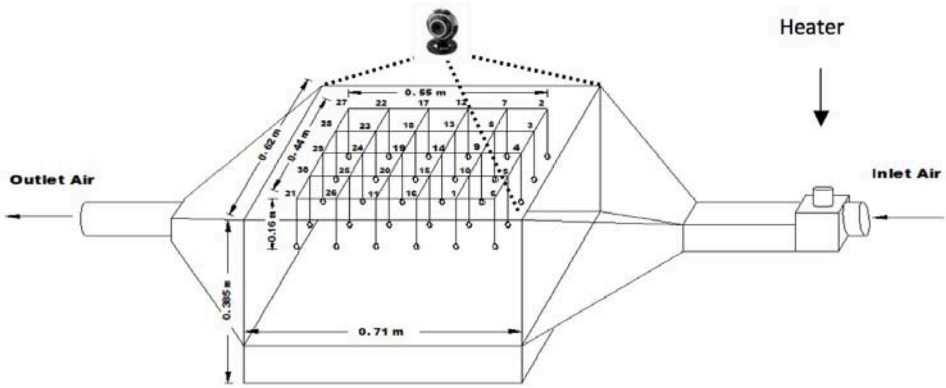

Figure 1. Schematic 3D diagram of the test chamber showing the middle chamber equipped with 2D grid of 30 temperature sensors and a prepared space under the senores grid for the chickens. A camera installed in the top of the test chamber to monitor the chickens' activity.

Two axial fans are installed, one in the inlet, which forced the incoming air over the heater before the air enters the chamber, whiles the second fan (exhaust fan) in the outlet to force out the air from the chamber. The chamber wall was constructed with Plexiglas, wood with aluminium framing. The ceiling of the chamber was constructed with Plexiglas of 0.08 m thickness rested on aluminium framing. The inlet of the system composed of two series of ducting system first a circular ducting of 0.1055 m inner diameter, where inlet fan was installed followed by a square ducting of outer dimension of 0.12 × 0.12 m of made up of 0.018 m thick wooden wall, inside this section the heater was fixed. The temperature inside the test chamber could be changed by changing the inlet temperature which is regulated by the in/outlet fans and the heater voltages.
A 2D grid of 30 calibrated temperature sensors (Semiconductors LM35) with and accuracy of ±0.1 oC were arranged uniformly in 6 × 5 matrix of with a total dimension of length = 0.55 m and width = 0.44 m. The 2D grid of sensors were lowered 0.16 m downward from the ceiling to make a horizontal 2D grid of sensors suspending on the empty space of the chamber. The velocity of the exhaust air was measured by velocity sensor, which was installed inside the circular outlet ducting. A measurement and data collection unit with programmable measurement frequency was used for the data acquisition. All measurements were recorded every second and logged in the computer. On the top of the test chamber, a webcam was installed to monitor the activity of the chickens.

<u>Experiments</u>

Air-flow-pattern investigation

During the course of the initial research in this paper, the air-flow-pattern within the test chamber was investigated at different ventilation rates. Set of smoke experiments were conducted by injecting smoke in the inlet to the chamber. Using the *Optical-Flow-Algorithm* (Lucas and Kanade, 1981) the airflow pattern throughout the chamber was visualised.

Step experiments

During the research work in this paper combinations of step-wise increases of different ventilation rate and inlet temperature were applied according to table 1.

Table 1. Combinations of steps in ventilation rate and inlet temperature.

Absolute time (min)	Inlet temperature (°C)	Ventilation rate (m^3/h)
0		1.5
15	40	3.0
30		4.5
45		1.5
60	45	3.0
75		4.5
90		1.5
105	50	3.0
120		4.5
135	End	End

Results and Discussion

Airflow pattern throughout the test chamber

The dominate airflow pattern in the test chamber was investigated using the optical-flow-algorithm (OFA). Visualisation of the dominant airflow pattern throughout the test chamber as a result of the optical-flow-algorithm is shown in figure 2a. The vectors, on the figure, represent the relative quantification of the air velocity in the test chamber. To ease the further analysis the chamber area was divided into four equal numbered zones (Figure 2b).

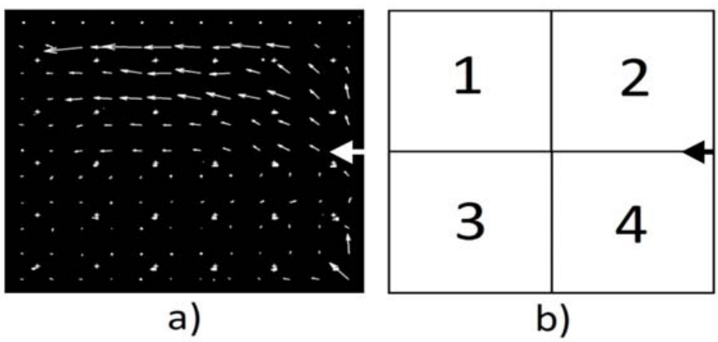

Figure 2. a) Optical-flow-field showing the dominant airflow pattern in the test chamber, the vectors representing the relative quantified air velocity; b) divided chamber area into equal four numbered zones to ease the further analysis.

According to the airflow pattern (figure 2), the air enters the chamber at the inlet and flows mostly through zone 2 and 1 to exit at the outlet (left side of zone 1), while little portion of the air. The plotted optical-flow-field (figure 2a) shows a turbulent airflow pattern. This can be attributed to some manufacturing problems of the chamber.

<u>Broiler activity response to steps in ventilation rate and inlet temperature</u>

Figure 3. shows an example of the inside temperature response at the sensor position number 26 to the step increase in both inlet temperature and ventilation rate.

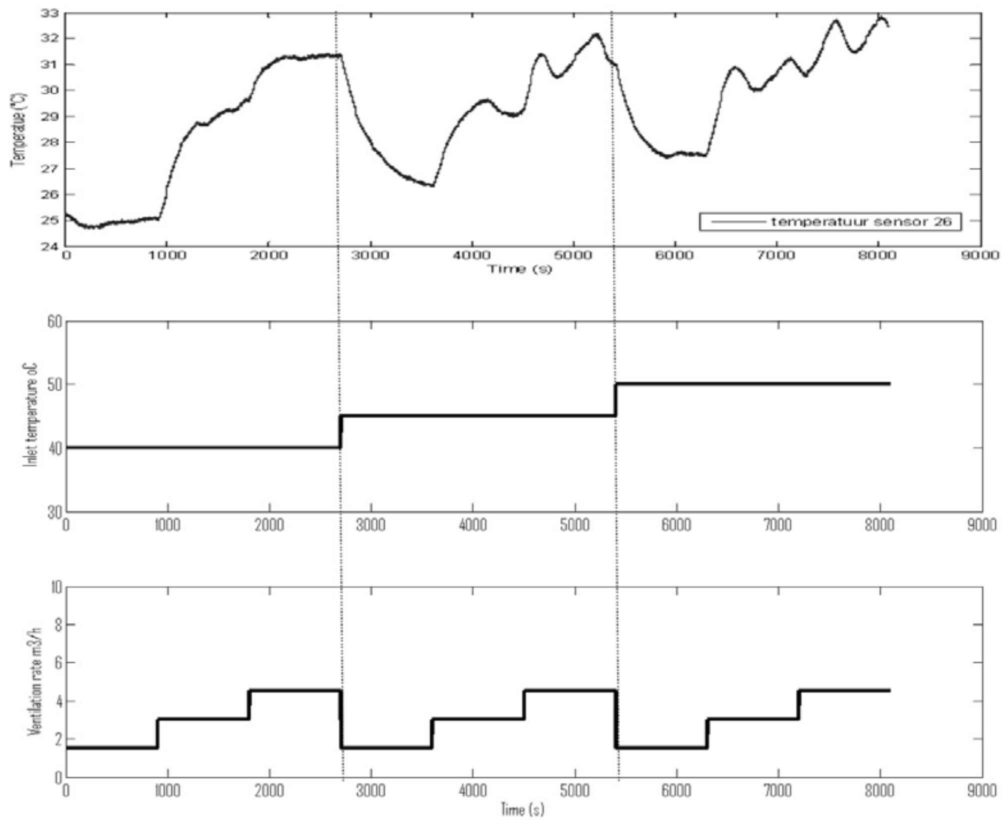

Figure 3. The inside temperature at sensor position number 26 (upper graph) in function to step increases of inlet temperature (middle graph) and ventilation rate (bottom graph).

At inlet-temperature of 40 °C (Step 2) the average temperature in each of the four zones were calculated and presented in figure 4.

It was expected that the chicks would respond on an increase of temperature. Higher temperature would cause more activity because of the flapping of the wings to cool down. Lower temperature would cause less activity because the chicks will get together to warm up each other. When the average temperature in the cage was compared with the average activity, it could be seen that the broilers do not really react on the temperature. They rather react on a change in temperature than on the temperature itself. This behaviour can be seen well if activity and temperature are plotted on the same figure (Figure 5). Each time the temperature drops, there is an increase in activity. This can be explained by the fact that when there is a change in their environment, the chickens get active to search for a place where the environment is better.

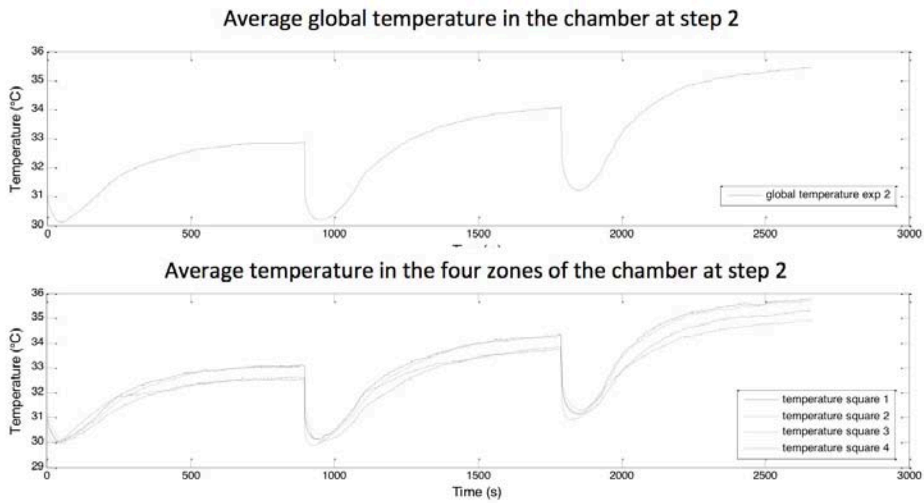

Figure 4. Average global temperature in the chamber based on the 30 sensors measurements (upper graph) and the average temperature in each of the four equal zones (squares) at inlet temperature of 40 °C (Step 2).

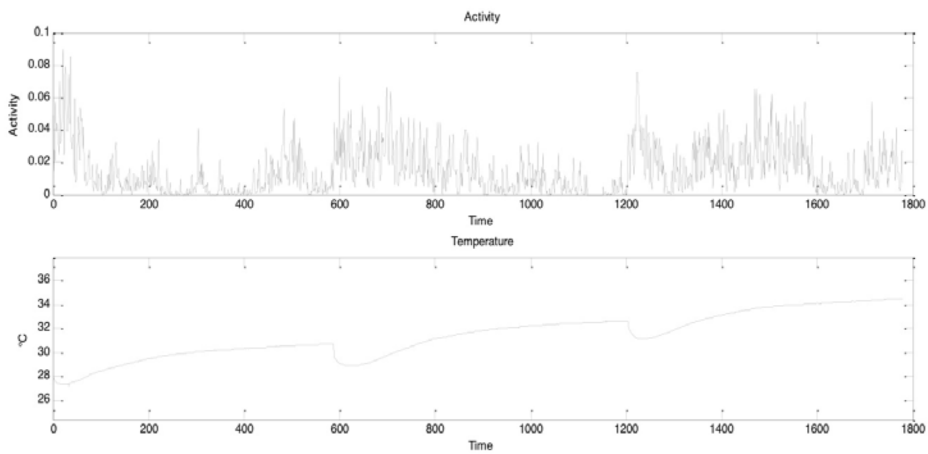

Figure 5. Average activity index for the broilers in the chamber (upper graph) in relation to step changes in average global temperature of the chamber (bottom graph).

Dynamic modelling of broiler activity in response to change in average global temperature in the chamber

Irrespective to the inherent oscillations in activity index, which were unrelated to the experimental factors, the chicken showed clear responses to step-wise changes in average global temperature in the chamber. The change in activity index of the chickens was modelled for step-wise increase in average global temperature in the chamber.

A first order *Transfer Function* (TF) model with one second pure delay was suitable to describe the dynamic response of the change in the activity index of the chickens to changes in the average global temperature in the chamber. Figure 6 shows an example of the modelled activity index as an output to the following model structure:

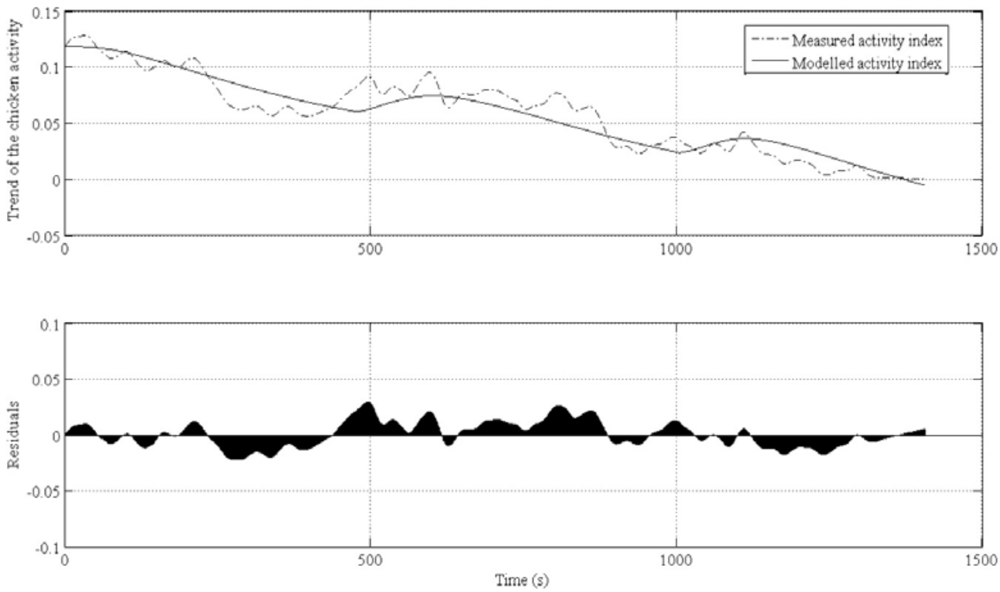

Figure 6. Measured and modelled activity index (upper graph) and the residuals (lower graph).

$$y(k) = \frac{B(z^{-1})}{A(z^{-1})}\, u(k)$$

where:

$A(z^{-1}) = 1 + a_1 z^{-1}$

$B(z^{-1}) = b_1 z^{-1}$

a_1 and b_1 are the model parameters.

The resulting model can be used to predict the activity level of the chickens and yet simple enough to easily design a control system to steer the chickens to a certain activity level.

Conclusion

In conclusion, this paper describes the first steps in research of broiler control using chamber inside temperature and ventilation rate as actuators. Experiments using smoke prove that airflow through a small chamber is not uniform making the control in chamber a difficult process. On the other hand it was proven that broiler chickens react on the temperature in the used set-up by varying their location in the chamber and by walking around. Further work is still to be done to steer the broiler distribution and activity. From this paper we can conclude that chickens react on a change in temperature.

References

Nowak, M. and Trziszka, T., 2010. Consumer Behaviour On The Poultry Meat Market. Zywnosx-nauka technologia Jakosc. 17: 114-122.

Aerts, J.-M. et al., 2003. Active Control of the Growth Trajectory of Broiler Chickens Based on Online Animal Responses. Poultry Science. 82:1853–1862.

[Kristensen, H.H. et al., 2006. Modelling the dynamic activity of broiler chickens in response to step-wise changes in light intensity. Applied Animal Behaviour Science. 101: 125–143.

Mitrović, S. et al., 2010. The influence of population density and duration of breeding on broiler chickens productivity and profitability. African Journal of Biotechnology. 9: 4486-4490.

Chedad, A. et al., 2003. Do heavy broiler chickens visit automatic weighing systems less than lighter birds?. British Poultry Science. 44: 663–668.

Sergeant, D. et al., 1998. Computer visual tracking of poultry. Computers and Electronics in Agriculture. 21: 1–18.

De Wet, L. et al., 2003. Computer-assisted image analysis to quantify daily growth rates of broiler chickens. British Poultry Science. 44: 524–532.

Xin, H. 1999. Assessing Swine Thermal Comfort by Image Analysis of Postural Behaviors. Journal of Animal Science. 77: 1-9.

Section 10
Smart Tracability

Comparative analysis of different meat traceability systems using social network approach

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Abstract

This study aimed to select the most appropriate meat traceability system "from farm to fork" applied to Brazilian pork production. The research used the results from a selection of the best on-farm livestock traceability using analytic hierarchy process (AHP). Then, the agents in the meat production chain where identified for building a framework with their defined role in the network. Results indicated that with an electronic traceability system it is possible to acquire better connections between the links in the chain and to provide the means for managing uncertainties by creating structures that facilitate information flow more efficiently.

Keywords: strategic consideration; food traceability; social network analysis.

Introduction

The future of international meat commerce depends mainly on an industry acting with honesty, openness, traceability, assurance of quality, and flexibility for making changes, all while having detailed information available. A number of collaborative studies have been undertaken in meat production to improve on-farm data acquisition (Caja *et al*., 2005) and the communication within the food production chain to enable early warnings and an all-encompassing health management system (Petersen *et al*. 2002).

The concept of traceability "from farm to fork" involves several linked actions between market segments and governmental bodies, which can be considered similar to a social network, and it can be studied using the principles of social network analysis (SNA). Initially developed to describe social structures, SNA has its origins in the studies of patterns of communication, influence and interactions within social groups (Scott, 2000; Richardson, 2009). Furthermore, a method of drawing on graph theory was developed for capturing and analyzing the relationships among members of a group with specific links and interactions (Carpenter & Westphal, 2001). The objective of this research was to select the most suitable pork traceability system "from farm to fork" that could be applied to Brazilian pork production with a focus on international trade applying the SNA concept.

Methodology

The research was carried out in two steps.
1) Field traceability data were collected in a commercial swine farm located in Brazil and the multicriterial analytic hierarchy process (AHP) was applied for identifying the best option. The tested identification (ID) alternatives were: electronic system (using implanted transponder and manual reader), total manual system (using written recording control data) and the mixed system (using quantitative data recorded manually-such as weight), and

2) The concept of network analysis (SNA) was applied in the pork meat food production and distribution chain. Although the food network is very complex and it contains a large number of players and characteristics that may be taken into consideration, this specific analysis adopted a more simplified approach which took into account the flow of information, payments and product in the food chain. This second part was solved by simulating the product path in the designed network and the interaction of food chain players using SNA.

Selecting the best ID alternative

During the first step the decision problem was disaggregated into a hierarchy of interrelated decision elements or attributes. The most macro-decision objective lied at the top of the hierarchy, while the lower levels of the hierarchy contained more detailed descriptions of attributes or groups of attributes that contribute to the quality of the choice between alternatives. For the specific system to be considered appropriate it was necessary to meet the manager and labor needs, as suggested by Petersen *et al.* (2002). The criteria considered important were: information security and reliability; the system needed to be practical, and the system needed to be easy to implement and fast in retrieving information. The results of the first part indicated that the best and most reliable ID system was the electronic data recording (AHP rank = 0.445), followed by the hybrid system (AHP rank = 0.361), and the manual (AHP rank = 0.194), as suggested by Nääs *et al.* (2005).

Development of a traceability network array using the social network concept

Network analysis was applied to this study to organise the information flow in the chain for pork production and then to select the best way to implement the traceability system from the farm (livestock production) until the product reaches the final costumer. The three different meat traceability systems (from the first step) were considered in a chain scenario of selected actors, while also allowing their bi-directional relationships.

The construction of the network began with the identification of the main actors in the meat supply chain in Brazil (Euclides Filho, 2004; Buainain & Batalha, 2007). Information flow starts from the livestock producer at the beginning of the chain and flows towards the consumer at the end of the chain. A communication protocol was built with the aim of allowing data to flow effectively among the chain elements/actors, as required by international trade standards. For the traceability analysis, the actors were grouped based on their objectives and interfaces to define a unified and embedded protocol. The interactions between players were limited to base data, health status, weights and financial transactions.

In order to simplify the network flow of information, data were separated into two different sets: (a) LIVE DATA, which was related to livestock while being reared on the farm and during transportation to the slaughterhouse, and (b) MEAT DATA, which was related to the slaughtered animal and furthermore called meat (Table 1).

An appropriate description of relationships between pairs of actors and links, and the flow of information (from one player to the next player in the chain) indicating which type of documented relationship is applied to the product or service (such as volume of product, financial documented transactions, certificates, etc) are shown in Table 2. As the relationship involves several actions taken during the trade process such as exchange in documents, etc, the weight of the *edge* between actors related in a specific relationship is evaluated by its complexity and importance within the whole process.

Table 1. Input data to the pork chain

LIVE DATA	MEAT DATA
Identity (ID)	ID Code
Health Status	Type of cut (description)
Environmental/Ethical	Type of processing (description)
Labour/Ethical	Processing date (Check Point)
Local Government Certificate	Time of storage under refrigeration (including transportation)
International Compliance Certificate	Local Government Certificate
Special Label Compliance Certificate	International Compliance Certificate.

Weights were given to the relationships, and the analysis was processed using the Ucinet® 6 for Windows® software tool (Borgatti, 2002). The goal was to survey the interactions, to identify the actors and their graphical structure, and to understand how the management chain develops.

In this research, the structural measurements of *centrality*, the identification of network subgroups, and the analysis of roles were done using the theory of graphs in the Ucinet® software integrated module NetDraw®, which also enabled visualization of the social network graph data.

Selection of the meat traceability system

The ideal and most complete network structural properties were found by processing data using the initial raw weight of the relationships between all actors. In the next step, the weights were adjusted using correction factors that were obtained from the AHP analysis using the electronic, hybrid and manual systems developed for the on-farm livestock traceability (Nääs *et al.* 2005).

The following network structural properties were compared: *density* (the ratio of all ties that are actually present to the number of possible ties), *degree centrality* (which refers to the amount of immediate ties the actor has within the network, %), *closeness centrality* (which relates the distance of an actor to all others in the networks by focusing in the distance from each actor to all others, %), *betweenness centrality* (which views an actor as being in a favored position to the extent that the actor falls on the geodesic paths between other peers in the network, %), *clustering coefficient* (which refers to the average of the densities of the neighborhoods of all actors), *clique* (which is a sub-set of a network in which the actors are more closely and intensely tied to one another than they are to other members of the network), *N-clique* (which is used to define an actor as a member of a clique if they are connected to every other member of the group at a distance greater than 1, with *N* being the length of the path allowed to make a connection to all other members), *node* (which is the same as element or actor), *edge* (which is the same as relationship), and *geodesic distance* (which is the length of the shortest path between the actors).

The higher the weight is given to the relationship, the better the interaction is between actors and the more reliable the data flow is within the network/chain (Hanneman & Riddle, 2005).

Table 2. Relationships established among the actors in the pork chain

From	To	Relationship units
Farm	Slaughterhouse	LIVE DATA Delivered Volume (ton)
	Local Government	Volume (ton) Health Status Certificate Tax ($)
	International Regulations	Volume (ton) LIVE DATA
	Private Compliance	Payment ($)
	Special Label	Payment ($)
Private Compliance	Farm	Auditing Emission of Label Compliance Certificate
Special Label	Farm	Auditing Emission of Compliance Certificate
Slaughterhouse	Farm	Requested Volume (ton) Payment ($)
	Local Government	Tax ($)
	International Regulation	MEAT DATA
	Wholesaler	MEAT DATA International Compliance Certificate Delivered Volume (ton)
Wholesaler	Slaughterhouse	Requested Volume (ton) Payment ($)
	Local Government	Tax ($)
	Retailer	Requested Volume (ton) Payment ($) MEAT DATA
Retailer	Local Government	Tax ($)
	Wholesaler	Requested Volume (ton) Payment ($)
	Customer	Requested Volume (ton) MEAT DATA
Customer	Retailer	Payment ($)
International Regulations	Farm	International Compliance Certificate
	Slaughterhouse	Emission of the International Compliance Certificate
Local Government	Farm	Infrastructure Health Certificate
	Slaughterhouse	Health Certificate Infrastructure
	Wholesaler	Infrastructure
	Retailer	Infrastructure

Results and Discussion

The use of adequate tracing technology in the food supply chain may lead to data that can warranty certain product qualities, enabling producers and other actors in the chain to respond for the chain safety “from farm to fork”. There are portions of the livestock raising process that occur off-farm that have traceability systems, such as the material needed to ensure the health (vaccines, medicine, etc.) and the supplementary feeding (minerals and premix fodder) of the herd, but the results here are presented assuming that the livestock traceability system starts at the production on-farm. This choice generates the input for the LIVE DATA, including imported information from the previous input data, which is transmitted through the actors in the production chain until the animal reaches the slaughterhouse. Within the slaughter house, the LIVE DATA is transformed into MEAT DATA, and it remains associated with a specific animal reared on-farm.
In international meat trade, most countries have already established a certain scope of control and accreditation. Initiatives for making information available to producers include preparing manuals, handbooks or protocols and giving specific guidelines for the development of facilities. The implementation of these processes is needed to implement the actions with government/certification organizations and producers.

<u>Pork traceability network array from “farm to fork”</u>
The Brazilian pork chain includes five sub-systems, described by Buainain & Batalha (2007): 1) Support system, made by basic input agents, which provide infrastructural support of livestock production; 2) On-farm production; 3) Processing and Industrialization; 4) Marketing; and 5) Consumer. The pork network graph was derived (Figure 1) by inputting the identified relationships (Table 1 and 2) into the Netdraw® software. The actors’ properties were adjusted and organized according to their geodesic framework. In these diagrams, participants are represented as points or *nodes*, and the relationship between them is represented by a line or *edge* (Carpenter & Westphal, 2001).

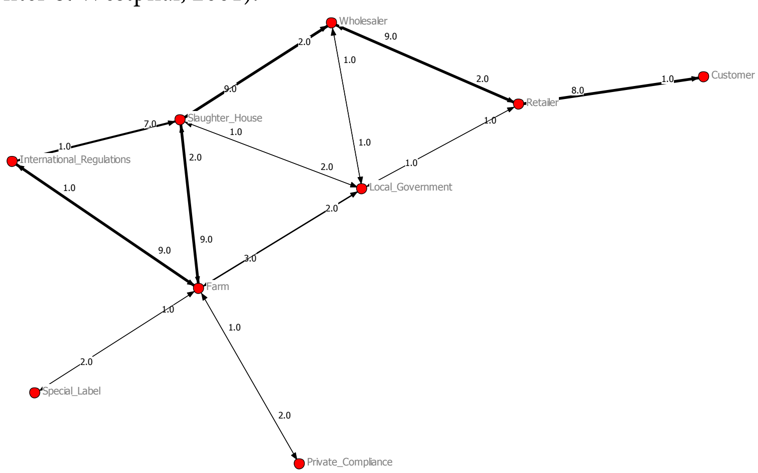

Figure 1. Pork network graph showing the interactions between actors within the swine production chain.

The thicker the line is, the more interactions there are between those individuals. The structural properties of the network with their original weights obtained from the relationships between the network nodes/elements/actors (chain protocol) were processed using the Ucinet® software environment, and the obtained values were applied to find the initial parameters to describe the ideal and most complete network (NET 1 Complete, Table 3).

Table 3. Specific values that defined the characteristics of the found network

NETWORK Parameters	NET 1 Complete	NET 2 Electronic AHP rank = 0.445	NET 3 Hybrid AHP rank = 0.361	NET 4 Manual AHP rank = 0.194
Density	0.867	0.386	0.313	0.168
Clustering Coefficient	0.876	0.481	0.424	0.352

The specific values that explained the network interactions were *density* and *clustering coefficient*, while the other variables did not change the values depending on the type of network. To find out how the network behaved using the three distinct types of livestock traceability, data were processed using the ranking values of AHP results. It was assumed that the criteria used for producing the livestock traceability selection was adequate to be replicated and embedded in the protocol application "from farm to fork". The results showed that the network density structural properties, number of current links between the network actors, and the possible links between them in the network change for each livestock traceability system adopted. When comparing the results of density for each network (NET 2, NET 3 and NET 4) to network 1 (NET 1) the best result was 0.386, which was related to the electronic data flow system. The second best result was found when using the hybrid system, while the worst result was obtained for the manual system of data flow.

Regarding the *clustering coefficient*, which is used to evaluate the proximity between the actors of the network, the results show that when using the electronic system (0.481) for data flow, the network structure allows a better interaction between the actors. The result when using the hybrid system (0.424) was lower than for the electronic system, but it indicates that it could be used in the traceability system with small losses in the quality of data flow. The manual system (0.352) presented a small *clustering coefficient* sign when compared to the other two systems, indicating a higher loss of quality in data flow if this system is used, which is not recommended. The remaining network properties did not present change due to the relatively small number of actors and connections considered, and the weights adopted were practically the same within the three scenarios (Borgatti, 2002). With a reliable traceability system, a purchaser might be able to verify production conditions and inspection protocols in addition to the information that is already provided, such as the packing date, place, and producer, and all of that information could be recovered through product labeling to identify specific product features. When the *density* is higher, the strength of the network' ties are greater, meaning better data flow. The *clustering coefficient* is defined in Equation 3 as:

$$C_i = 2n/k_i(k_i - 1), \tag{3}$$

where n represents the number of direct links connecting the k_i nearest actors of node i; it is equal to *1* for a node at the centre of a fully interlinked cluster, and it is equal to *0* for an actor that is part of a loosely connected group. Therefore, C_i, the average over all nodes i of a network, is a measure of the network's potential modularity. The results suggest that both electronic and hybrid traceability systems can supply nearly 50% potential modularity between active actors, providing acceptable tracking/tracing of the data flow (Antle, 1999). According to Schnettler *et al.* (2009) the information currently present on meat labels is useful for consumers, who would also value having information about on-farm livestock production. However, for adopting an electronic based system of meat traceability some factors may be taken into considerations such as the familiarity with IT tools and educational level of farm workers.

Conclusion

Applying the concepts of the SNA it was found that the meat traceability electronic-supported system "from farm to fork" for trading purposes presents higher degree of data exchange and higher reliability of data flow.

Acknowledgement

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References

Antle, J.M. 1999. Benefits and costs of food safety regulation. Food Policy **24** 605-623.

Borgatti, S.P., Everett, M.G. and Freeman, L.C. 2002. Ucinet for Windows: Software for social network analysis. Analytic Technologies: Harvard.

Buainain, A.M. and Batalha, M.O. 2007. Cadeia produtiva da carne bovina. Instituto Interamericano de Cooperação para a Agricultura – IICA: Brasília.

Caja, G., Hernández-Jover, M., Conill, C., Garín, D., Alabern, X., Farriol, B and Ghirardi, J. 2005. Use of ear tags and injectable transponders for the identification and traceability of pigs from birth to the end of the slaughter line. Journal of Animal Science **83** 2215-2224.

Carpenter, M.A. and Westphal, J.D. 2001. The strategic context of external network ties: Examining the impact of board appointments on director involvement in strategic decision making. Academy of Management Journal **44** 639–660.

Euclides Filho, K. 2004. Supply chain approach to sustainable beef production from a Brazilian perspective. Livestock Production Science **90** 53-61.

Hanneman R and Riddle, D. Introduction to social network methods. Available at: http://faculty.ucr.edu/~hanneman/nettext/introduction_to_social_network_methods.pdf, 2005. Accessed on: March 29 2010.

Nääs I.A., S. Campos, K. Silva, K. O. 2005. Comparison of manual and electronic traceability in swine production. Agricultural Engineering International: the CIGR Ejournal **7** 1-8.

Petersen, B., Knura-Deszczka, S. E., Pönsgen-Schmidt, E. and Gymnich, S. 2002. Computerised food safety monitoring in animal production. Livestock Production Science **76** 207-213.

Richardson, A.J. 2009. Regulatory networks for accounting and auditing standards: A social network analysis of Canadian and international standard-setting. Accounting, Organizations and Society **34** 571-588.

Scott, J. 2000. Social network analysis: A handbook. Sage Publications: London.

The role of traceability in Precision Livestock Farming: results from the EU project BrightAnimal

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Abstract
The EU Coordination and Support Action (CSA) BrightAnimal has investigated as one of its topics the role of advanced traceability in Precision Livestock Farming. Most efforts in this area concentrate on the animal lifecycle only (birth, death and movements in between) without utilising the full range of opportunities that bidirectional transport of information along the supply chain offers. In this contribution we would like to discuss the feed – animal – food chain as a generator and consumer of important information and the advantages of a bi-directional exchange in this chain. The optimisation potential along the chain is important and its realisation would benefit all partners in this chain. Reference to existing efforts in this area will be made, as well as its challenges discussed.

Keywords: Traceability, feed, farmer, slaughterhouse

Introduction

Food and feed traceability is an established concept in most of the high-value markets. The European Union, Japan, the United States and Canada (to cite a few) have somewhat varying requirements, but still use food traceability especially at their borders as a risk management tool related to food safety. The European Union has introduced food traceability in the form of a law, the General Food Law (European Parliament, 2002), in vigour since 2004. Although it is certainly debatable whether the General Food Law actually gives rise to a traceability system (as opposed to the simpler and less efficient chain of custody system), there is no doubt that food traceability has established its role in the toolbox of providing safe food to the consumers.

In traceability a somewhat arbitrary distinction is made between internal and external traceability. Internal traceability refers to all information kept in one enterprise, while external (or chain) traceability refers to the information link between enterprises. Precision livestock farming can use traceability for information storage and transport. Current PLF efforts would most use internal traceability to establish the animal history or link the animal's history to other incidences. An example in general livestock farming is of course the geographical aspect, i.e. linking an animal's history with geography to aid in case of a disease outbreak.

However, only isolated use is being made so far of the many other benefits that food traceability can bring to enterprises, regulators and consumers. Many of these additional benefits stem from the flow of *electronic information* between parties, as opposed to keeping information on paper and limited to isolated information islands. This concept of chain traceability, external traceability or *Chain Food Information Management* as we will call it here is also not new. Conceptually it is a logical extension of the well established supply chain management. And yet, the bidirectional flow of information *about food* adds very interesting new services that are yet to be established.

Definition of Chain Food Information Management

Chain Food Information Management can be defined as:

> Chain Food Information Management refers to the distributed collection, storage and usage of information items, connected by traceability, that can be accessed via electronic systems.

The idea behind it is strikingly simple:

- Collect data as a food item moves through the chain
- Make sure all processes are traceable to connect inputs to outputs
- Transport or calculate relevant indicators and make them available to stages in the chain that are n-times removed

The last point proves to be the point where most information chains actually break. Many companies run a relatively decent internal traceability system (i.e. confined to their enterprise) and even pass on a number of information elements to the next link in the value chain. However, that next link will in the process of manufacturing his products from the inputs lose the link to such information elements.

Figure 1. Some of the advantages of Chain Food Information Management

Chain Food Information Management (or C-FiM) has many known advantages, some of which are listed in Figure 1. Apart from the usual compliance to standards and regulations (under which food safety would fall), brand assurance and sustainability measurements deserve mentioning. New, foreseeable business models such as carbon or water indexed ingredients lie somewhat in the future, but will become increasingly important in the next decade.

For the purpose of this article, however we would like to concentrate on the efficiency angle that stems from the exchange of information. It is immediately apparent that the efficiency of whole supply chains can be greatly increased if information was to flow freely back and forth. Sourcing based on dynamic shelf-life calculations would greatly reduce waste and forward and backward logistics would be much more efficient (as can already be seen in international container management). In the case of animal production, which we will analyse below, the efficiency of feed and feeding could be greatly improved, thereby reducing the most important cost factor to animal farming.

Making Chain Food Information Management a reality

However, making C-FiM a reality requires overcoming a number of obstacles that currently exist. These obstacles can be grouped into three groups:

- Standardisation
- Ownership of data and systems
- Smallholders

<u>Standardisation</u>

The food industry is highly interconnected and typically volatile. Although perhaps in animal production supply chains have a stable core, at certain intervals material needs to be bought or sold to a large number of additional channels. The existence of lots of different communication channels requires a standard language of communication. More specifically, it requires a standard syntax and standard semantics, as expressed in a standard ontology.

On the standard syntax, the EU-funded research project TRACE[3] concluded that in spite of its own efforts to create such a syntax, it was better to try to adapt into an existing industry standard. The project chose GS1's EPCIS as the promising international standard. GS1 is an international non-profit identity provider, best known for their GS1-13 barcodes that is found on most consumer products. EPCIS or the Electronic Product Code Information System is an effort led by this organisation to standardise an information exchange between business partners. While EPCIS was created largely for logistics purposes and radio frequency identifiers, it was shown by TRACE that its abstract food traceability model can be expressed in EPCIS. More information about TraceCore and the TraceFood framework is available on (Lehr, 2008).

TRACE also initiated a standard ontology for a number of food items. ISO has lately picked up the subject, starting with caught and aquaculture fish. A standard will probably be released later in 2011 and it can be hoped that standardisation for other animal production systems will also be undertaken.

However, as of current, there is no established, global and actionable standard for food traceability or Chain Food Information Management.

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[3] www.trace.eu.org

Ownership of data and systems

A critical element in the equation of traceability adoption is the ownership and access to food information management systems and data stored therein.

There are currently four approaches being followed world-wide

- State-run, full access to data (favoured in South East Asia)
- State-run, partial access only (US)
- Industry-run (Norway, Denmark)
- Privately run (FoodReg and other private entities)

Each of these have their own advantages and flaws in their pure format, which has led us to favour a mix of most of the above models. Taking into consideration all the world-wide experience (see (Smith, 2008), a 3-tier model is best; cf.
Figure 2

- Tier 1 (or the main tier) is made up of a private network using a standardised syntax and semantics with a *private* agreement between parties on the information carried on the system. Via this private agreement it can be controlled which data is carried on the network, who has access to it and what part of the information can travel in which direction.
- Tier 2 (or the regulatory tier) is made up of a state/regulatory body owned system. This system holds only the data which are legally required (or if the regulatory body is an industry body, as is required by the statutes of that body). These data may very well be aggregated data, i.e. data that does not necessarily allow knowing specific details about a particular enterprise. From data available in this tier, the regulatory body can derive services like recall withdrawal, border services, quarantine services, industry statistics and other services.
- Tier 3 (or the certification tier) consists of a real-time access of certification bodies to data that is required by certain certification schemes. In this way certifiers could make sure that the basis for certification is given at any point in time. The need for this has become apparent, e.g. in a recent scandal with organic certification; see e.g. (Animal Health Online, 2010)

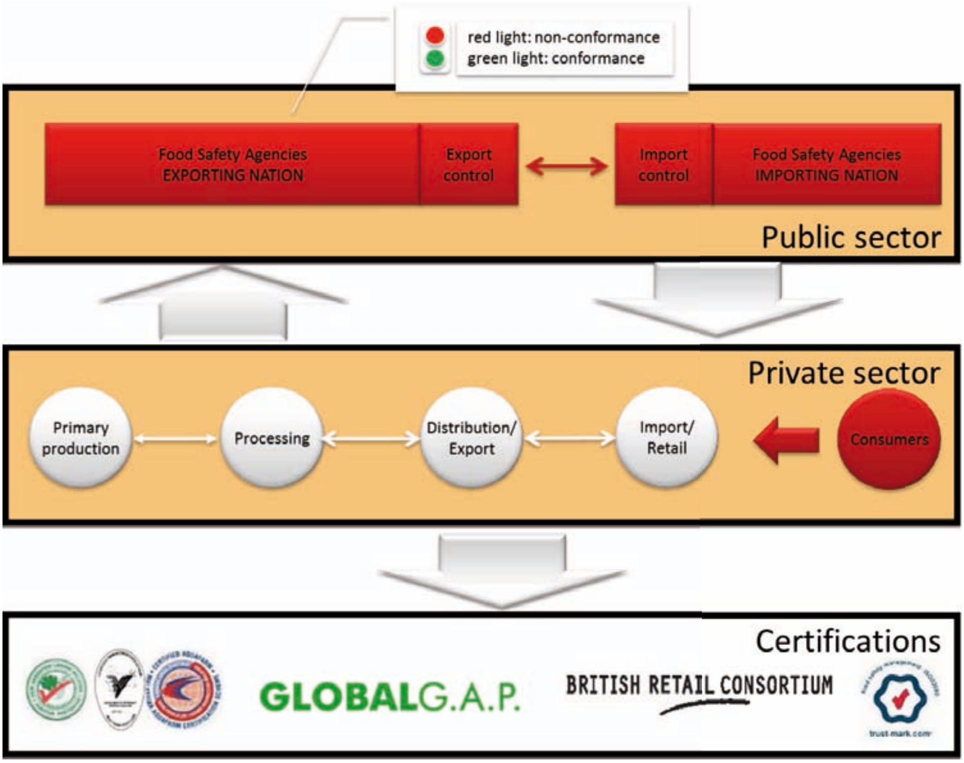

Figure 2. The 3-tier model for implementing Chain Food Information Management

Smallholders

Smallholders present very particular problems to food traceability, especially since they control the vast majority of food production. In Vietnam, out of 500,000 fish business operators, more than 480,000 are micro-enterprises. The same picture holds true in most countries, even in Europe; cf. Table 1. Smallholders typically are not organised in industry bodies, reticent to sign up to any professional organisation, technologically less advanced and with little interest to invest in increased performance, since more often than not their animal or food production is not the main contributor to their income. (These are obviously generalisations.)

	Total	1-99	100-999	1000-2999	3000-4999	5000-9999	10000-49999	50000-99999	>=100000
dk	360	190	10	0	0	0	60	70	20
de	9820	8340	450	60	20	30	590	240	90
gr	181770	176870	4130	30	20	180	450	50	20
it	43680	40770	1340	190	170	60	710	260	180
at	2740	2310	60	60	40	70	200	10	
pt	122820	121500	320	100	220	210	400	60	20
uk	1970	570	150	50	20	60	460	290	380
Totals	363160	350550	6460	490	490	610	2870	980	710
		97%	**2%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**

Table 1. Number of agricultural holdings with broilers, by size of the holding in 2005 (source EUROSTAT)

Organising such large crowds of smallholders into a food information network is a very complicated task that requires time and the right tools. Clearly mobile devices will play as important a role in the future as will the pressure from their supply chain. Pressure by regulatory bodies is not as efficient. (There was e.g. a strong backlash from small organic producers to the proposal of a new US food regulation made by Mr Obama.)

In the meantime, however, we believe that a mixed paper-electronic system is the best solution world-wide. Early stages of the supply chain should use a simple paper based system. Processors should then made responsible to transfer the data into an electronic system.

FoodReg has made a proposal for such a system which relies on a globally unique traceability code (T-code), a special pre-printed label (T-label) with barcoded information and a much simplified form (T-form) (Lehr, 2009).

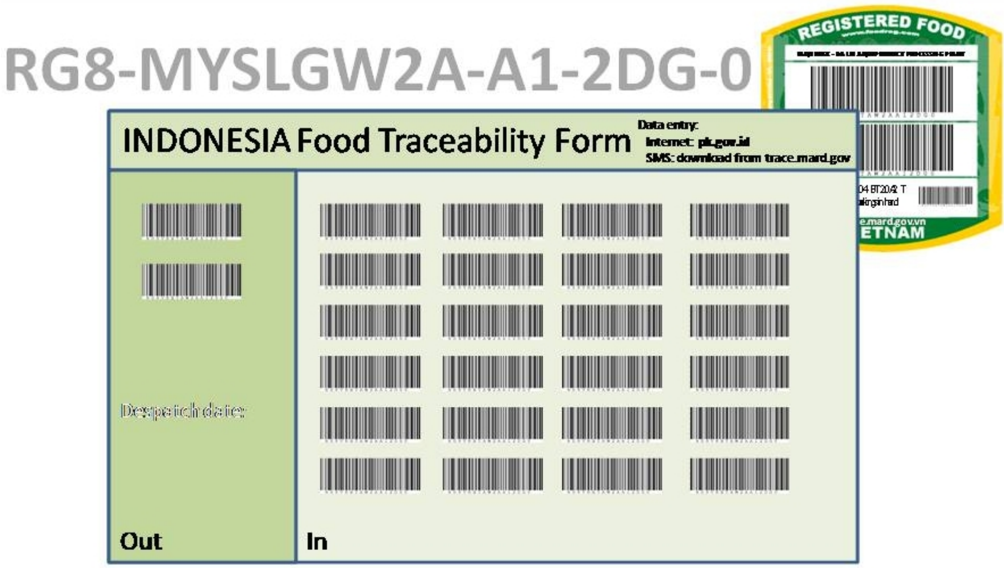

Figure 3. Elements of a smallholder paper-based traceability system apt for later conversion into electronic information.

This extremely simple system does not require smallholders to write at all, but makes the data capture by processors very easy thanks to the barcoded information. The system establishes only the product flow, but can obviously be extended. Details are available from the author.

It should be noted that the globally unique traceability code is not based on GS1's system. Due to GS1's membership based business model it is very difficult for such an organisation to deal with microenterprises. Collective ownership of codes (as is the suggested solution to this problem from GS1) is not the best way forward, since it neglects the possibility of growth for individual members of such a collective. Collective code ownership is also not necessarily the accepted solution of all GS1 country organisations.
This is not a trivial problem and a global solution should be sought.

Results and recommendations

Turning to a concrete application of C-FiM we would like to discuss shortly the application of C-FiM to the feed-animal-food chain.

Feed constitutes the single most important cost factor in animal production. Depending on the particulars, questioned producers have reported up to 80% of production cost coming from feed especially for pigs and poultry holdings. In addition, feed is in many places imported, increasing thus the dependency on external trade, currency fluctuations etc. As such there are good reasons to try to optimise feed both on the micro (i.e. farm) as well as on the macro (i.e. country) level.

However, due to the lack of access to real data, feed manufacturers have to rely on test or research farms, farmers have to rely on experience and the offering of the feed industry and slaughterers have little say at all, with exception of fines for off-spec animals. Given that even slight decreases of feed need make huge differences on micro and macro level, the current approach is not optimal.

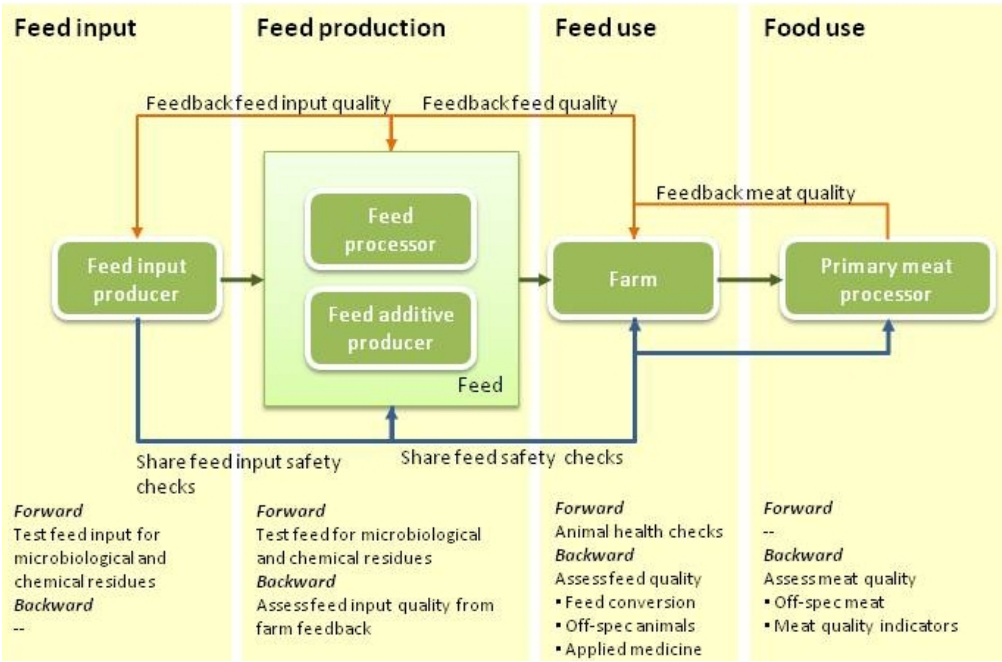

Figure 4. Feed(back) on the feed-animal-food chain

We suggest here a privately run system where carcass composition data is made available to farmers for their individual animals. Farmers would then (via an electronic system) make averaged data available to the respective feed producers who can aggregate this data with that from other farms to judge the performance of their feed compositions. Based on real and massive data, feed producers can on one hand optimise their products and on the other hand offer better products to individual farms.

(Such a feed-animal-food C-FiM system can of course also carry other information elements, such as health/food safety check results. Trusted sources can then receive better ratings; the inspection history can be used to analyse animals/feed based on risk. This would also increase the efficiency of the supply chain.)

The value of such an exchange of information has been realised by the Danish broiler industry. They introduced the KiK (Kvalitetssikring i Kyllingeproduktion) system already in 2000. In remarkable openness, the system collects detailed data on poultry production that all parties can use to their benefit. Farmers can use the system to benchmark themselves against other farms, feed producers use it to analyse their products and slaughterhouses to assess their supply chain.

Such an open system is almost unimaginable in most other countries. However, one has to bear in mind that both feed companies as well as slaughterhouses for poultry (and pigs) in Denmark are largely owned by farmer cooperatives. The KiK system is therefore also run by these cooperatives. As a result, the power situation is completely different from most other countries. In addition it has to be born in mind that one key motivator for farmers is to measure themselves against other farmers.

The Danish KiK system has shown that Chain Food Information Management is possible and practical if the key challenges standardisation and ownership of data/systems are solved. The economic optimisation potential has not been formally assessed, but should be of the order of a few percent points of total feed intake. An economic study of the KiK system would be very helpful to initiate similar initiatives in other places or industries.

Summary

In the extensive analysis undertaken by us in the framework of the EU CSA project BrightAnimal based on literature, pre-existing knowledge, expert networks and site visits to Estonia, Norway, Denmark, Malaysia, Australia, Vietnam and Indonesia showed both the great potential that Chain Food Information Management (C-FíM) has for increasing the efficiency of animal production as well as its challenges.

Chain food information management and traceability are base technologies for Precision Livestock Farming and as such their importance is undisputable. Many companies and governments have realised that and have implemented traceability systems. However, there are a number of issues related to food information management and traceability in the context of PLF.

First of all, most farmers do not have access to a set of standardised identifiers. Most farms come up with own identification systems that of course lose their meaning, as soon as the animal leaves the premise. They do not apply or use identifiers for other elements than animals. The reason for this is the lack of a free, globally managed and unique identifier for premises, products and animals. We recommend that the provision of such identifiers is studied at international level. Alternatively, existing organisations, such as GS1, should study in earnest how to deliver their identification products to the primary sector. The membership model does not work for animal producers, especially in the case of smallholders.

Secondly, the exchange of information that enables chain traceability is a very important matter that has received too little attention so far. Although some efforts like TraceFood (Lehr *et al.,* 2008, Bjørnson, 2008) exist, so far there is no international standard in sight that will actually be "the" standard for the exchange of traceability information. EPCIS may well be a good candidate, but only if it is adapted to the special needs of food traceability. We believe that governments have an important role to play in pushing for an international standard and helping in its implementation.

Thirdly, traceability is still far from being implemented by small food business operators. The reasons are – in our view – not so much related to traceability being complicated or requiring technology that is not yet ripe to be deployed to smallholders. We are convinced that this is mainly due to misinformation and bad positioning of traceability by the community and the regulators and to the lack of a simple enough system that will allow a gradual entry into the world of traceability. We have proposed here a solution to the latter problem in the form of an extremely simple, mixed paper-electronic traceability system. This system needs to be tested on large scale and again we believe that governments play a crucial role in this.

Finally and related to all the above, the feed – animal – food chain requires some urgent attention. Traceability in this chain should be used to transport information bi-directionally. Fundamentally important information on (average) carcass composition, milk quality and composition in case of dairy, is being left lying around. Feed and feed input companies could greatly benefit from getting access to such information. But it would also be a great help to farmers if they could benchmark themselves on quality, composition, on-spec quantities and other indicators both in their own area as well as within their larger sphere of interest.

Once such a system is in place, it can also be used for other purposes, mainly the calculation of sustainability related indicators. This could make the discussion about sustainable animal production a lot more substantial. Practical methodologies to calculate key sustainability indicators along the chain have been developed by FoodReg. However, there is a need for the industry to understand the value of transparency and how to best make use of it.

All this requires a certain amount of data capture and data management. As somebody so aptly put it in our opening conference “Farmers don’t like paperwork and accountant don’t like manure”. This calls for the creation of a service industry that would – very much like tax consultants – receive raw data from the farm in a way that is convenient to the farmers, store the data and make sure that traceability is possible. As an additional service, they would analyse the data and derive – either in an automated or manual fashion – advice for the farmer. Again, this idea needs somewhat more research and we hope that research funding bodies can provide the framework where such research can be carried out.

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References

Animal Health Online 2010. Datenbank soll vor Bio-Betrug schützen (Database to be created to avoid fraud with bio-products), http://www.animal-health-online.de/lme/2010/12/20/datenbank-soll-vor-bio-betrug-schutzen/5561/.

Bjørnson, Finn Olav and Olsen, Petter 2008. www.tracefood.org.

European Parliament and Council 2002, REGULATION (EC) No 178/2002.

Lehr, Heiner 2008. The IT view exercise. On website: Tracing your food.

Lehr, Heiner, O'Donelly, Kathryn and Bjørnson, Finn Olav 2008, www.foodtraceability.eu. http://www.foodtraceability.eu/page/it-exercise.

Lehr, Heiner 2009, Traceability models for tra catfish in An Giang and shrimp in Ben Tre, Mission Report.

Smith, Ian G. 2008, Food Traceability Around The World edited by Ian G. Smith and Anthony Furness , Vicarage Publications, 2008.

Virtual Reality Design Approach for Animal Production Infrastructures Projects Development

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Abstract

For an ellaborative concept visualisation of the developed precision cattle handling system prototype, Virtual Reality (VR) tools were utilised. These tool assisted junior research engineers visualise and appreciate intended design outcomes without physical modeling. VR introduction, facilitated designs intepretations during the preliminary stages through ellaborative visualisation. This article showcase our experience in integrating various low-cost VR to aid instructional delivery and junior researchers visualisation of a cattle handling system prototype. The project was a collaborative effort of various institutes to enhance junior research engineers interest in visual design and graphics whilst stimulating interest in leading-edge technology.

Keywords: Virtual reality, animal infrastructure, design, South Africa

Introduction

In precision cattle farming systems research, design and development, the most effective way to improve junior research engineers' ability to visualize 3-D designs is to make their experience of the output, while learning, as realistic as possible. However, in general, it is very difficult to clearly describe to researchers a 3-D cattle handling system components and the spatial relationship between the prototype components, without using a physical mockup. Physical mockups take a lot of time to construct, especially for more complex objects like the cattle handling system prototypes. As a result, senior research engineers at the Agricultural Research Council's Institute for Agricultural Engineering have started urtilising Virtual Reality(VR) tools to help their junior collegues understand the spatial relationships between objects. However basic CAD tools only allow trainees to examine models from outside flat computer monitors. In other words, the models and the viewers are in different realms. Using traditional CAD tools, junior research engineers cannot view models with natural stereoscopic vision.

Virtual reality (VR) is a computer technology of simulating or replicating a physical environment to give users a sense of being there, taking control, and physically interacting with the environment (Ausburn & Ausburn, 2004). VR technology breaks down barriers between humans and computers by immersing viewers in a computer-generated stereoscopic environment. With advances in hardware and software, most PC computers now have the capability to support VR use. Thus, VR has now become an affordable visualization tool that can be used in skills transfers. As Ausburn and Ausburn (2004) indicated, there is a significant opportunity to expand and explore the use of VR in the design review. Research suggests that VR is an effective tool that enhances knowledge interchange in areas such as engineering (Sulbaran & Baker, 2000). In addition, VR engages the intellectual, social, and emotional processes of learners. The impact of VR is due to its ability to encourage interaction and ability to motivate learners (Winn *et al.*, 1997). Salzman (1999) found that VR applications in informative sessions depends on VR features, contents, junior research engineers' characteristics, and trainees' prior experiences.

With regards to precision cattle infrastructures development, the emphasis of engineering graphics education has been placed on design, problem-solving, presentation, and communication skills. Three dimensional spatial visualization ability is the core requirement for successfully developing those skills. The use of VR may also represent an effective strategy that supports the development of spatial skills. It is important to combine exposure to VR models with activities such as sketching or drawing as a means for developing a capacity for visual imagery and creativity (Deno, 1995; Devon *et al.*, 1994; Sorby, 1999). Sorby (1999) explained that in most cases, prototype development begin with multi-view sketching/drawing and then move to pictorial sketching. However, this sequence of topics is opposite of how most tutors say that junior research engineers learn. Although there are many advantages in VR applications in, it is important to consider challenges in integrating VR in the prototype deleopment process. There is little guidance regarding the instructional design and information room facilitation of VR technologies (Ausburn & Ausburn,2004). These challenges include lack of necessary computing equipment for testing VR applications (Riva, 2003), lack of standardization of VR systems (Riva, 2003), and difficulty in establishing equivalent control groups (Crosier *et al.*, 2000).

This paper examines the use of VR at the ARC-IAE including the precision livestock farming division. This paper considers how the use of new technology in precision cattle infrastrutures development affects the institute and junior research engineers. Experiences and survey results are presented for interested researchers to follow

Materials and methods

A VR software tool, REVIT an Autodesk product, and instructional materials necessary for design visualisation use such as a variety of cattle system prototype were developed. The institute utilises an Autodesk licenced software and other open source VR softwares.

Project activities

During the project year, these tools were used for agricultural infrastructures design and precision livestock prototype design courses for both PDP Students and qualified junior reseach engineers. Figure 1 shows a virtual prototype of an automated precision cattle handling system from one of the design classes. Junior research engineers were taught about orthographic projection as a part of their drafting studies. Traditionally, this unit of instruction requires the junior research engineers to identify surfaces and classify them (normal, inclined, and oblique). They were also asked to examine a drawing of an object with a set of orthographic views and to identify and classify surfaces according to information from the drawing. With the advent of computer technology, VR becomes another avenue by which the instructors can attempt to reach these junior research engineers .

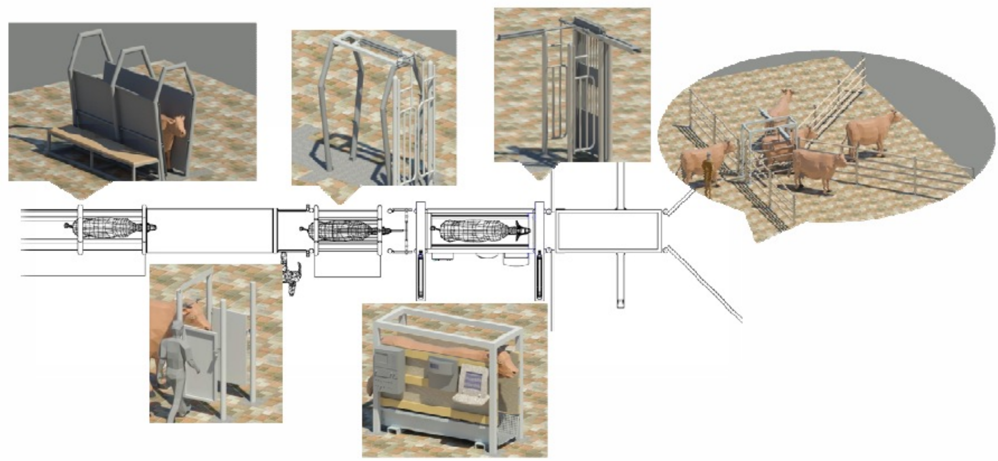

Figure 1. Virtual prototype of an automated cattle handling system (after Mutenje, 2011)

During the information interchange, precision cattle systems models were projected onto the screen. Once junior research engineers had shown an understanding of the differences between the surfaces, and their roles within the orthographic representational system, more complex models were presented for the junior research engineers to practice. Through these exercises, the engineers were allowed to develop an understanding of the process of the precision cattle handling system, relating surfaces and edges to their representation in orthographic views.

<u>Precision cattle farming informative session</u>

Six Junior engineers and a lecturer were invited to attend a 5-day precision cattle systems prototype development illustrative course. During the course, hands-on REVIT/CAD courses, VR presentations, team work projects, design competitions, industry tours, and career talks were provided. Figure 2 shows researchers presenting their VR models at the end of the training period. During the final presentation, the institute managers were invited to assist in the final assessment and results analysis.

Figure 2. Engineer Mutenje presenting during the precision cattle systems session

After attending the illustrative course, most participants demonstrated increased interest of anhancing their careers in agricultural infrastructures, precision animal production systems and technology. Approximately 74% of the participants in the training course indicated that availability of VR would be a factor in their choice of technology in precision livestock farming technology development.

More male junior research engineers than female junior research engineers indicated that the availability of VR would be a more important factor in their technology choice. Most research engineers also expressed that learning with VR gave them a better understanding of livestock infrastructure development than by traditional methods. Before junior research engineers attended the course, there was also a significant difference between male and female researchers in their responses concerning their interest in enhancing careers in precision cattle farming systems design and development. However, the differences in male and female junior research engineers' attitudes faded away after they were exposed to VR in the training sessions.

Evaluation process

In this project, various tests and surveys were administrated to examine junior research engineers' conceptual growth and changes in their spatial abilities and sessions engagement. Reports from the focus groups conducted in the project duration, and comments from the open- end questions from the engineers survey supported the quantitative evaluation activities. The results from the evaluation provided clear evidence on how the use of VR influenced junior research engineers' understanding of spatial concepts of precision cattle systems development.

Spatial ability has been shown to be positively correlated with retention and achievement in engineering disciplines (His *et al.*, 1997). Spatial ability has identified several different spatial domains, including spatial visualization and spatial orientation. Spatial visualization refers to the ability to image the movements of objects and spatial forms, and involves tests of mental rotation. Spatial orientation refers to the ability to imagine the appearance of objects from different orientations of the observers. The improvements of junior research engineers' spatial abilities were measured with specific measures, such as the Mental Rotation Test (MRT) and the Picture Test (PT) developed by Hegarty and Waller (2004).

Mental rotation is somewhat localized to the right cerebral hemisphere. It is thought to take place largely in the same areas as perception. It is associated with the rate of spatial processing and intelligence (Johnson 1990, Jones 1982, Hertzog 1991)

Results and analysis

Influence on spartial ability

Survey results showed that VR was an efficient instructional method to develop the spatial ability of junior research engineers who were incuntering problems to understand the precision cattle system development process. Engineers who performed poorly in the pre-PT were more likely to improve their post-test scores than those who did better in the pre-test.

In surveys, researchers also noted that, with the new VR tools and learning methods, they were able to better see and understand examples that related to even more complecated cattle facilities. Junior researchers further explained that they were able to see inside the models and to visualize objects without physically modelling them. Other survey results concerning junior research engineers‘ spatial ability are contained in the tble below.

Table 1. Influence on spartial ability of VR introduction

Measurable Parameter	Details and Outcomes
Influence on spartial ability	• About 80% of the poor performers in the pre-MRT reported their posttest scores increased by 10% or more.
	• More than 68% of the juniors reached the project's goal, improving their spatial visualization abilities and test scores by 10% or above in the post-MRT
	• About one-half (53%) of the junior research engineers increased their scores in the post-PT

Virtual reality efficiencies

Efficiency in the evaluation is about efficiency in learning and teaching, including junior researchers‘ perceptions or experiences with VR as an easy, fun, and motivational instruction method as well as instructors' experiences with VR as an interactive and time-efficient tool for teaching. Survey results concering VR was fun, non-threatening, and interesting are indicated in the following table below.

Table 2. VR usability efficiency

Measurable Parameter	Details and Outcomes
Usability efficiencies	• About 92% of the junior research engineers said that VR was fun.
	• More than 90% of the engineers said that VR was not frustrating and they did not consider dropping out of the program.
	• 80% Trainees agreed that VR was easy to use and very user-friendly.

VR was efficient for junior research engineers' acquisition of advanced concepts or skills in precision cattle system prototype development. Survey results showed that VR was an efficient instructional method to increase knowledge bases of infrastrutures design among those junior research engineers who performed poorly by the traditional instructional method. Due to fun, non-threatening, and the interesting nature of VR, junior research engineers reported high achievements in mastering the advanced or difficult concepts. Other survey results are as indicated in the table below.

Table 3. Acquisition of advanced concepts efficiencies

Measurable Parameter	Details and Outcomes
Acquisition of advanced concepts efficiencies	• About 87% of the junior research engineers indicated that the VR sessions improved their abilities in precision cattl systems design, graphics communication, confidence in 3-D visualization, and so on.
	• More than 90% reported attainment of the advanced course objectives, such as 3-D solid modeling and visual rendering.
	• About 83% of the junior research engineers perceived VR and the instructional materials positively.

Gnerally it was hard to draw conclusions and visualize from 2D drafting drawings. When you see a bunch of lines and hidden lines, it is hard to understand what it is. It is easier when it is actually shown as an object one could spin it and see what it is. It also helps junior research engineers recognize the views (front, top, right) of the precision cattle handling system prototype components.

VR was efficient for both male and female junior research engineers. Female junior research engineers were more likely to report a lower mean than male junior research engineers in the pretest; and were more likely to belong to the poor performer group in the pretest than male junior research engineers. However, after female junior research engineers were exposed to VR in their proceedings, they were more likely to have higher mean scores than male junior research engineers on the post-test. Female junior research engineers also responded to VR learning methods more positively and less negatively than male junior research engineers. Both male and female junior research engineers improved in their post-test of MRT and PT.

Female junior research engineers who performed poorly with the traditional instructional method showed greater improvement after they were exposed to VR.
VR was a time-efficient instructional tool for junior research engineers and instructors. Instead of spending time trying to understand how parts of the precision cattle handling system components interact during normal operation, the presentation of a VR prototype allows them to move their attention to later phases of the problem-solving process. Junior research engineers commented that VR was useful to explain complex concepts to them as it enabled them to go inside, zoom in, or go through the individual components of the cattle handling system prototype.
Also, it was time efficient for instructors. VR enhances the likelihood of interactions between demonstrators-junior engineers and among themselves because the instructors were able to quickly provide precision cattle facilities models through VR. Thus, additional time was available. Rather than focusing on either the development of physical models or attempting to help junior research engineers visualize specific components of an object, instructors are able to concentrate on the learning objective and to coach in achieving this goal.

Discussion

Survey results showed that junior research engineers were more confident when sketching projection views of the precision system prototype after visualizing VR models. They gave VR instruction high ratings for stimulating their interest in design of precision agricultural instructures. Project results also showed that VR instruction stimulates better interaction between instructors and junior researchers because participants often have higher engagement and are more interested in discussing, with their instructors, what they see or discover during VR instruction. Participants were asked to locate surfaces on objects, identify the type of surface (e.g., inclined, oblique, or normal), and to identify how edges were formed at the intersection of surfaces. This exercise requires them to visualize an object in order to successfully locate and identify characteristics. By using the VR technology, they were able to concentrate on basic concepts before focusing on the development of their visualization skills.
For the precision cattle handling system prototype development process about 91% of the junior research engineers expressed physical comfort in using VR; whereas, 8.6% did not. Female junior research engineers were more sensitive and expressed less physical comfort in VR than male junior research engineers , although the difference was not statistically significant. These results will provide valuable information for future precision cattle handling system prototype development VR related projects that require end-product visualisation prior to construction.

Conclusions

VR is an emerging visualization tool in precision cattle systems prototype development which can help junior research engineers and other interested parties acquire better knowledge about data or images. Many major companies or research institutions now use VR to enhance their visualization activities. It is important to use VR in design sessions, not only for enhancing visualization, but also for helping junior research engineers to become familiar with the important emerging technology before they enter into the thorough or detailed design sessions. As demonstrated by this project, VR technology is now readily available, both technically and financially, for cattle infrastructures development use. This paper describes our experiences in integrating low-cost VR into precision livestock farming system design and technical representation information sessions. The project was a collaborative effort between a several institutes of the ARC. A low-cost VR functionality requirement list, consisting of hardware and software was developed to enhance instructional delivery and junior research engineers' 3D visualization skills. Using the innovative tools in precision systems will also provide competitive advantages in retaining junior research engineers interested in design and graphics in the field, and will promote their engagement in lifelong learning, by stimulating interest in leading-edge technology

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References

Ausburn, L. and Ausburn, F. 2004. Desktop virtual reality: A powerful new technology for teaching research in industrial teacher education, Vol. 41, No. 4. Journal of Industrial Teacher Education, 33-58 pp.

Crosier, J., Cobb, S. and Wilson, J. 2000. Experimental comparison of VR with traditional teaching methods for teaching radioactivity. Education and Information Technologies **5** (4), 329-343.

Deno, J. (1995). The relationship of previous experiences to spatial visualization ability,

Devon, R., Engel, R., Foster, R., Sathianathan, D. & Turner, F. 1994. The effect of solid modeling on 3d visualization skills, Vol. 58, No. 2. The Engineering Design Graphics Journal, 4-11 pp.

Idea21. 2010. Virtual Reality and Prototyping [Internet]. Ideas21 Ltd. London EC1M 5UD, UK. Available from: http://www.ideas21.co.uk/categories/20080217_12 [Accessed 20/01/2011].

Mutenje, T. J. 2009. The Application of Radio Frequency Identification for the Management of Beef Cattle. Unpublished MScEng Proposal Design Project, School of Bioresources Engineering and Environmental Hydrology, University of Natal, Pietermaritzburg, RSA

Mutenje, T. J. 2011. *Radio Frequency Identification(RFID) Based Cattle Handling System Prototype Design Report.* ARC-IAE, Silverton, RSA.

Riva, G. 2003. Applications of virtual environments in medicine, Vol. 42. Methods of Information in Medicine, 524-534 pp.

Salzman, M., Dede, C., Loftin, R. and Chen, J. 1999. A Model for Understanding How Virtual Reality Aids Complex Conceptual Learning [Internet]. George Mansion University. Northen Virginia, Washington DC. Available from: http://www.virtual.gmu.edu/pdf/presence.pdf. [Accessed 21/01/2011].

Sorby, S. A. 1999. Developing 3-D spatial visualization skills, Vol. 63, No. 2. Engineering Design Graphics Journal, 21-32 pp.

Sulbaran, T. and Baker, N. 2000. Enhancing engineering education through distributed virtual reality, The 30th ASSEE/IEEE Frontiers in Education Conference.

Winn, W., Hoffmann, H., Hollander, A., Osberg, K., Rose, H. and Char, P. 1997. The effect of student construction of virtual environments on the performance of high and low- ability junior research engineers., The meeting of the American Educational Research Association, Chicago, IL.

Section 11
Poster session

Forced ventilation and evaporative cooling of waiting and milking areas and its influence on the physiological and production responses of crossbred Holstein × Zebu cows

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Abstract

The main objective of this work was to evaluate the effect of forced ventilation and evaporative cooling on the physiological and production responses of dairy cows Holstein × Zebu.
Experiments were conducted with 32 crossbred cows (Holstein × Zebu) in the same lactation phase, mean daily production of 17 kg and mean body weight of 550 kg. Four different treatments were randomly assigned to groups with eight cows each. The treatments were: Evaporative cooling in the waiting room + forced ventilation with Evaporative cooling in the milking room (NW+VNM), Evaporative cooling in the waiting room (NW), forced ventilation with Evaporative cooling in the milking room (VNM) and a control treatment without forced ventilation and evaporative cooling (CON). Experimental work was realised in a commercial farm located in the interior of Bahia State, Brazil, during 45 days in January and February.
Climatic data were measured using a meteorological station. Temperature Humidity Index (THI) and Wet Bulb Globe Temperature (WBGT) were calculated. In order to study animal responses milk production, udder temperature, heart rate, respiratory rate, temperature of white and black spots and rectal temperature were measured.
It was observed that the cows under VNM treatment presented higher milk production and lower udder temperature, heart rate, respiratory rate, temperature of white and black spots. No significant differences occurred in the rectal temperature. Results showed that forced ventilation and evaporative cooling positively influenced environmental conditions showing the importance of evaporative cooling for dairy cows.

Keywords: Environmental control, evaporative cooling, thermal comfort

Introduction

The cows, as a homoeothermic animal, when remaining in conditions outside the thermo neutral zone modify their metabolism in an attempt to maintain internal body temperature, with negative effects on milk production. Berman *et al.* (1985) reported that selection for milk production reduced the thermoregulatory ability for heat stress conditions. The optimum temperature for milk production depends on the species, race and tolerance to heat and cold. According to Keown *et al.* (2005), the ideal temperature for dairy cattle is in the range between -4 °C and 18 °C. When the temperature reaches values above 26.7 °C, these animals reduces food intake, causing a negative impact on production. At 32 °C or above, a decrease in milk production ranging from 3 to 20% can be observed.

To minimize the problem of heat stress in dairy cows it is recommended the genetic development of animals less sensitive to heat (Beede and Collier, 1986). In this sense, the intersection of Indian cattle with European dairy breeds has been widely used to enhance the potential of animals for milk production in the tropics and give rusticity which means that the animals can be more resistant to diseases, plagues and climatic conditions among other factors (Syrstad, 1996). McDowell (1996) considered this as an economical option. Comparing with European cattle, Indians are more resistant to heat stress and other environmental stressors that limit the expression of the production characteristics in tropical and subtropical areas (Bo *et al*., 2003). Most of the Zebu breeds resistance to heat is due to the lower milk production, the basal metabolic rate and an increased ability to sweat (Blackshaw and Blackshaw, 1994). Therefore, it is expected that crossbred animals have become less stressed, in tropical climates than the pure breed originated in temperate climates.

Crossbred animals European × Indian are widely used in Brasil mainly in those places with poor food quality and/or where the price of milk is low, or where the environmental and economic factors turns impractical the production with European breeds (Hansen and Arechiga, 1999). Studies in Brazil (Madalena *et al*., 1990) and in Sudan (McGlothen *et al*., 1995) indicate that the intersection of local animal breeds with pure milk increases milk production according to the management and quality of the diet. Before occurs a decrease in production levels heat production rises in around 14%, being higher in cows subjected to high temperatures (> 35 °C). This increase in heat production is reflected in the rectal temperature (Robinson *et al*., 1986).

The reactions of cattle under moderate climate change are often compensatory, targeted for maintain or restore the thermal balance (Kibler and Brody, 1953; Terui *et al.* 1984; Chikamune, 1986; Gerken *et al*., 1998). Several physiological mechanisms to withstand heat stress have been studied, such as sweating, increased respiratory rate and vasodilatation with increased blood flow to the skin surface (Reece, 1998, Harper 2000). The reduction in metabolic rate decreases dry matter intake and nutrient and water metabolism changes in response to heat stress. These responses to heat stress have negative effects on the physiology of the cow and milk production (West, 2003).

Dairy cows in many regions of the globe, such as the southern United States and many tropical and subtropical regions are subjected to high ambient temperatures and (or) high relative humidity for long periods. In the southwestern United States and northeast Brazil the high temperatures and humidity causes the temperature and humidity index (THI) very high for about 4 to 6 months per year or more (Kabuga and Sarpong, 1991; Holter *et al*., 1996). Therefore, knowledge of environmental conditions to which animals are subjected in these regions and mechanisms that can minimize heat stress are essential for improving production and animal welfare.

THI is one of the thermal comfort indices commonly used, which can accurately describe the effects of environment on the ability of cows to dissipate heat (Araki *et al.* 1984). For Holstein cows the milk production and total digestive nutrients (TDN) intake decreases slightly when the THI exceeds 72 and drastically when it exceeds 76 (Johnson *et al*., 1963). Milk production decreases when body temperature exceeds 38.9 °C and for each increase of 0.55 °C in rectal temperature, milk production and TDN intake decreased 1.8 and 1.4 kg, respectively (Johnson *et al*., 1963). Consequently, the creation of environmental conditions that avoid or minimize the increase in rectal temperature may improve food intake and milk production.

Various researchers have reported the benefit of environmental control for the management of dairy cows as a way to increase milk production through the reduction of heat stress (Thatcher, 1974; Igon *et al*., 1987, Chen *et al*., 1993, Barbosa *et al*., 2004). To cool dairy cows without increasing the humidity during the summer is difficult in warm humid climates like the northeast of Brazil. Cooling methods have been studied in order to minimize the heat stress caused by conditions of high temperatures and humidity (Bucklin *et al*. 1991; Flamenbaum *et al*., 1995, Lin *et al*., 1998, Turner *et al*. 1992 - 1993).
Until relative humidity of around 70% the best way to cool a room for lactating animals, is to make use of water, since it has high heat capacity and high latent heat of vaporization (Nääs and Arcaro, Jr., 2001).
Ventilation with spraying resulted in 7.1% more milk production in Israel and 15.8% more in Kentucky (USA) in Holstein cows, according to Bucklin *et al*. (1991). In some places around the country and abroad it is common to apply water in the form of spray. Bucklin *et al*., (1991) have shown that this method is efficient in California (hot and dry climate), which has not happened in Florida where the humidity is higher.
This work was conducted in order to evaluate the effects of using evaporative cooling systems in the waiting and milking rooms in the productive and physiological responses of crossbred (Holstein × Zebu) cows.

Material and Methods

<u>Location of the experiments</u>
The experimental work was conducted in a commercial property in the southwest of Bahia - Brazil (Lat. 15° 69' S and Long. 40° 74'W, Area of 128 ha, 62 cows), during 45 days (15 days adaptation animal) from January to February. The farm uses artificial milking system. Cows pass the evening in pasture of Elefant Grass (*Pennisetum Purpurium)* and the day in one with Tanzania Grass (*Panicum Maximum*). The cows are also feed with a commercial ration specific for milking cows which is furnished according to the individual milk production. The place is characterized by a tropical climate with dry winters and humid summers, located 865m above sea level with average annual temperature of 22 °C and rainfall of 1200 mm.

<u>Animals and management</u>
The 32 crossbred cows of Holstein × Zebu were distributed at random into four treatments with eight cows per group. The blood level ranged from 7/8 Holstein and 1/8 Zebu to 31/32 Holstein and 1/32 Zebu multiparous. All cows were at the same stage of lactation curve, with an average production of 17 kg/day and mean body weight of 550 kg.
The diet formulated to obtain the nutritional requirements for maintenance and milk production (NRC, 2001), consisted of natural pasture and supplementation based on soybean, corn and minerals. The mechanized milking was performed twice daily at 6:00 a.m. and 16:30 p.m.

<u>Cooling Systems</u>
The waiting room consisted of an opened area (13.5 m long and 8.7 m wide) located next to the milking room. Water was supplied to the animals "ad libitum" in this room, through a water tank (2.6 x 1.0 m). In the waiting room it was built a spray cooling system that used a PVC pipe (¾ ″ diameter), parallel to the water tank at a height of 2.5 m. In this tube,

6 microsprinklers nozzles were coupled, facing down and spaced 1m. These nozzles produced a spray of water on the animals at a flow rate of 25 l/hour.

The milking room had dimensions of 12 m long, 6 m wide and 2,5 m ceilings. Its sides were open and its orientation was east-west. The roof was covered with tile cement and he floor was simple concrete. It was installed the ventilation + Evaporative cooling system which is constituted of two fans of 0,97 m in diameter and propeller 3 blades 40 cm, with power of 0,5 HP and maximum flow of 5 m^3/s, 18.83 Hertz direct drive, positioned at a height of 2,0 m with a slope of 20%. In each fan, it was engaged four screw-type spray nozzles with anti-drip and flow of each 6,3 L/hour.

The water supply to the cooling system was composed of centrifugal pumps with power ¾ HP and flow of 7,8 m^3/h. The sprinkler systems were activated automatically when the temperature was above 25 °C. Since the systems are mechanically actuated and maintenance is simple it can be done by employees of the farm. Data concerning the investment and energy costs and the historical price of the milk paid to producers was recorded in order to find the time of amortization.

Data registration

Climate data were collected and registered along the experiments: maximum and minimum temperatures, relative humidity, black globe temperature, dry bulb and wet bulb temperatures, wind speed and rainfall. Temperatures were collected with thermocouples connected to a datalogger (CR23X - Campbell Scientific Instruments Inc.), storing the average value every five minutes. In the waiting and milking rooms, black globe temperature, wet and dry bulb sensors were installed, above the dorsal area of the animals.

A mini-weather station (La-Crosse Technology 433 MHZ) was installed to measure temperature and relative humidity inside and outside the milking room, as the rainfall and wind speed and direction. The control device for sprinkler systems and fogging was placed next to the temperature sensor of the meteorological station.

The thermal comfort index THI (Temperature and Humidity Index) according to Thom (1958) and WBGT (Wet Bulb Globe Temperature) described by Bond and Kelly (1955) were calculated.

Data related with the animals were measured twice a day, morning and afternoon, in all the animals: rectal temperature (with the aid of digital thermometer), surface skin temperature on the dorsal side, in black and white spots, the temperature of the udder (with infrared thermometer), respiratory rate (by counting the respiratory movements on the flank of the animal during 15 seconds and multiplying the result by four and computing the average four the 32 animals), heart rate (counting heartbeats obtained with the aid of a stethoscope and computed the same way as the respiratory frequency) and milk production. The experiment was conducted without causing any unnecessary discomfort for the animals, with the use of adequate management techniques and constant professional veterinarian assistance.

Experimental design and statistical analysis

The treatments were: T1 - Evaporative cooling in the waiting room + forced ventilation with evaporative cooling in the milking room (NW+VNM), T2 - Evaporative cooling in the waiting room (NW), T3 - forced ventilation with evaporative cooling in the milking room (VNM) and T4 - control treatment without forced ventilation and evaporative cooling (CON).

The experimental design was completely randomized, with animals as replicates. The averages results of the treatments were compared using the Tukey test at 5% probability. Data analysis was performed using Excel, SPSS 13.0 and the software R.

Results and Discussion

Table 1 shows the climate data recorded in the meteorological station. Maximum air temperature was slightly higher during the morning (6:00 to 9:30 h), which can be explained by the fact that during the afternoon milking (16:30 to 19:30 h) ambient temperature began to decrease. However, in the milking room the temperature in the afternoon exceeded 26 °C, considered as critical limit by Berman *et al.* (1985) to the occurrence of heat stress in dairy cows. In spite of that the average temperature during that period remained within the thermoneutral zone (5 to 25 °C) for dairy cows reported by Yousef (1985) and Roenfeldt (1998). In some moments the temperature in the milking room reached 38 °C, representing thermal conditions potentially stressful for the lactating cows. The experimental period was characterized by rain. The average daily precipitation was 6.23 mm, totalling 187 mm for the 30 days, which represents 15.0% of total annual rainfall of the previous year (2007). Depending on the rain there were some limitations for the use of evaporative cooling system, meaning it was not activated in some periods of day.

Table 1. Mean and variation of the several meteorological variables recorded in the meteorological station during the period of recording phisyological data (28/01 to 26/02).

Variables	Daily mean	Morning (1ª milking)	afternoon (1ª milking)	Variation
Maximum temperature inside the room (°C)	24.8	24.4	24.0	17.2 a 34.9
Minimal temperature inside the room (°C)	18.4	19.0	17.6	13.9 a 22.3
Relative humidity inside the room (%)	64.2	71.8	54.8	34 a 85
Relative humidity outside the room (%)	71.2	73.5	68.4	33 a 95
Temperature inside the room (°C)	24.2	23.2	26.8	19.3 a 38.0
Temperature outside the room (°C)	24.3	24.5	24.0	17.2 a 34.9
Wind Velocity(m/s)	0.6	0.7	0.4	0.0 a 4.3
Precipitation (mm)	6.2	-	-	0.0 a 57.0

The average results of thermal comfort index (THI) and Wet Bulb Globe temperature (WBGT) obtained in the morning and afternoon for the conditions of the waiting and milking rooms are presented in Table 2.

Tabela 2. Mean of Thermal Humidity Index (THI) and Wet Bulb Globe Temperature (WBGT) in both rooms during the two experimental periods

		TREATMENTS							
		(NW+VNM)	(NW)	(VNM)	(CON)	(NW+VNM)	(NW)	(VNM)	(CON)
ROOM		THI				WBGT (°C)			
WAITING	Morning	72.4aA	72.8aA	74.6aB	75.5aC	22.1aA	22.4aA	23.5aB	24.1aC
	Afternoon	74.6bA	73.6aA	72.2bB	71.1bC	23.1bA	22.6aA	21.9bB	21.3bB
MILKING	Morning	70.2aA	70.8aA	71.6aB	72.4aB	20.7aA	21.1aB	21.5aC	22.0aD
	Afternoon	73.2bA	73.4bA	72.3bB	72.1aB	22.6bA	22.9bA	22.3bB	22.2aB

Means followed by the same lowercase letter in the line and capital letter in collun do not differ significantly for the 5% probability by using the Tukey test.
(NW+VNM) = Evoporative cooling in the waiting room + forced ventilation with Evoporative cooling in the milking room; (NW) = Evoporative cooling in the waiting room, (VNM) = forced ventilation with Evoporative cooling in the milking room and (CON) = control treatment without forced ventilation and evaporative cooling

The values found for the THI and WBGT indicate differences ($P < 0.05$) between the morning and afternoon in the milking room and in the waiting room.
The waiting room compared to the milking room had higher values of THI in the morning. In the afternoon, it was found the same trend for THI, with the exception of the control (CON), averaging 71.1 and 72.1 for the waiting room and milking room, respectively (Table 2).
The average value of THI in the waiting room for all treatments was higher than the commonly considered critical to the production of milk, which is 72 for high production cows. However, in the afternoon the control treatment showed an average value below the critical value (Table 2). In the milking, the mean values observed during the morning were satisfactory in all treatments, characterized as mild heat stress, according to the classification of Armstrong (1994), for high producing cows.
The highest values of THI in the waiting room can be explained by the non existence of coverage, so the animals become more exposed to solar radiation. This shows the importance of shade or cover in the animal permanence places. It is well known that high production cows suffer with heat stress when THI exceeds the value 72 (Baêta and Souza, 1997). This value was observed in both rooms and in both milking periods. However, as mentioned the experimental animals were crossbred, with medium milk production and did not show physiological responses indicative of thermal discomfort (Table 4). According to Baêta and Souza (1997), THI values until 73 generaly represents secure environments; between 74 and 78 require caution or warning, between 79 to 84 are dangerous, and higher than 85 emergency condition. In this experiments the values for THI remained within the range considered as a safe environment, except the control treatment during the morning in the waiting room.
The WBGT showed the same tendency of THI in the morning. The variation of WBGT is mainly due to the daily solar radiation variation, black globe temperature, dew point temperature and ambient temperature. Araujo (2001) found reductions in the WBGT values

in tie-stall and free-stall facilities (20.87, 19.56), equipped with ventilation and Evaporative cooling, compared to the stable and field (23.67, 25.05). In our experiment we did not found such reduction probably because air humidity was high. However, even with this small reduction physiological variables were affected as will discussed below.

Tabela 3. Mean daily milk production for each treatment and for both milking periods

TREATMENT**								
	(NW+VNM)		(NW)		(VNM)		(CON)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Morning	9.2aA	2.1	9.6aA	2.3	9.5aA	2.3	10.0aA	2.2
Afternoon	6.8bB	1.7	7.2bB	2.0	7.5bB	1.5	6.7bB	1.9
Day	25	3.6	24	4.0	26	3.1	23	3.6

Means followed by the same lowercase letter in the line and capital letter in collun do not differ significantly for the 5% probability by using the Tukey test. SD is the standard deviation.

The milk production in the morning was significantly higher than those recorded in the afternoon (Table 3). This fact can be explained probably by the shortest interval between the first and second milking. When analyzing the effect of climate on milk production, it appears that in all treatments, there was no satisfactory response from changes in the environment. In this period the climate control equipments were in most of the days disconnected, being only activated when the temperature reached values above 25 °C.

Native animals with low milk production or crossbreed reduce the milk production for temperatures higher than 29 °C (Yousef, 1985). In this work the average in the milking remained around 24.8 °C, representing favorable conditions for milk production. However, at the most critical moment's air temperature reached 38 °C (Table 1), which is unfavorable for milk production.

When analyzing the total milk production of the day, the highest value was obtained with the VNM treatment. Although the small differences, the results show that the use of cooling systems, especially for ventilation and fogging in the milking room (VNM), showed positive effects, helping to improve milk production. These results are consistent with those of Igon *et al*. (1985), which found benefits in the use of spraying equipment in cows producing milk, with increases of 0.70 kg on average, concluding that the cooling system adopted improved the comfort of the cows and reduced the decline in milk production in summer.

Bouraoui *et al*. (2002) recorded in the Mediterranean climate, a decrease in milk production of 0.4 kg / day when the THI exceeds 69, which was not observed in this study with Holstein-Zebu cows medium production.

Mean values of rectal temperature (RT), respiratory rate (RR), heart rate (HR), temperature of the black mesh (BST), temperature of the white spot (WST) and temperature of the udder (UT) of animals subjected to different treatments are shown in Table 4. There was no significant difference between treatments for the rectal temperature during the 24 hours. However, effects were observed, for all treatments, during the day period, being higher in the afternoon. Studies conducted by Turner *et al.* (1992) found a decrease in rectal temperature of rats under evaporative cooling system. The body temperature of homeothermic animals is relatively uniform, hovering around 39 ± 1 °C in conditions of no severe stress (Bligh, 1973). Body temperature also varies with time of the day, tending to be lower in the morning and higher in early afternoon (Bohmanova, 2001).

Table 4. Means for the rectal temperature (RT), respiratory rate (RR), heart rate (HR), black spots temperature (BST), and white spots temperature (WST) and udder temperature (UT) during both milking periods

VARIABLES		TREATMENTS			
		(NW+VNM)	(NW)	(VNM)	(CON)
		Mean	Mean	Mean	Mean
RT (°C)	Morning	38.3A	38.4A	38.5A	38.3A
	Afternoon	39.1B	39.1B	39.2B	39.1B
RR (mov. min^{-1})	Morning	32aB	33aB	31aA	33aB
	Afternoon	39bA	38bA	37bA	37bA
HR (bat. min^{-1})	Morning	73aA	71aB	71aB	73aA
	Afternoon	75bB	74bB	72baA	74bB
BST (°C)	Morning	32.5aA	33.0abA	33.1abA	33.5aB
	Afternoon	32.5aA	31.9bA	31.2bB	31.4bB
WST (°C)	Morning	31.9aA	32.1aA	32.5abA	32.9bA
	Afternoon	31.7aB	31.1abB	30.6bB	30.9abB
UT (°C)	Morning	33.1a	33.3a	33.5a	33.4a
	Afternoon	32.1bA	33.9bC	32.5bB	34.0bD

Means followed by the same lowercase letter in the line and capital letter in collun do not differ significantly for the 5% probability by using the Tukey test.

The rectal temperature remained within the physiological range from 38.0 to 39.5 °C (Gibbons, 1966 cit in Baccari Jr., 2001). More recent studies concluded that the rectal temperature with a value greater than 39.2 °C is indicative of heat stress (Dhiman and Zaman, 2001; West 2002). Temperatures with this value (39.2 °C) were observed in animals in the treatment VNM during the afternoon, despite the values of THI and WBGT were within the range of thermal comfort and other physiological variables have low values in this treatment.
Respiratory rate was different in all the treatments concerning the morning and afternoon milkings. It was observed that the average values were higher in the afternoon, when

compared with values obtained in the morning, an average of 5.5 mov. min^{-1}. Showing a trend similar to rectal temperature, or elevation of the values measured during the course of the day. The respiratory rate of animals when exposed to VNM in the morning, was significantly lower (31 mov. min^{-1}) in relation to other treatments. Considering the NW + VNM treatment, the respiratory rate reached values lower than those found in the NW treatment and control group, but this difference was not significant. In the afternoon the VNM and the CON, showed lower values compared to VNM + NW and NW, but again these differences were not statistically significant. The results for respiratory rate in all treatments and periods, indicated that this variable remained within the normal range for thermoneutral conditions and for dairy cows, which is between 24 and 36 mov. Min^{-1}, according to Stober (1993).

Lemerle and Goddard (1986) reported that the respiratory rate increases when THI reaches values above 73 and probably increases rapidly when THI values are higher than 80. Several authors (Arcaro Junior *et al.* 2005; Nääs and Arcaro, 2001; Silva *et al.*, 2002, Wise *et al.*, 1988 and Fuquay *et al.*, 1979), also reported effectiveness of treatments in reducing respiratory rate.

According to Swenson and Reece (1996) the normal heart rate of a dairy cow is in the range 48 to 84 beats. min^{-1}. In this study no values higher than these were observed. Nääs and Arcaro Junior (2001) studied the influence of ventilation and spraying in shaded environments, and found that the treatment with only shade had the lowest heart rate, both in the afternoon as in the morning. The same authors explain that the equipment used had a high noise level and could have influenced the results.

Concerning the white spots temperature it was found that in the morning it was higher than in the afternoon in all treatments. When the skin temperature is higher than the surroundings, the body loses heat to the air. So when air temperature drops the animal will dissipate more heat, decreasing the body temperature, which can explain the decreasing during the afternoon.

Silva *et al.* (2001) reports that a black coat is a surface with high absorptivity for thermal radiation, resulting in higher skin surface temperature in comparison with the white ones. The same authors found in Holstein cows exposed to solar radiation for three hours during 10 days in summer, values between 44.10 and 37.73 °C for the black coat and white, respectively.

The udder temperature increase is considered as a major symptom to identify clinical mastitis, which is an inflammation of the mammary gland, resulting from an infection cause by microorganisms such as bacteria (mainly) and fungi. The measurement of udder temperature was used by other researchers such as Souza (2004b), Pinheiro *et al.* (2000) and Arcaro Junior *et al.* (2005), in conjugation with the temperatures of other parts of the animal body, to determine the skin temperature.

For the udder temperature it was observed that in the morning the average values in all treatments did not differ statistically. This was not true for the afternoon, where all treatments were significantly different. The NW + VNM and VNM showed lower values when compared with the treatments NW and CON. These results show that treatments NW + VNM and VNM were more efficient in reducing the temperature of the udder being in agreement with Arcaro Junior *et al.* (2005). Keister *et al.* (2002) mentioned the impact of increasing the external temperature of the udder, since it affects the health of the mammary gland and therefore the milk synthesis.

Conclusions

The use of forced ventilation and evaporative cooling in the waiting and milking rooms did not provide significant differences in rectal temperature. However, the values found in the afternoon were significantly higher than those found in the morning. When the ventilation and evaporative cooling was used in the milking room (VNM) resulted in a decrease in some physiological variables, such as temperature of the udder, heart rate, respiratory rate, temperature of black and white spots and an increase in the milk production. The use of cooling equipment (spray in the waiting room, ventilation and evaporative cooling in the milking room) have brought positive changes in the physical environment studied, highlighting the importance of using evaporative cooling in facilities for lactating cows.

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References

Araki, C.T.; R. M. Nakamura,R.M.; Kam, L.W.G.; Clarke, N.. 1984. Effect of Lactation on Diurnal Temperature Patterns of Dairy Cattle in Hot Environments. Journal of Dairy Science, 67, 1752-1760.

Araújo, A.P. 2001. Estudo comparativo de diferentes sistemas de instalações para produção de leite tipo B, com ênfase nos índices de conforto térmico e na caracterização econômica. 2001. 69 f. Dissertação (Mestrado em Zootecnia). Faculdade de Zootecnia e Engenharia de Alimentos — USP, Pirassununga, 2001.

Arcaro Júnior, I.; Arcaro, J. R. P.; Pozzi, C. R.; Matarazzo, S. V.; Fagundes, H. Efeitos da climatização em sala de espera sobre as variáveis fisiológicas e produtivas de vacas em lactação. B. Indústr. Anim, v. 60, n. 2, p. 173-177, 2003.

Arcaro Junior, I.; Arcaro J.R.; Possi, C.R.; Del Fava, C.; Fagundes, H.; Matarazzo, S.V.; Oliveira, J.E. 2005. Physiological responses of dairy cows to fan plus sprinkler in holding pen. Cienc. Rural, 35(3), 639-643.

Armstrong, D. V. 1994. Heat Stress Interaction with Shade and Cooling. Journal of Dairy Science, 77, 2044-2050.

Baccari Júnior, F. 2001. Manejo ambiental da vaca leiteira em climas quentes. Londrina: UEL, 142 p.

Baêta, F. C. E Souza, C. F. 1997. Ambiência em edificações rurais: conforto animal. Viçosa:
UFV, 246 p.

Barbosa, O. R., P. R. Boza, G. T. Santos, S. Sakagushi, N. P. Ribas. 2004. Efeitos da sombra e da aspersão de água na produção de leite de vacas da raça Holandesa durante o verão. Anim. Sci. 26(1):115-122.

Beede, D.K.; Collier, R.J. 1986. Potential nutritional strategies for intensively managed cattle during thermal stress. Journal Animal Science, 62, 543-555.

Berman, A.; Folman, Y.; Kaim, M.; Mamen, M.; Herz, Z.; Wolfenson, D.; Arieli, A.; Graber, Y. 1985. Upper Critical Temperatures and Forced Ventilation Effects for High-Yielding Dairy Cows in a Subtropical Climate. Journal of Dairy Science, 68(6), 1488-1495.

Blackshaw, J.K.; Blackshaw, A.W. 1994. Heat stress in cattle and the effect of shade on production and behavior: a review. Australian Journal of Experimental Agriculture, 34, 285- 295.

Bligh J. 1973. Temperature Regulation in Mammals and Other Vertebrates. Amsterdam: North-Holland.

Bó, G.A.; Baruselli, P.S.; Martinez, M.F. 2003. Pattern and manipulation of follicular development in Bos indicus cattle. Animal Reproduction Science, 78, 307-326.

Bond, T.E.; Kelly, C.F. 1955. The globe thermometer in agricultural research. Agricultural Engineering, California, 36(5), 251-255.

Bohmanova, J. 2006. Studies on genetics of heat stress in us Holsteins. Dissertation to the Graduate Faculty of The University of Georgia. pp.122. Available to http://www.aps.uoguelph.ca/~jbohmano/publication/bohmanova_jarmila_200605_phd.pdf

Bouraoui, R., M. Lahmar, A. Majdoub, M. Djemali, and R. Belyea. 2002. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research. 51:479-491.

Bucklin, R.A., Turner, L.W., Beede, D.K., Bray, D.R., Hemken, R.W. 1991. Methods to relieve heat stress for dairy cows in hot, humid climates. Applied Engineering, 7, 241-246.

Chen, K. H., J. T. Huber, C. B. Theurer, D. V. Armstrong, R. C. Wanderly, J. M. Simas, S. C. Chan, and J. L. Sullivan. 1993. Effect of protein quality and evaporative cooling on lactational performance of Holstein cows in hot weather. J. Dairy Sci. 76:819–825

Chikamune, T. Effects of environmental temperature on thermoregulatory responses and oxygen consumption in swamp buffaloes and holstein cattle. Buffalo Journal, v.2, p.151–160, 1986.

Dhiman, T.R.; Zaman, M.S. 2001. Desafios dos sistemas de produção de leite em confinamento em condições de clima quente. In: Simpósio De Nutrição e Produção de Gado de Leite, 2., 2001, BH... Belo Horizonte: Universidade Federal de Minas Gerais, 05-20p.

Flamenbaum, I., D. Wolfson, P. L. Kunz, M. Maman, A. Berman. 1995. Interactions between body condition at calving and cooling of dairy cows during lactation in summer. J. Dairy Sci. 78:2221.

Frazzi, E., L. Calamari, F. Calegari, and V. Cappa. 1997. The aeration with and without misting: Effects on heat stress in dairy cows. In Proc. 5th Int. Symp. "Livestock Environment V", Bloomington, Minn., 29-31 May, 2: 907-914. St. Joseph, Mich.: ASAE

Fuquay, J. W.; Zook, A. B.; Daniel, J. W.; Brown, W. H.; Poe, W. E. 1979. Modifications in freestall housing for dairy cows during the summer. J. Dairy Sci., 62:577-583.

Gerken, M.; Barow, U.; Snell, H. 1998. Methodical investigations into thermoregulation in suckler cows under field conditions. Annual Meeting Of The European Association Of Animal Production, 49., Warsaw, 1998. Abstracts. Warsaw: 1998. p.179.

Hansen, P. J., Aréchiga, C. F. 1999. Strategies for managing reproduction in the heat-stressed dairy cow. J. Anim. Sci., 77, 36-50.

Harper, D.L., 2000. The value of infrared thermography in the diagnosis and prognosis of injuries in animals. In: Proceedings from Inframation 2000, Vol. 1, Orlando, Florida, 115–122.

Holter, J. B., J. W. West, M. L. McGilliard, and A. N. Pell. 1996. Predicting ad libitum dry matter intake and yields of Jersey cows. J. Dairy Sci. 79:912–921.

Igono, M. O.; Steevens, B. J.; Shanklin, M. D.; Johnson, H. D. 1985. Spray cooling effects on milk production, milk, and rectal temperatures of cows during a moderate temperature e summer season. J. Dairy Sci., 68(4):979-985.

Igono, M. O., H.D. Johnson, B. J. Steevens, G. F. Krause And M. D. Shanklin. 1987. Physiological, productive, and economic benefits of shade, spray, and fan system versus shade for Holstein cows during summer heat. J. Dairy Sci. 70(5):1069-1079.

Johnson, H. D., A. C. Ragsdale, I. L. Berry, and M. D. Shanklin. 1963. Temperature-humidity effects including influence of acclimation in feed and water consumption of Holstein cattle. Univ. Missouri Agric. Exp. Stn. Res. Bull. 846. Columbia.

Keister, Z. O., K. D. Moss, H. M. Zhang, T. Teegerstrom, R. A. Edling, R. J. Collier, and R. L. Ax. 2002. Physiological responses in thermal stressed Jersey cows subjected to different management strategies. J. Dairy Sci. 85:3217-3224.

Lemerle, C.; Goddard, M.E. 1986. Assessement of heat stress indairy cattle in Papua New Guinea. Tropical Animal Health and Production, 18(4):232-242.

Lin, J. C., B. R. Moss, J. L. Koon, C. A. Flood, R. C. Smith, K. A. Cummins, D. A. Coleman. 1998. Comparison of various fan, sprinkler and mister systems in reducing heat stress in dairy cows. Appl. Eng. Agric. 14:177.

Kabuga, J. D.; Sarpong, K. 1991. Influence of weather conditions on milk production and rectal temperature of Holsteins fed two levels of concentrate. International Journal of Biometeorology, 34(4), 226-230.

Keown J, Kononoff P, Grant R. 2005 How to reduce heat stress in dairy cows. University of Nebraska. Extension. http:// www.ianrpubs.unl.edu/epublic/live/g1582/build/g1582.pdf

Kibler, H. H., and S. Brody. 1953. XXII. Influence of humidity on heat exchange and body temperature regulation in Jersey, Holstein, Brahman and Brown Swiss cattle. Univ. of Missouri Agric. Exp. Stn. Res. Bull. 522. Columbia.

Madalena, F. E., A. M. Lemos, R. L. Teodoro, R. T. Barbosa And J. B. N. Monteiro. 1990. Dairy production and reproduction in Holstein-Friesian and Guzera crosses. J. Dairy Sci. 73:1872-1886.

Matarazzo, S. V.; Silva, I. J. O.; Perissinoto, M.; Moura, D. J. *et al*. 2007. Eficiência de sistemas de climatização na área de descanso em instalações do tipo Freestall e sua influência nas respostas produtivas e fisiológicas de vacas em lactação. B. Indústr. Anim., 64(3):221-232.

McDowell, R.E. 1996. Economic viability of crosses of Bos Taurus and Bos indicus for dairyng in warm climates. Journal Dairy Science, 79, 1292-1303.

Mcglothen, M. E., F. E. L. Amin, Wilcox, C. J., Davis, R.H. 1995. Effects on milk yield of crossbreeding Zebu and European breeds in the Sudan. Rev. Brasil. Genet. 18:221-228.

Müller, P. B. 1982. Bioclimatologia aplicada aos animais domésticos. 2ª ed. Porto Alegre: Sulina, 158 p.

Nääs, I.A.; Arcaro Júnior, I. 2001. Revista Brasileira de Engenharia Agrícola e Ambiental, 5(1), 139-142.

NRC - National Research Council. 2001. Nutrient requirements of dairy cattle. 7 ed. Washigton DC: National Academy Press. 381p.

Perissinoto, M.; Moura, D. J.; Matarazzo, S. V.; Silva, I. J. O.; Lima, K. A. O. 2006. Efeito da utilização de sistemas de climatização nos parâmetros fisiológicos do gado leiteiro. Engenharia Agrícola, 26(3):663-671.

Pinheiro, M. G.; Roma Júnior, L. C.; Lima, M. L. P.; Nogueira, J. R.; Macari, M.; Santos, A. L.; Leme, P. R.; Nääs, I. A.; Lima, N. C.; Laloni, L. A.; Simili, F. F. Efeito do ambiente da sala de espera sobre a temperatura da pele de vacas da raça Jersey. In: Reunião Anual da Sociedade Brasileira de Zootecnia, 37, 2000, Viçosa. Anais... Viçosa: SBZ, 2000. CD Rom

Reece, W.O., 1998. Physiology of domestic animals. Grada Publishing Praha.

Robinson, J. B., D. R. Ames, and G. A. Milliken. 1986. Heat production of cattle acclimated to cold, thermoneutrality, and heat when exposed to thermoneutrality and heat stress. J. Anim. Sci. 62:1434:1440.

Roenfeldt, S., 1998. You can't afford to ignore heat stress. Dairy Manage. 35 (5), 6–12.

Silva, I. J. O.; Pandorfi, H.; Arcaro Jr., I.; Piedade, S. M. S.; Moura, D. J. 2002. Efeitos da climatização do curral de espera na produção de leite de vacas holandesas. Revista Brasileira de Zootecnia, 31(5):2036-2042.

Silva, R.G. 2001. Transmissão de radiação ultravioleta através do pelame e da epiderme de bovinos. Revista Brasileira de Zootecnia, 30(6):1939-1947.

Stober, M. 1993. Identificação, anamnese, regras básicas da técnica do exame clínico geral. In: Rosemberg (Ed). Exame clínico dos bovinos. Rio de Janeiro: Guanabara Koogan, 419p.

Syrstad, O. 1996. Dairy cattle crossbreeding in the tropics: choice of crossbreeding strategy. Tropical Animal Health Production, 28, 223-229.

Swenson, M.J. and Reece, W.O. 1996. Dukes: Fisiologia dos Animais Dométicos. 11ª ed. Rio de Janeiro: Guanabara-Koogan, 799 p.

Terui, S., Terada, Y., Kariya, Y., 1984. Studies of meteorological factors on physiological functions in cattle. J. Bull. Nat. Grassl. Res. Inst. 32, 59–65.

Thatcher, W.W. 1974. Effects of season, climate, and temperature on reproduction and lactation. J. Dairy Sci. 57(3):360-368.

Thom, E.C. 1958. Cooling degrees - days air conditioning, heating, and ventilating. Transactions of the ASAE, 55(7), 65-72.
Turner, L. W., J. P. Chastain, R. W. Hemken, R. S. Gates, W. L. Crist. 1992. Reducing heat stress in dairy cows through sprinkler and fan cooling. App. Eng. Agric. 8:251–256.
Turner, L. W., R. C. Warner, J. P. Chastain, E. Collins C. Boon. 1993. Reducing heat stress in dairy cows through improved facility and system designs. In Livestock Environment IV. Conference Proc. p 356. Coventry, UK.
West, J. W. 2002. Physiological Effects of Heat Stress on Production and Reproduction. In: Tri-State Dairy Nutrition Conference, 2002, University of Georgia: Animal e Dairy Science Department, abril 16 e 17, p.1-9.
West, J. W. 2003. Effects of heat-stress on production in dairy cattle. Journal of Dairy Science, Champaign, 86(6), 2131-2144.
Wise, M. E.; Armstrong, D. V.; Huber, J. T.; Hunter, R.; Wiersma, F. 1988. Hormonal Alterations in the lactating dairy cow in response to thermal stress. J. Dairy Sci., 71:2480-2485.
Yousef, M.K., 1985. In: Basic Principles. Stress Physiology in Livestock, Vol. 1. CRC Press, Boca Raton, FL

Electronic Tagging of Sheep – Results of a Large Field Trial in Germany

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Abstract

During a triennial trial in Germany, 8,989 sheep were tagged with 20 different electronic identification devices (EIDs) to investigate the suitability of these EIDs regarding tagging performance, animal well-being and durability. The monitoring of the ears four weeks after tagging showed a significant influence of the ear tag on the incidence of suppuration ($P<0.0001$). The incidence of suppuration was also influenced by the age of the animal and the position of the ear tag.
Furthermore, the read distance for nine handheld readers in combination with 16 EIDs was examined under laboratory conditions. Results of the read distance evaluation showed remarkable differences between different combinations of handheld readers and transponder. The orientation of reader and transponder to each other had also an influence on the read distance.

Keywords: animal welfare, read distance, RFID, sheep.

Introduction

Since January 1st 2010, the Regulation (EC) No 21/2004 provides a compulsory electronic identification of ovine and caprine animals. Different studies on electronic identification of sheep and goats showed that the electronic identification of animals is basically practicable (ADAS, 2005; Ribó *et al.*, 2002). But the results of these studies also emphasize that there are still certain weak points concerning the general implementation. To work out recommendations for German farmers and administration, a triennial trial started in September 2007. The aim of this trial was to investigate the suitability of different EIDs, different readers and management programs in different husbandry systems with the typical sheep breeds in Germany. Additionally, the read distance for nine handheld readers in combination with 16 EIDs was investigated. Different orientations between reader and EID were examined. The test was carried out under laboratory conditions in cooperation with DLG (German Agricultural Society).

Materials and methods

Reliability, loss rate and infection rate of EIDs

To investigate the tagging reliability, loss rate and the rate of infection of EIDs under farm conditions a total amount of 9,352 sheep and goats were tagged with 20 different EIDs in two tagging periods (2008 and 2009). The trial included 16 different ear tags and four different ruminal boluses, which were applied by three different tagging persons. The animals of 27 breeds and crossbreeds were kept in different husbandry systems on 28 farms in seven regions of Germany. The flock size varied from 10 to more than 2,000 ewes per farm.

The tagging periods were February 2008 until October 2008 and February 2009 until November 2009, respectively. All different EIDs were used on every farm, with the restriction, that at least 10 pieces of each type of EID had to be used. On small farms with less than 200 animals not each type of EID could be used. In 2008, all animals which were older than nine months and in 2009 the young stock (4-22 months old) were tagged. The ears of the animals were not cleaned or disinfected before tagging, but contamination of the wound was sought to be limited by avoiding touching ear tag pins. For tagging and controlling, the animals were fixed in a restraining box. For easy data collection and to ensure the correct link of already existing animal numbers with the new assigned number, a database was developed. With this tool also important information like other animal identification numbers, animal age, breed, tagged device, person who tagged etc. were collected on site.

Control readings were carried out four weeks, one year and two years after tagging to investigate the impacts on health, the tagging reliability and loss rates. At the control readings, the transponder were read out with hand-held readers and the ears were examined for the healing progress.

In order to find out whether the position of the ear tag has an influence, the sheep ears were divided into 16 sections. Figure 1 shows the 16 zones describing the position of the ear tag. The division of the ear is based on the ridge in the middle of the ear (positions M1 – M4; Figure. 1). The positions O1 – O4 describe the area over and the positions U1 – U4 the area below the ridge. The positions R1 – R4 were used to subdivide the area below the ridge when examining breeds with large ears. The sheep ears were examined for suppuration, incrustation, mechanical stress, enlarged holes and pulling through of the ear tag at each control reading. Each parameter was classified in categories (e.g. the parameter "suppuration" was classified in three different levels, healed, slight and severe suppuration).

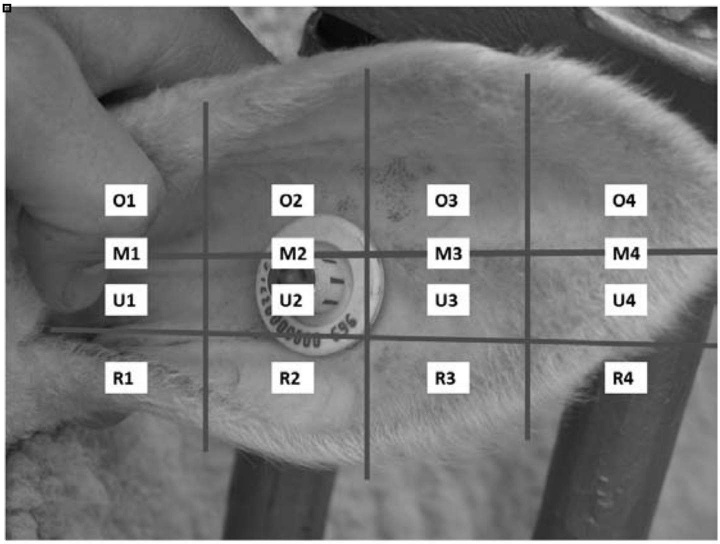


Figure 1. Definition of possible positions of ear tags.

<u>Read distance</u>

The read distance for nine handheld readers in combination with 16 EIDs was investigated under laboratory conditions in cooperation with DLG. Different orientations between reader and EID were examined in a modified test setup according to ISO (ISO 24631). Four of the 16 EIDs were ruminal boluses and 12 ear tags. 11 transponders were equipped with full duplex B (FDX-B) and five with half duplex (HDX) technology. The measurements were carried out stepwise (cm) in different orientations of EID and reader to each other to simulate most of the possible approach directions (Figure 2). Also the orientation of the transponder itself was changed in 0° and +90° position to investigate the best and worst read distance.

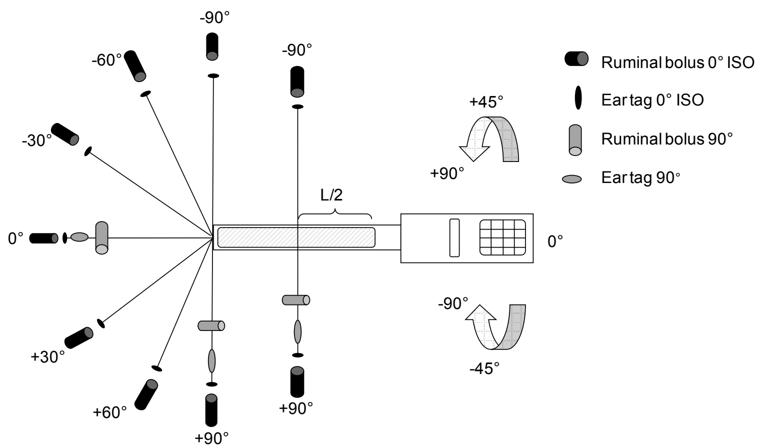


Figure 2. Test setup for measuring read distance

Statistical analyses

For statistical analyses, SAS 9.1 (SAS Institute Inc., Cary, NC, USA) was used. Categorial data from the control readings on the farms were analysed with the procedure GENMOD and the chi-square test. Results from the read distance measurement were analysed with the procedure GLM. For the multiple comparisons of the determined least square means (LS Means), the Tukey test was used. The level of significance was 0.05.

Results

Reliability, loss rate and infection rate of EIDs

A total of 8,779 sheep were controlled 4 weeks after tagging (excluded goats and not usable datasets). At this first control reading few EID losses (<1 %) were recorded. Ear tag losses and not readable EIDs which occurred in further periods are shown in Table 1. All in all, the level of recorded EID losses was low (<5 %). Especially in the first year after tagging losses like pulling out (2.4 %) and dropping out (1.2 %) of ear tags were determined (Table 1).

Table 1. EID losses in different periods after tagging

		Tagging – 1 year after tagging		1 year after tagging – 2 years after tagging	
Parameter		n	%	n	%
Ear tags pulled out		146	2.4	8	0.2
Ear tags drop out		73	1.2	21	0.6
Electronically not readable EIDs	Ear tag	37	0.6	2	0.1
	Bolus	6	0.4	1	0.1
Total	Ear tag	256	4.2	31	1.0
	Bolus	6	0.4	1	0.1
Controlled animals	Ear tag/Bolus	6,133/1,516		3,253/1,286	

Beside the EID losses, ear tags with broken pin pieces (but still in the ear) were recorded. 108 (1.8 %) broken ear tags were found until one year after tagging and additional 96 (2.9 %) two years after tagging. Broken pin pieces might cause a higher loss rate of ear tags in the further life of the animal.

Results regarding the animal well-being showed that there is a significant ($p<0.0001$) influence of the type of ear tag on the suppuration incidence at the first control reading. The occurrence of slight and severe suppurations varied from 6 up to 57 % four weeks after tagging (Figure 3).

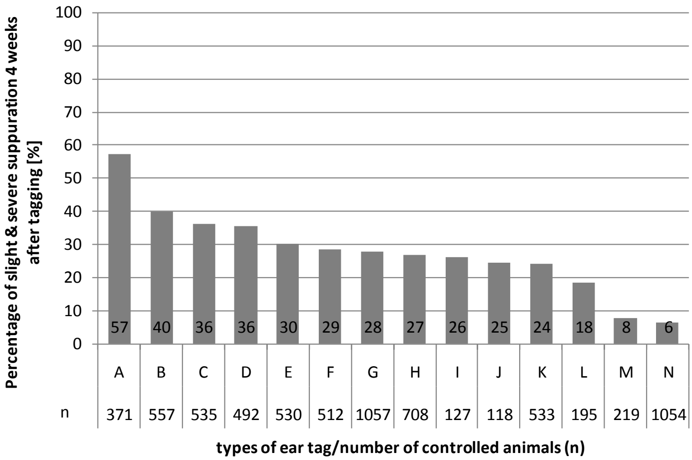
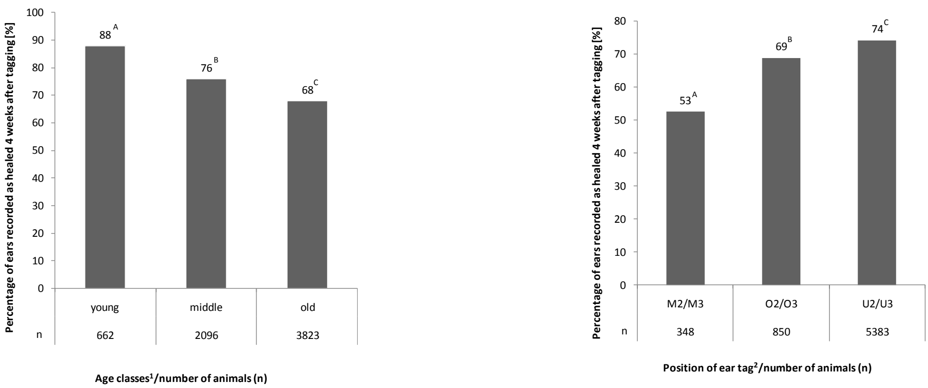


Figure 3. Distribution of suppuration four weeks after tagging

Furthermore the age class (young (<10 month), middle (10 – 22 month), old (>22 month) of the animals and the position of the ear tags (3 classes, positions O2+O3, M2+M3, U2+U3 (see Figure 1) had a significant ($p=0.0003$ / $p<0.0001$) influence on the occurrence of suppuration. Figure 4 shows the percentage of ears recorded as healed four weeks after tagging for the effects animal age and position of ear tag. The left graph illustrates the influence of the age on the occurrence of suppuration. In young animals, significantly more healed ears were recorded than in animals which were 10-22 month old or older than 22 month. The right graph shows that ear tags at the positions M2/M3 caused significantly more suppuration than ear tags at positions O2/O3 and U2/U3. Least suppuration was recorded at the positions U2/U3.



[1] age at tagging: 3 classes, young (<10 month), middle (10 – 22 month), old (>22 month)
[2] *3 classes, positions O2+O3, M2+M3, U2+U3 (see Figure 1)*

Figure 4. Influence of animal age (left graph) and position of ear tag (right graph) on the percentage of ears recorded as healed four weeks after tagging

One and two years after tagging further parameters like enlarged holes in sheep ears were recorded. The occurrence of enlarged holes one year (16.8 %, 994 animals) after tagging was correlated to the occurred inflammations four weeks after tagging (R^2 = 0.53). Additional 437 animals with enlarged holes (13.6 %) were found two years after tagging.
Seasonal effects or the influence of the tagging person might also affect the healing process. However, these factors could not be analyzed statistically because of unbalanced data structure.

Read distance

Results of the read distance evaluation showed remarkable differences between different handheld readers and transponder as well as between the different combinations of the devices. Also the orientation of reader and transponder to each other had significant influence on the read distance. Read distance over all combinations and orientations varied from 2 cm up to 56 cm. In optimum orientation average read distance over all readers and transponders was 25.25 ± 7.68 cm.
Table 2 shows the LS-Means of the read distance of nine readers over all transponders and of the 16 EIDs in optimum orientation. Significant differences regarding the read distance between different readers were recorded. The worst reader had an average read distance of 16.97 cm, the best reader reached 39.07 cm in optimum orientation. The read distance of the 16 EIDs varied between 21.05 cm and 33.64 cm.
Regarding the possible combinations of reader and transponder the reading range reached from 13.1 cm up to 52.5 cm in optimum orientation.

Table 2. LS-Means of read distance of readers over all transponder (left table) and transponder over all readers (right table) in optimum orientation

Reader	LS-Means cm	stddev cm
R1	31.00^{2}	0.03
R2	16.97^{8}	0.03
R3	24.90^{4}	0.03
R4	28.39^{3}	0.03
R5	24.37^{5}	0.04
R6	25.04^{4}	0.03
R7	39.07^{1}	0.03
R8	17.74^{7}	0.03
R9	18.98^{6}	0.03

Figures within a column lacking a common superscript differ (α = 0.05)

Transponder	LS-Means cm	stddev cm
T1	24.33^{g}	0.04
T2	26.86^{c}	0.04
T3	24.15^{g}	0.04
T4	27.71^{b}	0.04
T5	25.56^{ef}	0.04
T6	23.48^{h}	0.04
T7	25.37^{f}	0.04
T8	25.73^{e}	0.04
T9	21.28^{k}	0.04
T10	25.64^{e}	0.04
T11	21.05^{l}	0.04
T12	22.07^{j}	0.04
T13	22.41^{i}	0.04
T14	33.64^{a}	0.04
T15	27.04^{c}	0.04
T16	26.28^{d}	0.04

T1-T12 = ear tag
T13-T16 = ruminal bolus
Figures within a column lacking a common superscript differ (α = 0.05)

Figure 5 shows a schematic illustration of the reading range of one handheld reader. In the best orientation, the transponder could be read out in a range of approximately 30 cm. In the worst orientation of transponder and reader to each other the read distance decreased to less than 10 cm. No significant difference between transponder with HDX and FDX-B technology was recorded.

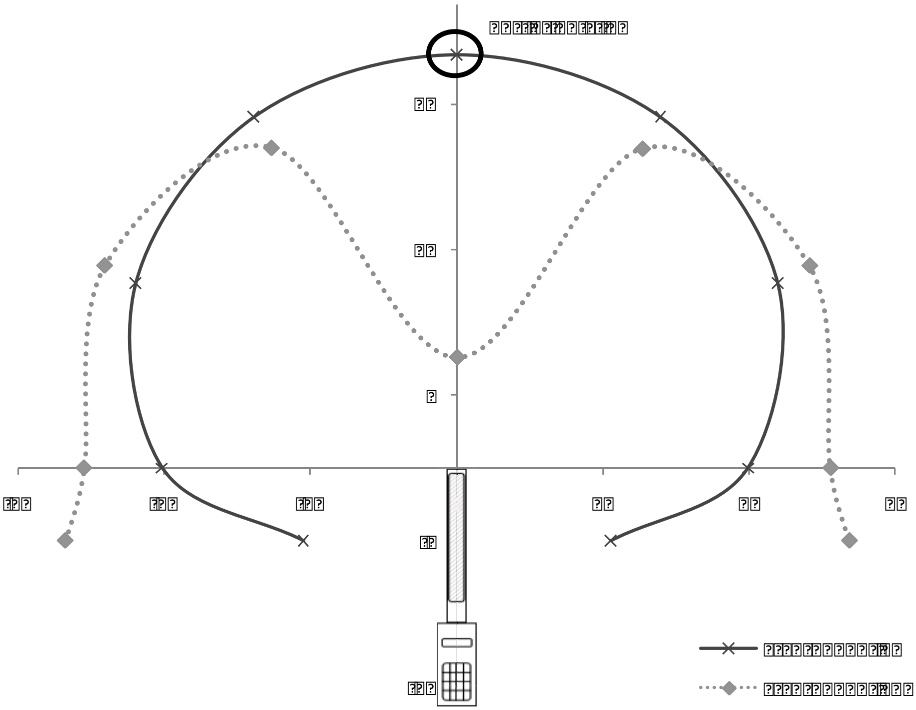


Figure 5. Schematic illustration of the reading range of one handheld reader [cm]

Discussion

<u>Reliability, loss rate and infection rate of EIDs</u>

Regarding level of EID losses of less than 5 % similar results were found in an investigation in Great Britain (ADAS, 2005). JRC (2009) suggested 5 % ear tag losses as a calculation basis.
A relation between EID losses and possible influences like tag type, position of ear tag, husbandry system etc. could not be established because of not enough observations.
The losses of ruminal boluses of less than 1 % were similar to observations made by Ghirardi *et al.* (2006). Pinna *et al.* (2006) and Carné *et al.* (2010) found similar loss rates in goats.
A high percentage of severe suppuration (up to 24 %, one tag type even up to 43 %) 29 d after tagging was recorded. Smits *et al.* (2005) also reported a high inflammation rate for lambs and ewes four weeks after tagging (over 20 % of severe inflammations). However, Edwards *et al.* (2001) reported up to 77 % severe lesions in sheep tagged with conventional plastic ear tags.

According to Smits *et al.* (2005) and Heckenberger *et al.* (2009) less inflammation were observed in young animals than in ewes.
This investigation showed that the position of tagging has an influence on occurrence of inflammations. Fewer problems occurred on position U2 and U3 than on other positions of the ear. This is probably caused by the anatomy of the ear, especially the different curvature and thickness of the ear at different positions.
The relation of the parameter "suppuration" four weeks after tagging and enlarged holes one year and two years after tagging was also found in other studies (ADAS, 2005). Enlarged holes can cause a higher loss rate of ear tags.

<u>Read Distance</u>

Regarding the remarkable differences in the reading range between different combinations of reader and transponder, similar results could determined in other studies (Bryant *et al.*, 2006; Ryan *et al.*, 2010). Besides the reader and transponder combination, the reader and transponder orientation to each other had an influence on the read distance.

Conclusions

Important facts for a smooth wound healing were choice of the correct tag for sheep breed, correct position of ear tag, careful and clean application, tagging of young animals etc. When considering these facts, EID losses and incidence of suppuration is limited to reasonable numbers and militate in favour of a general implementation.
If high read distance is necessary on field application a careful selection of readers and transponders is recommended.
Further examinations regarding read distance under farm conditions are necessary to give helpful recommendations for farmers. This applies also for the practicability of EIDs, readers and management programs, which was found to be improvable.

Acknowledgements

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References

ADAS – Agricultural Development and Advisory Service. 2005. English pilot trials of EID/EDT in sheep. Final Report. Department for Environment, Food and Rural Affairs – DEFRA. London, UK, pp. 28-29, pp. 118-120.

Bryant, A.M., Blasi, D.A., Barnhardt, B.B., Epp, M.P. and Glaenzer, S.J. 2006. Variation in performance of electronic cattle ear tags and readers. Beef Cattle Research, Report of Progress 959. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, pp. 33-37.

Carné, S., Caja, G., Rojas-Olivares, M.A. and Salama, A.A.K. 2010. Readability of visual and electronic leg tags versus rumen boluses and electronic ear tags for the permanent identification of dairy goats. Journal of Dairy Science, Vol. 93, pp. 5157-5166.

Edwards, D.S., Johnston, A.M. and Pfeiffer, D.U. 2001. A comparison of commonly used ear tags on the ear damage of sheep. Animal Welfare, Vol. 10, pp. 141-151.

Ghirardi, J. J., Caja, G., Garín, D., Hernández-Jover, M., Ribó, O. and Casellas, J. 2006. Retention of different sizes of electronic identification boluses in the forestomachs of sheep. Journal of Animal Science, Vol. 84, pp. 2865-2872.

Heckenberger, G., Lucke, G., and Kassuhn, R. 2009. Versuchsbericht. Untersuchungen zum Einsatz von Ohrmarkentranspondern bei Schafen. (Investigation of the application of electronic ear tags in sheep.) Landesanstalt für Landwirtschaft, Forsten und Gartenbau. http://lsa-st23.sachsen-anhalt.de/llg/infothek/dokumente/Transponderohrmarken1.pdf, accessed 28. April 2010.

JRC – Joint Research Centre 2007. SESAMONET – A Secure and Safe Mobility Network developed (patent pending) by the JRC to improve the mobility of visually impaired people. http://ec.europa.eu/dgs/jrc/downloads/jrc_sesamonet_flyer_en.pdf, accessed 5. October 2010.

Pinna, W., Sedda. P., Moniello. G. and Ribó. O. 2006. Electronic identification of Sarda goats under extensive conditions in the island of Sardinia. Small Ruminant Research, Vol. 66, pp. 248-257.

Ribó, O., Cuypers, M., Korn, C. and Meloni, U. 2002. Large-scale project on livestock electronic identification – IDEA Project. Final Report. v. 3.0, http://idea.jrc.it/pages%20idea/final%20report.htm, accessed 20. May 2007

Ryan, S.E., Blasi, D.A., Anglin, C.O., Bryant, A.M., Rickard, B.A., Anderson, M.P. and Fike, K.E. 2010. Read distance performance and variation of five low-frequency radio frequency identification panel transceiver manufacturers. Journal of Animal Science, Vol. 88, pp. 2514-2522.

Smits. D., Ipema. B., Hogewerf P. and Schuiling. E. 2005. Feasibility of electronic ear tags for identification and registration: the sheep and goat case. In: Bau. Technik und Bauwesen in der landwirtschaftlichen Nutztierhaltung. Beiträge zur 7. Internationalen Tagung 2005. March 01-03. 2005. Braunschweig. pp. 625-630.

Automatic measurement of the silage cutting length by artificial vision

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Abstract

For feeding their animal, the farmers would like to have a tool to measure the granulometry of maize or grass silage samples, in a field, or to appreciate this one making the discrimination between silage particles cut with different cutting lengths. From this knowledge, the aim would be to adjust some machine parameter, in order to obtain silage samples, with a desired granulometry, taking into account the harvest conditions. This control of ganulometry would improve the digestibility of the animals. Artificial vision was used to measure the silage particles cutting length which varies much, during harvest operations, because it depends of several parameters concerning the product and the harvesting conditions. An image processing method was developed to measure automatically this cutting length.

Keywords: silage, sieving, automation, image processing

Introduction

The heightened interest in physical form of feeds for ruminants is partially related to research on starch digestion and lactation performance, ruminal pH and health disorders. Although the effect of particle size of diets on ruminal pH was not clear in the literature review of Sauvant (Sauvant et all, 1999), probably because the particle size was not measured, it is classically assumed that intake of physically effective fiber stimulates chewing activity (Mertens, 1997), and, in turn, chewing stimulates saliva secretion. Bicarbonate and phosphate buffers in saliva neutralize acids produced by fermentation of organic matter in the rumen. The balance between the production of fermentation acid and buffer secretion is a major determinant in ruminal pH (Allen, 1995). The differences in physical effectiveness of feeds vary in a large proportion with particle size distribution of feeds. Chewing time decreases with particle size. A large variability between maize silages can be observed in the particle size distribution, mean particle size lay between 1.1 and 3.9mm, measured by wet sieving, in a laboratory, but the factors of variation were not known. The effect of maize silage on chewing time and ruminal pH was studied in the Wisconsin University (Dhiman et all, 2000), but the particle size of silages was not measured and only mean ruminal pH was reported. Some experimentations carried out in 2002-2003 by INRA (French National Institute for Agricultural Research) showed that the maize silage particle size did not vary with the grain roller-mill presence on harvester machine. The mean particle size increased significantly with the maturity stage of the plant and the theoretical Chop Length (CL). There was also an interaction between maturity stage and CL, and also a significant and positive relationship between mean particle size and residual Dry Matter (DM) amount.
The silage granulometry depends on the maturity stage for one CL adjusted on the machine, and the chopping fineness of maize silages.

We can say that, on one hand, the silage particle size depends of CL, but also other parameters like maturity stage or harvester type and on the other hand, the particle size of maize silages has an effect on ruminal digestion (Philippeau and Michalet-Doreau, 1997; Fernandez and Michalet-Doreau, 2003), and then on fermentation rate, volatile fatty acids production, and ruminal pH kinetics. We saw the importance of the measurement of the silage cutting length. So the farmers, to have a correct digestibility of their animals, need a tool or a sensor to measure and control this cutting length.

Materials and methods

The aim was to find a sensor to measure this cutting length, which depends of several parameters concerning the product and the harvesting conditions. The kind of sensor chosen is artificial vision. Different image processing methods were tested on maize silage samples images. Finally, the image processing algorithm retained is a sieving by vision method. It consists in the definition of a grid format and a size, on an image. All the objects which have a size superior (inferior) as the grid size stay on the grid (fall down). This method will be compared with the weight sieving principle. To test, validate and see the performances of this image processing algorithms, some images containing calibrated stones were used, in the experimentations. The maize and grass silage product can be cut with different lengths, between 4 mm and 22 mm, depending of various elements like for example the country, the breeding, the fields, the climatic conditions. Some maize silage images are presented in the Figure 1.

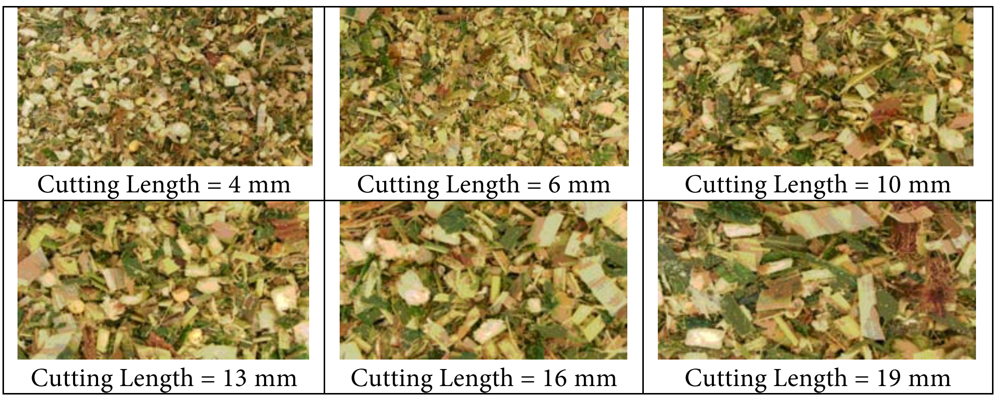


Figure 1. Maize silage images cut with various cutting lengths

Weight sieving experimentation

A weight sieving operation was carried out in order to analyse in detail the granulometry composition of maize silage, cut with the following lengths: 4, 6, 10, 13, 16 and 19 mm (see Figure 2). In the beginning of this experimentation, several sieving times were tested, in order to find the necessary time to sieve correctly the maize silage samples. The optimal time obtained and retained to sieve all the samples was 5 minutes. Images were taken with a colour vision system, to see the silage particles composition, on the different grids (A, B, C, D, E and F). Some images for the cutting lengths 4, 8, 13 and 19 mm are presented in the Figure 3.

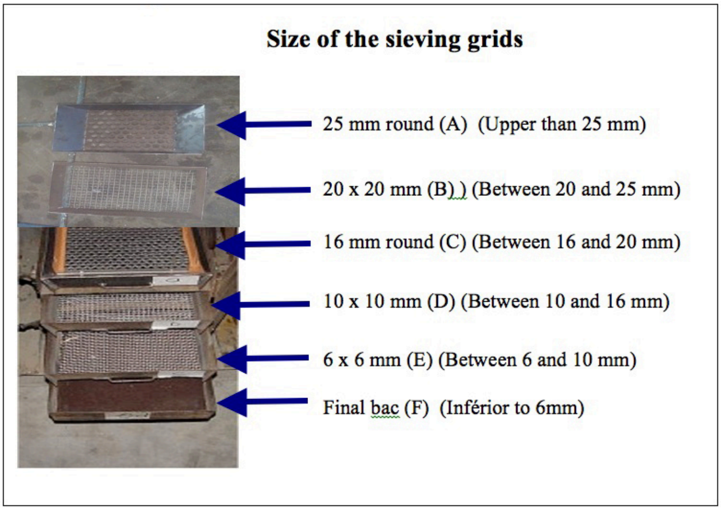


Figure 2. The sieving machine with some grids

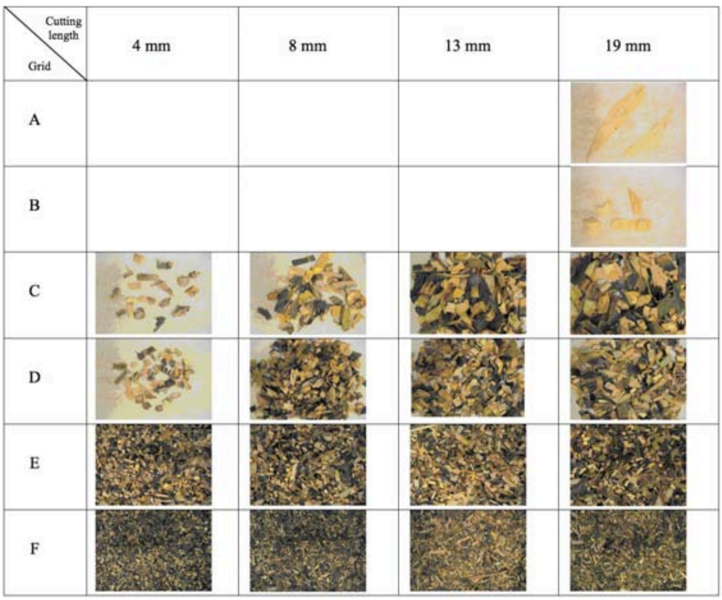
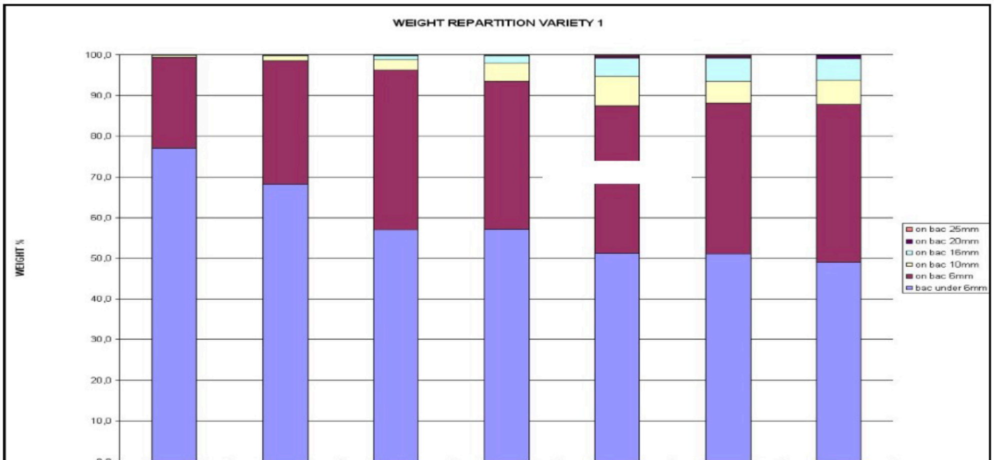


Figure 3. Composition of the silage samples on the sieve grids A, B, C, D, E and F

The weight repartition was realized, to appreciate the granulometry composition of the samples corresponding to various cutting lengths (5, 7, 10, 13, 16, 19 and 22 mm) (see Figure 4).



	5mm	7mm	10mm	13mm	16mm	19mm	22mm
on bac 25mm	0,0	0,0	0,2	0,1	0,3	0,4	0,3
on bac 20mm	0,0	0,0	0,1	0,2	0,4	0,5	0,8
on bac 16mm	0,0	0,2	0,9	1,8	4,6	5,7	5,3
on bac 10mm	0,7	1,2	2,5	4,5	7,3	5,4	5,9
on bac 6mm	22,3	30,4	39,3	36,3	36,2	37,1	38,8
bac under 6mm	77,1	68,2	57,0	57,1	51,2	51,0	49,0

Figure 4. Weight repartition for silage samples

The results obtained show that the most important part of the silage particles is on the bac F (bac under 6 mm), and also on the grid E (particles between 6 and 10 mm), for the different cutting length values. So, we can say that, for a cutting length, small or big, the product obtained, during a harvest operation, in the fields is not uniform, and contain a very important number of small particles. But we can say also that this mechanical sieving method with the weight measurement is not a relevant method to obtain the granulometry of silage particles, for various samples, because, in this method many particles, even very big particles, which have a rectangular shape, can fall down to inferior grids. So the weight measurements, for the different grids are not corrects.

The sieving by vision method to discriminate automatically the cutting lengths of silage particles

The aim was to find an image processing algorithm able to discriminate the silage particle cutting length, in real time, in the particle flow and to measure automatically the cutting length by artificial vision. Different image processing methods were tested, in a first time, like for example, morphologic mathematic algorithms, relatively long about time computation, and edge segmentation methods, too sensitive to noise, in order to detect on images the silage particles and to measure the width of these ones. Finally, a method that looks like the weight sieving was developed and tested on silage images, and permitted to obtain the best results about the discrimination of the silage particles corresponding to various cutting lengths. The

edge segmentation method detected the edge points of the silage particles whereas the sieving by vision method, based on morphological operations, took into account, directly, the surface of the particles, to discriminate the different cutting size of silage particles.
This method consists in the definition of a grid format (square or round) and a grid size expressed in pixel^2, on an image. All the particles on the image which have a size superior to the grid size stay on the grid. In terms of image processing, we can say that these objects keep their color. The particles which have a size under the grid size fall down. In terms of image processing, these objects loose their color and become dark. The principle and the different steps of this method are presented in the Figure 5 and Figure 6.

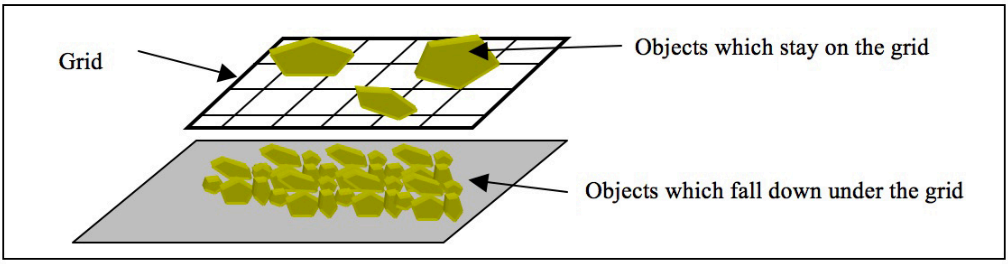


Figure 5. Principle of the sieving by vision method

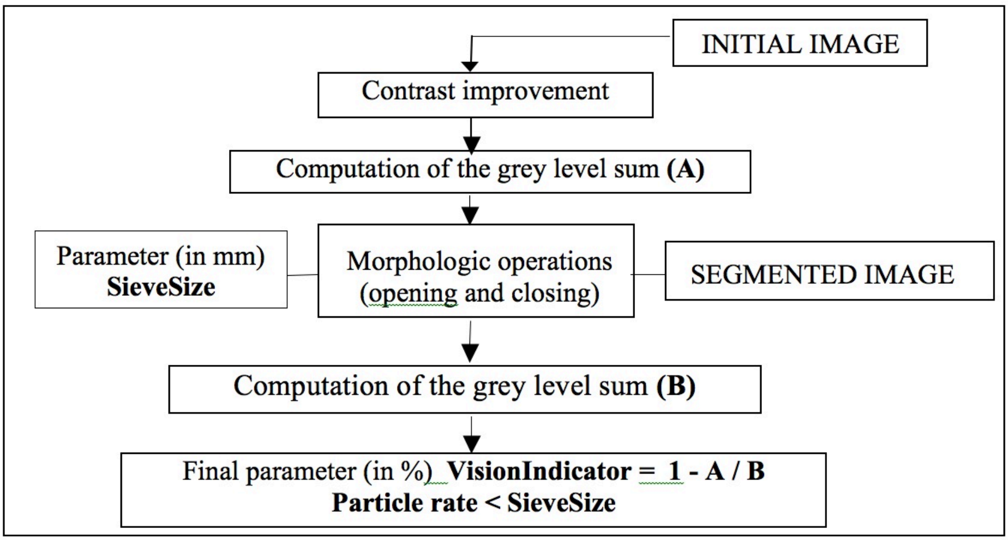


Figure 6. The sieving by vision algorithm

This algorithm computes only the intensity component of a color image. The sieve can have a circular or square shape, but generally when the considered objects have a rectangular shape, it is better to choose a square shape. It is the case for silage particles.
The parameter called **SieveSize** which defines the size of the sieve, is the square size expressed in mm. Taking into account the image resolution, we can convert this value in pixels. The

result of this image processing method, called **VisionIndicator** is the particle rate inferior to the grid size, in an image. An example for two maize silage images is presented in the Figure 7. The values of the parameter SieveSize considered here are the following: 6, 10, 20 and 40 pixels. The aim is to find the best parameter value, to obtain the best discrimination as possible.

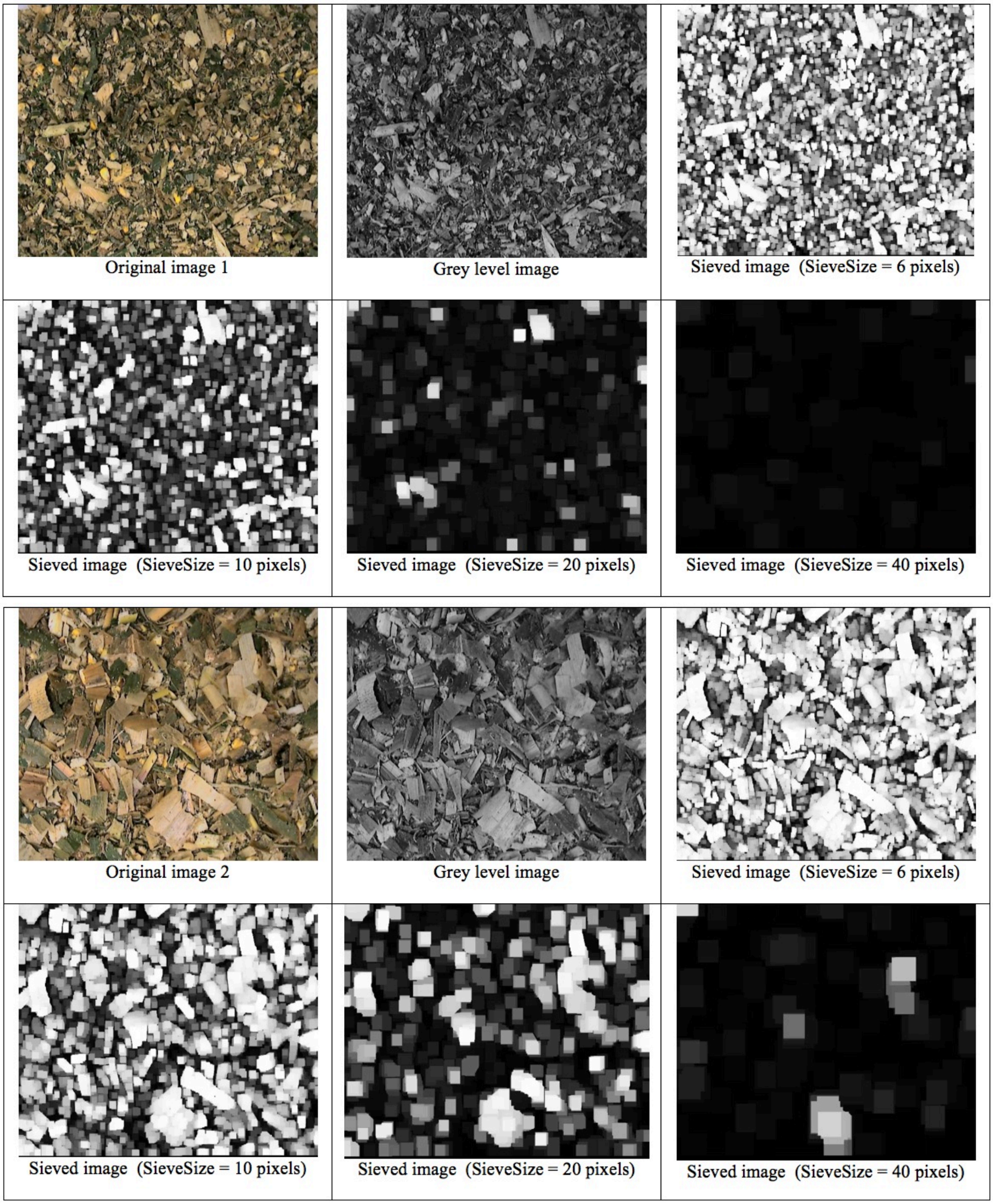


Figure 7. The sieving by vision algorithm applied on maize silage images

Results and discussion

Before the application of the sieving by vision image processing algorithm, to discriminate and to measure the silage particle cutting length, on images, a study was carried out on calibrated stones, to test and validate this method. Various size of stones (5 – 10 – 12,5 – 16 – 20 – 25 mm) (see Figure 8) and several values of the parameter **SieveSize** of the algorithm were used in this test experimentation.

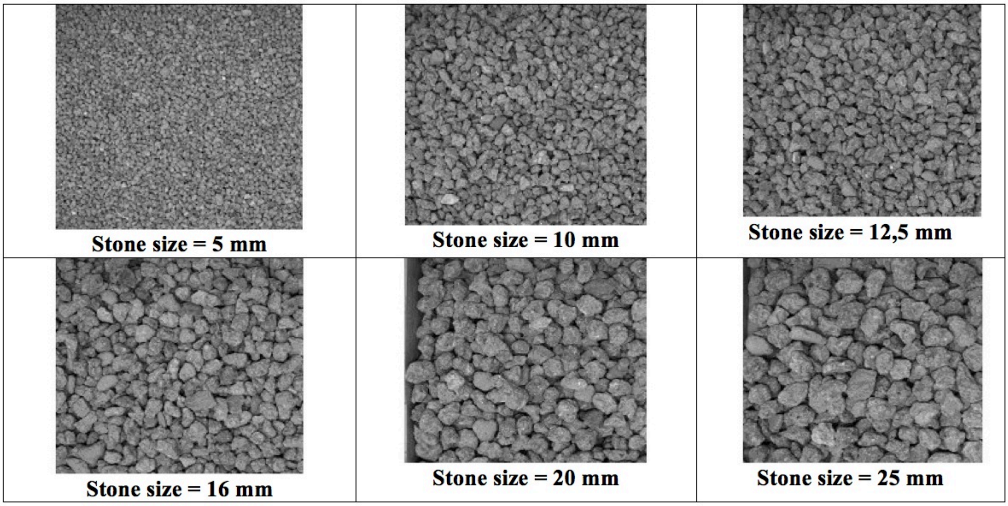


Figure 8. The calibrated stones used for the sieving by vision algorithm test

<u>Results on stone images for various parameter values</u>

The results obtained considering grid sizes of 5 mm 10 mm 12,5 mm 16 mm and 20 mm, are presented in Figure 9. The best results to discriminate all the different stone sizes, from 5 mm to 25 mm, are obtained with grid sizes of 10 mm 12,5 mm and 16 mm. We see a regular decreasing curve. With a grid size of 5mm, the big stone sizes are not correctly detected and with a grid size of 20mm, the small stone sizes are not correctly detected. We considered groups of two grid sizes, and we present the particle rates which have a size between both grid sizes. These groups are: 0-5 mm, 5-10 mm, 10-12.5 mm, 12.5-16 mm, 16-20 mm, and 20-25 mm. We can see that the maximum value of the vision indicator for particles between 0 and 5 mm, is obtained for the stones of 5 mm. Also the maximum value for particles between 5 and 10 mm, is obtained for the stones of 10 mm, and so on up to the stones of 20 mm.

The vision indicator values corresponding to particles between 0 and 5mm, and also between 5 and 10 mm, are much more important than those for particles between 10 and 12,5 mm, between 12,5 and 16 mm, between 16 and 20 mm, and also between 20 and 25 mm, for short stones (under 16 mm). This point shows that this vision method detects a lot of short particles, for small stones, but also for big stones.

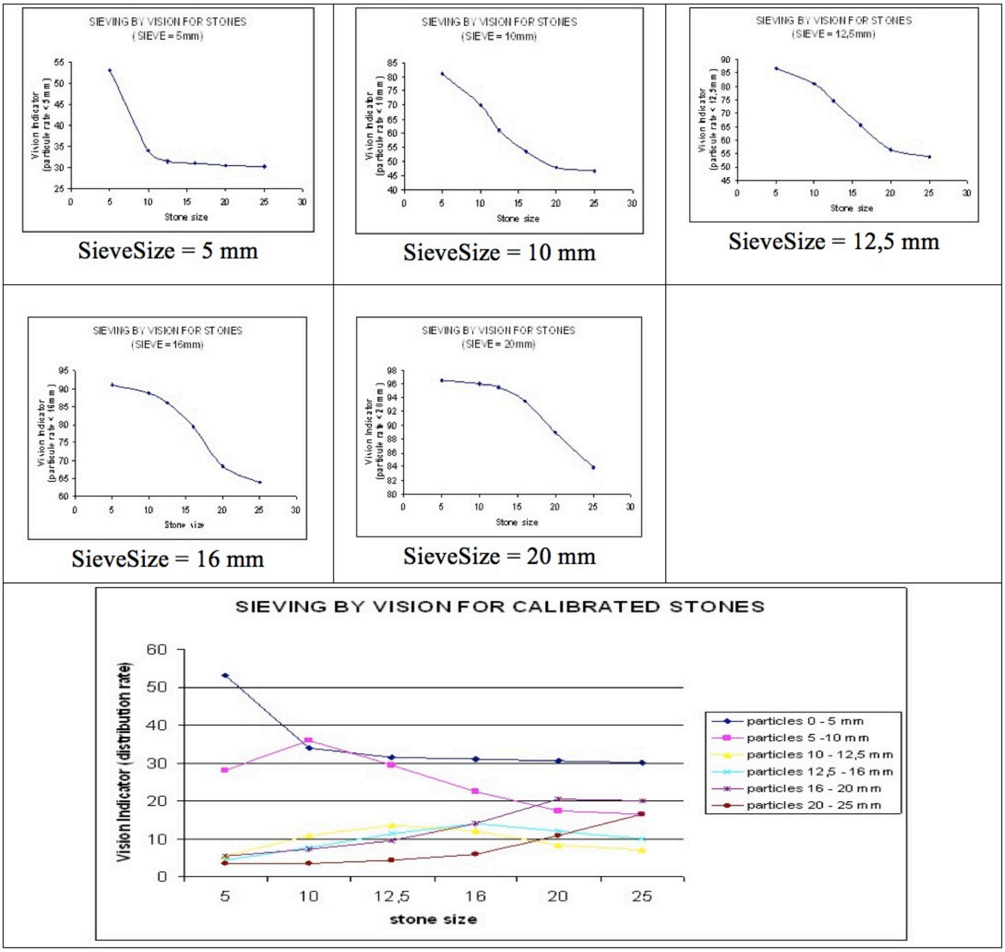


Figure 9. Sieving by vision method applied on calibrated stones for different grid sizes

<u>Results on maize silage images for various parameter values</u>

The results obtained with this sieving by vision method on some maize images, corresponding to several cutting lengths from 4 mm to 18 mm are presented in Figure 10. The sieving parameters chosen for the test were 2 mm, 6 mm, 10 mm, 16 mm and 20 mm. To discriminate the best as possible maize silage samples corresponding to various cutting lengths, we can say from these results that the value of the parameter SieveSize of this method, must be comprised between 10 mm and 16 mm. We have a similar result as for stone images. For a short value of the parameter, for example 2 mm or 6 mm, the discrimination for big cutting lengths is difficult and for a big value of the parameter, for example 20mm, the discrimination for short silage particles is difficult.

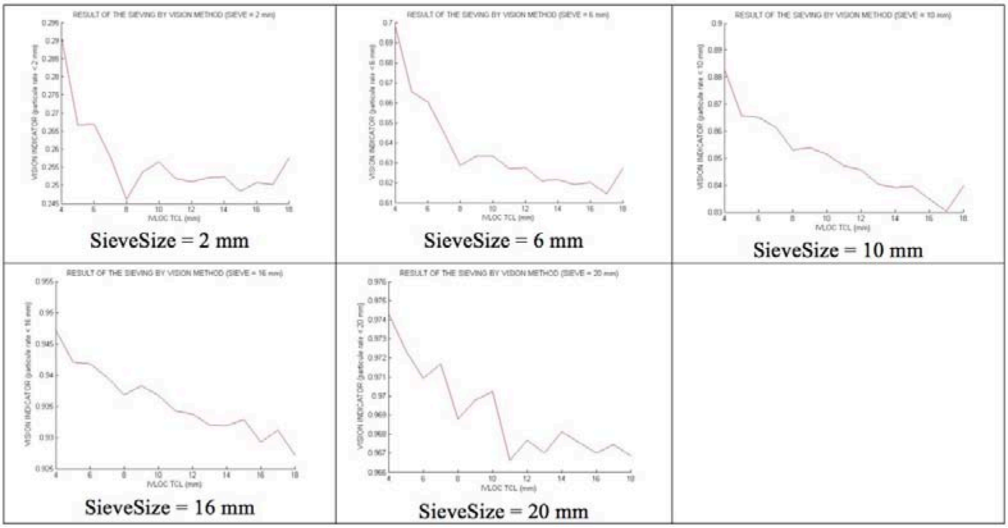


Figure 10. Sieving by vision method applied on maize silage images for various grid size

Modelisation of the vision results

From the curve obtained in Figure 10, with a value of 10 mm for the parameter SieveSize, a logarithmic model was obtained to have a relationship between the silage cutting length and the vision indicator (Figure 11).

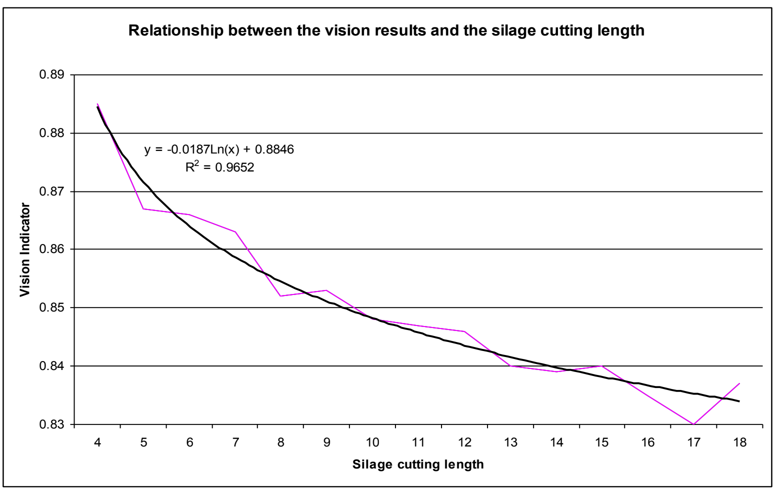


Figure 11. Relationship between the vision indicator and the silage cutting length

Using this model, for each silage image, we obtain the silage cutting length, from the artificial vision value (VisionIndicator) obtained with the image processing method. This cutting length is the mean size of all the silage particles, in the image.

Conclusions

An image processing algorithm, able to discriminate, different maize silage cutting lengths classes, was developed. This one is the sieving by vision algorithm. With this method, we obtain a vision indicator which permits to make the difference between various maize silage cutting lengths, between 5 mm and 22 mm. The vision indicator value obtained is the pixel rate which falls down under a grid. With this method, if we would consider different grid sizes, we could have information on the granulometry distribution of the silage particles on the images. For example, if we consider two grid sizes (6 mm and 10 mm), we could have an information on the granulometry distribution of the particles inferior to 6 mm, between 6 mm and 10 mm, and superior to 10 mm.
From the image processing results obtained with the sieving by vision method, with a parameter SieveSize equals to 10 mm, we can modelise the silage cutting length data with the artificial vision data obtained, using a logarithm curve.

The weight sieving operations realized, from many silage samples, to study the composition of the silage product for different cutting length values, showed that the silage products contain a very important number of small particles. It is the case for all the different cutting lengths values, from 5mm up to 22 mm. But concerning the analysis of the results obtained with this mechanical method, we have to take into account that this one is not a perfect reference to measure the particle granulometry.

This image processing method was tested on calibrated stones, to evaluate its capability to discriminate several stones sizes. From this works and the results obtained, we can say that this method could be applied in many applications, in the field of precision agriculture, to realize measurements or classifications, on different products.

References

Allen M.S., 1995. Fiber requirements : finding an optimum can be confusing. Feedstuffs; 15.

Dhiman T.R., Bal M.A., Wu Z., Moreira V.R., Shaver R.D., Satter K.J., Shinners K.J., Walgenbach R.P., 2000. Influence of mechanical processing on utilization of corn silage by dairy cows. J. dairy Sci. 83, 2521-2528.

Fernandez I, Michalet-Doreau B., 2003. Starch and fibre distribution in maïze silage in relation to particle size. J. Sci. Food Agric., 83, 147-150.

Mertens D., 1997. Creating a system for meeting the fiber requirements of dairy cows. J. Dairy Sci., 80, 1463-1481.

Philippeau C., Michalet-Doreau B., 1997. Influence of genotype and stage of maturity of maize on rate of ruminal starch degradation. Anim. Fed Sci. Technol., 68, 25-35.

Sauvant D., Meschy F., Mertens D., 1999. Les composantes de l'acidose ruminale et les effets acidogènes des rations. INRA Prod. Anim., 12, 49-60.

Monitoring of transport environment and effect of transport duration on zootechnical performances, health and welfare during rearing period.

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Abstract

The objective of this experiment was to study the transportation of day-old chicks (different durations) and its impacts on i) the environment in truck and chicks' nearest environment, ii) zootechnical performances, welfare and health during rearing period. Just after hatching, 16800 chicks (ROSS PM3) were distributed in three groups, the first one was transported in a truck for 4 hours, the second group was transported in the same track for 10 hours and the last one was moved directly from the hatchery to farm (0 hour). Temperature, humidityand vibration were measured by sensors to evaluate the environment quality during the transport. Before and after transportation, chicks' weight, temperature, activity and hematocrit were assessed. Then from one day old to slaughtering (36 days) zootechnical parameters (mortality, feed consumption, feed conversion ratio and body weights), welfare parameters (activities, foot pad dermatitis) and environment quality (litter quality, temperature, hygrometry) were registered. Experiments are in progress and results will be available later. The aim of this study is to give us some information about the transport condition of chicks. Further studies are required to study the effect of age of breeders flock and the rearing conditions.

Keywords: day-old chicks, broiler, welfare, zootechnical performances, transport, sensor.

Selecting the most appropriate flooring system for growing-finishing pigs using analytical hierarchy process

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Abstract

This research aimed to select the most appropriate bedding material for growing-finishing pigs using the analytical hierarchy process (AHP). The aspects considered for the analysis were: rearing ambient, animal welfare, performance, health status and economic feasibility. The input system used previous results of a trial with three treatments: whole concrete floor, coffee and rice husk bedding and wood shavings bedding. Physiological parameters, performance, rearing conditions, behaviour and health status were registered and analyzed. The producers' options were also taken into account. Results showed that the best flooring material was the use of deep-bedding with coffee or rice rusk.

Keywords: multicriterial analysis, analytic hierarchy process, pig farming.

Introduction

Pig production is an important economic activity in tropical countries; however, traditional rearing conditions and manure handling in confinement using whole floor is considered as causing significant environmental impact (Oliveira, 2004; Cordeiro *et al.*, 2007). The use of deep bedding substrate over the whole floor for pigs may reduce NH_3 emission by reducing airflow across surfaces soiled by urine, and by immobilization of ammonium–N (Oliveira *et al.*, 1998; Gilhespy *et al.*, 2009).

Bedding improves the physical comfort of the floor, and it functions as an important stimulus and outlet for exploration, foraging, rooting and chewing behaviors (Tuyttens, 2005). Pigs that are feed restricted or housed in barren environments can be strongly motivated to express behavioral problems or anomalies (Lay *et al.*, 2000). Among the critical points for achieving good welfare it is the confinement environment (Silva *et al.*, 2009) which involves the exposition to certain types of stress (heat stress, social adaptability, hunger, etc). The adoption of straw and others substrates as deep bedding is reported to function as recreational material improving the general welfare status of pigs, and the time engaged in negative social behaviors increased with group size in the absence of bedding (Lay *et al.*, 2000; Day *et al.*, 2008; Averós *et al.*, 2010). The use of deep bedding is mainly to avoid build up of moisture on floor, and consequent excessive ammonia concentration inside the housing. Several bedding materials and their depth used in piggeries have been studied, such as rice husk, wood shavings, barley and wheat straws (Andersson, 1996; Morrison *et al.*, 2003; Corrêa *et al.*, 2009). Each alternative either enhances a certain benefit the material may provide (Matte, 1993) or points out the changes in the animal' behavioral pattern, due to the use of a certain bedding substrate (Fraser, 1985), not leading to a specific solution.

The selection of the deep bedding material is clearly a multicriterial task, as it involves distinct aspects related to the animal benefit and the producer, such as availability and price of the material. Amongst the possible mathematical solutions the use of the analytic hierarchy process (AHP) enables the possibility of arranging the selected criteria in a level structure, and by weighting the alternatives it is possible to classify them according to established parameters. AHP has been applied in several scenarios were there are several possible alternatives and the array of solutions can be arranged in a matrix (Ananda e Herath, 2003; Shrestha *et al.*, 2004; Omkarprasad e Sushil, 2006).

The aim of this research was to select the most appropriate bedding material to raise pigs during growing and finishing under tropical conditions, considering specific restrictions of producers and seeking the best solution for the pigs' welfare, and using the multicriterial analysis named analytic hierarchy process (AHP).

Materials and Methods

Animals, housing and husbandry

A completely randomized design experiment was conducted with 24 crossbred (Large White × Landrace) pigs (castrated males, growing and finishing pigs). Piglets were raised in a conventional pig room until they reached ten weeks of growth with weight of approximately 30 ± 0.53 kg. The pigs were reared in six $14m^2$ rooms (4 pigs / room) with semi automatic feeders and nipple type drinkers. The animals received the same diet based on the nutritional recommendations by Rostagno *et al.* (2005). Both feed ration and water were given *ad libitum*. The trial lasted seven weeks and it was approved by the Ethical Research Group of the UFGD (protocol 01/2010).

Treatments and field experimental procedure

The pigs were randomly distributed in the following treatments: (1) whole concrete floor, (2) concrete floor covered with 0.5m of depth of wood shavings, and (3) concrete floor covered with 0.5m of depth of coffee and rice husk. The animals were weighted in the beginning of the trial and individually marked in the ears. The fodder consumption was registered weekly. After the trial ended they were weighted again for determining the average weight gain. The pigs behaviour was registered every 5 min done during 8 hours once a week during 7 weeks, according to Ferreira (2005). Data were used for structuring the frequency the animals spent eating, drinking, sleeping, interacting with others and exploring. Skin and rectal temperature and respiratory frequency were recorded in 4 pigs randomly chosen in each treatment. Statistical analysis was carried out using the Scott-Knott test. Data from this trial were used as input for the AHP analysis.

Structuring the multicriterial analysis

The AHP involves five stages: (a) to structure the problem, (b) to identify the possible technological options, (c) to identify the selected criteria, (d) to develop the weights of the criteria, and (e) to apply the weights and rank the options.

a) To structure the problem: In order to structure the qualitative base for the selection of the most appropriate bedding material results from the experiment was used, added to literature data. Producers were consulted and two swine specialists were asked to guide on the analysis (Keeney, 1992). The hierarchy was established taken into consideration the criteria used by both the producers (initial cost, management cost of manure, availability of material, performance) and the reared animals (rearing ambient BGTHI, bedding surface temperature, ammonia concentration, rectal and skin temperature, behavioural interactions and health);
b) To identify the possible technological options: The technological solution involves a set of options which allows reaching the goal. In this particular case the treatments (bedding materials) were the possible solutions;
c) To identify the selected criteria: The selection of the criteria was based on the trial's results. The system was defined into three distinct levels (Figure 1);
d) To develop the weights of the criteria: The purpose of the AHP is to provide a vector of weights expressing the relative importance of those layout alternatives for each criterion. The adopted scale of importance was defined according to Satty (1977) using the 1–9 scale for pairwise comparison; and to apply the weights and rank the options: In the application of the AHP approach, a pairwise comparison matrix is formed.

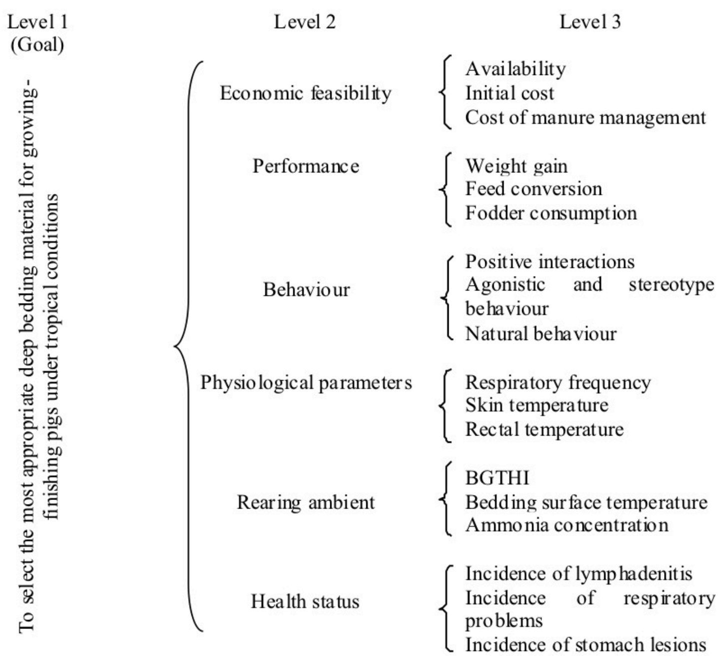


Figure 1. Scheme of the selected criteria to reach the goal of selecting the most appropriate deep bedding material in growing/ finishing pig production

e) In the pairwise comparison matrix, rows and columns are allocated to the components belonging to the same parent component in the decision hierarchy. The weight of component i compared to component j with regard to the parent component is determined using Saaty's scale (Saaty, 1977) and assigned to the $(i, j)^{th}$ position of the pairwise comparison matrix A (Saaty, 1980) chosen to support comparisons within a limited range but with sufficient sensitivity. A is consistent if and only if $\lambda_{max} = n$. As the inequality $\lambda_{max} > n$ tends to exist the average of the remaining eigenvalues can be used as a "consistency index" (CI, Eq 1) which is the difference between λ_{max} and n divided by the normalizing factor (n – 1).

$$CI = (\lambda_{max} - n)/(n - 1) \quad (1)$$

f) The CI of the studied problem is compared with the average RI obtained from associated random matrices of order n to measure the error due to inconsistency (Saaty, 1977, Saaty, 1980). A consistency ratio (CR = CI/RI) value ≤ 0.1 should be maintained for the matrix to be consistent; otherwise the pairwise comparisons should be revised. Homogeneity of factors within each group, smaller number of factors in the group, and better understanding of the decision problem would improve the consistency index.

The weights for each criterion in levels 2 and 3 were given based on the results of the field experiment previously, and using the field experience of the researchers who worked in the trial. Each criterion was pairwise compared and the local weight was calculated as the geometrical mean of each matrix line, representing the local weights. The global weight is the weight related to the specific criterion, taking into account the related weights given to all items which compose that level, and pairwise compared. In each aspect, such as comparing criteria or alternatives under each criterion, a decision maker gives intuitive judgment as pairwise comparisons. The researchers involved in the field experiments attributed the local weights for each criterion taking into account the field results.

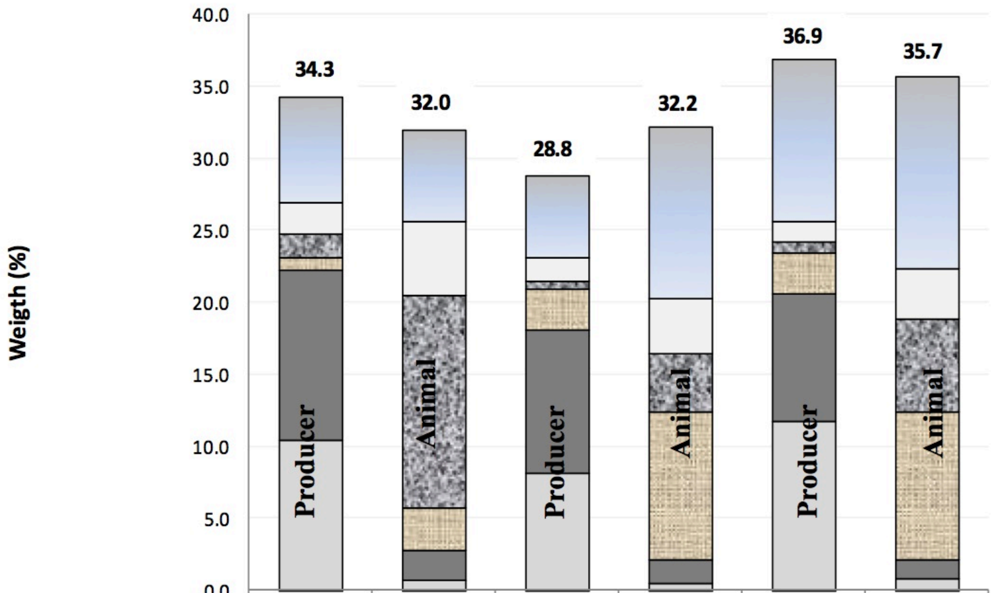
In this research two scenarios were applied adopting two distinct criteria of priority for selecting the most appropriate deep bedding material. Scenario (1): pig performance was the focus (producer view), while in the second scenario (2): the animal welfare (animal view) was given priority. In this procedure the weights changed in each scenario for each criterion. Computational analysis was done using the web based software AHPProject (2010).

Results and discussion

The provision of straw in animal production systems is widely presumed to be beneficial for the welfare of the animals. The presence of straw or coffee and rice hulls also functions as an important stimulus and outlet for exploration, foraging, rooting and chewing behaviors. Pigs that are feed restricted or housed in barren environments, in particular, can be strongly motivated to express these behaviors and the inability to do so may result in behavioral problems or anomalies.

Regarding the scenario that gave priority for pig performance (the producer) results showed that the best flooring system was the deep-bedding system using either coffee or rice hulls. The results on the scenario which considered the priority the pig welfare (the animal) pointed that the criterion that was the most significant one was the physiological parameters (17.0%), followed by the rearing ambient (16.0%) and economic feasibility (14.0%). Although the best alternative on the physiological parameter was the whole concrete floor (38.1%), the deep bedding material that indicated the most appropriate physiological parameters was wood shavings (28.3%). Regarding the rearing ambient results, again the indication was to the whole concrete floor as the best alternative (37.1%), but the most appropriate deep-bedding was the wood shavings (30.7%).

The overall results pointed out that the most appropriate flooring system is that which uses deep-bedding system either from coffee beans or rice hulls, from both stand points the producer (36.9%) and the animal (35.7%), as shown in Figure 2.



	Whole concrete floor		Wood shavings		Coffee and rice husk	
Health status	7.3	6.3	5.7	11.9	11.2	13.3
Rearing ambient	2.2	5.2	1.6	3.8	1.5	3.5
Physiological parameters	1.7	14.8	0.5	4.1	0.7	6.5
Behaviour	0.8	2.9	2.9	10.3	2.9	10.3
Performance	11.8	2.1	9.9	1.6	8.8	1.3
Economic feasibility	10.5	0.7	8.2	0.5	11.8	0.8

Figure 2. Summary of weight results for the alternatives proposed and the selected criteria for choosing the most appropriate flooring system for growing-finishing pigs.

Pigs have difficulties in exchange heat when housed under tropical conditions decreasing their performance (Machado, 1985; Baêta & Souza, 1997). It was found in current literature that deep-bedding present some advantages over the whole concrete flooring system (Oliveira, 199;

Paulo, 2003). Although the presence of deep-bedding may increase fermentation heat, this flooring system seems to present advantages in terms of reducing the use of cleaning water and adsorbing the excess of moisture in the floor due to the residues. Paulo (2003) comparing two types of deep-bedding found that rice hulls were the most efficient substrate when relative humidity is above 75%. Bridi *et al.* (2003a and b) compared pigs reared at free range, on deep-bedding and concrete floor and did not find difference in their carcass quality.

Regarding pigs' behavior authors (Lay *et al.*, 2001; Fraser *et al.*, 2001) showed that pigs in deep-bedding flooring systems played and interacted more with each other, and presented less skin lesions. Hötzel *et al.* (2009) found that swine reared in deep-bedding systems had similar performance to those reared on whole concrete floor, although those in deep-bedding presented higher skin surface temperature than those reared in whole concrete floor. This might be because deep-bedding material alters the heat exchange to the concrete floor and avoids the moisture and cold as well as dejects' adherence to the animals (Lancini, 1986).

Deep-bedding also altered ammonia concentration in the rearing environment, leading to respirators diseases (Heber *et al.*, 2002). The maximum amount of concentration allowed by NIOSH (1996) is around 25 ppm. However, European researchers suggest the upper limit of 10 ppm. Oliveira (2000) found lower ammonia concentration in pigs reared on deep-bedding, as the substrate tends to absorb the excessive moisture from the manure (Chapin *et al.*, 1998). Similar results were found by Paulo *et al.* (2009) being ammonia concentration 37% higher on whole concrete floor, when compared to Wood shavings deep-bedding and 44% higher when compared to deep-bedding of rice hulls. Emissions and odors are lower in pigs on deep-bedding systems (Oliveira, 1999; Paulo, 2003).

When evaluating respiratory problems no difference was found between the systems (Oliveira, 1999). Results on the slaughter house showed higher hyperqueratosis in pigs reared on whole concrete floor, when compared to those reared on deep-bedding. Pigs reared on deep-bedding presented in average 70% less mucous problems than those reared on whole concrete floor.

There are several alternatives of deep-bedding systems for pig production and the selection of the most appropriate one is not a simple task. Controversial suggestions have been made by authors in experiments under tropical conditions (Perdomo *et al.*, 1997; Oliveira, 1999; Corrêa *et al.* 2000) that the performance of pigs on deep-bedding systems was lower than those on concrete flooring due to the excess of moisture kept under the substrate. However, the authors recognize that this is more related to a matter of management than to the system itself. When selecting the material the availability of each substrate needs to be taken into account by the producer, thus the use of alternative material which is residue from another agriculture activity may present better economic overview.

Conclusions

Coffee and rice husk deep-bedding provided the best alternative for flooring system of growing –finishing pigs, followed by the use of whole concrete flooring.

Acknowledgements

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References

AHPProject. 2010. Available at: http://ahpproject.com. Accessed on: 03.04.2010.

Andersson, M. 1996. Performance of bedding materials in affecting ammonia emissions from pig manure. Journal of Agricultural Engineering Research **65** 213-222.

Averós, X., Brossard, L., Dourmad, J-Y., de Greef, K.H., Edge, H.L., Edwards, S.A., Meunier-Salaün, M-C. 2010. A meta-analysis of the combined effect of housing and environmental enrichment characteristics on the behaviour and performance of pigs, Applied Animal Behaviour Science **127** 73-85.

Baêta, F.C., Souza, C.F. 1997. Ambiência em edificações rurais: conforto animal. Viçosa, MG: Editora UFV. pp.246.

Chapin, A., Boulind, C., Moore, A. 1998. Controlling odor and gaseous emission problems from industrial swine facilities – Recent laws and new ideas. Yale: Environmental Protection Clinic. pp81.

Corrêa, E.K., Bianchi, I., Perondi, A., de los Santos, J.R.G., Corrêa, M.N., Castilhos, D.D., Gil-Turnes, C., Lucia Jr., T. 2009. Chemical and microbiological characteristics of rice husk bedding having distinct depths and used for growing–finishing swine. Bioresource Technology **100** 5318-5322.

Day, J. E.L., Van de Weerd, H.A., Edwards, S.A., 2008. The effect of varying lengths of straw bedding on the behaviour of growing pigs. Applied Animal Behaviour Science **109** 249-260.

Gilhespy, S.L., Webb, J., Chadwick, D.R., Misselbrook, T.H., Kay, R., Camp, V., Retter, A., Bason A.L. 2009. Will additional straw bedding in buildings housing cattle and pigs reduce ammonia emissions? Biosystems Engineering **102** 180-189.

Heber, A., Jones, D., Sutton, A. Indoor air quality: Controlling ammonia gas in swine buildings. Purdue University Cooperative: Extension Service. http://cdc.gov/niosh/nasd/docs4/in98003.html. 20 Ago. 2002.

Hötzel, M.J., Lopes, E.J.C., de Oliveira, P.A.V., Guidoni, A.L. 2009. Behaviour and performance of pigs finished on deep bedding with wood shavings or rice husks in summer. Animal Welfare **18** 65-71.

Lancini, J.B. 1986. Aspectos gerais sobre a intoxicação e contaminação através da cama aviária. Avicultura Industrial **76** 32-34.

Lay, D. C. Jr., Haussmann, M. F., Daniels, M. J. 2000. Hoop housing for feeder pigs offers a welfare-friendly environment compared to a non bedded confinement system. Journal of Applied Animal Welfare Science **3** 33-48.

Machado, L.C.P. 1985. Instalações para suínos. Suinocultura Industrial **7** 6-14.

Machado, L.C.P. Instalações para suínos. Suinocultura Industrial, v.7, n.75, p.6-14, 1985.

Morrison, R.S., Hemsworth, P.H., Cronin, G.M., Campbell, R.G. 2003. The social and feeding behaviour of growing pigs in deep-litter, large group housing systems, Applied Animal Behaviour Science **82** 173-188.

NIOSH – National Institute of Occupational Safety and Health, 1996. Safety in swine production systems. North Carolina: Cooperative Extension Service Publications. n. PIH. pp104.

Oliveira, P. A. V. Produção de suínos em sistema "deep bedding": experiência brasileira. 1997. In: Seminário Internacional de Suinocultura 2000: Proceedings of the 5th Seminário Internacional de Suinocultura, edited by Embrapa, CNPSA, pp101-107.

Oliveira, P.A.V. 1999. Comparaison des systèmes d'élevage des porcs sur litière de sciure ou caillebotis intégral, (unpublished PhD thesis, University of Rennes, France).
Paulo, R. M. 2003. Uso de camas sobrepostas durante as fases de crescimento e terminação de suínos em condições de verão, (unpublished Master's dissertation, University of Viçosa, Brazil).
Paulo, R.M., Tinoco, I.F.F., Oliveira, P.A.V. 2009. Avaliação da amônia emitida de camas sobrepostas e piso concretado utilizados na criação de suínos. Revista Brasileira de Engenharia Agrícola e Ambiental **13** 210-213.
Silva, R.B.T.R., Nääs, I.A., Moura, D.J. 2009. Broiler and swine production: animal welfare legislation scenario. Scientia Agricola **66** 713-720.
Tuyttens, F.A.M. 2005. The importance of straw for pig and cattle welfare: A review. Applied Animal Behaviour Science **92** 261-282.

Digital image processing methods for the identification of pigs posture during weight estimation

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Abstract

Variations in the postures of pigs can contribute to significant amounts of error during automatic weight estimation of pigs using image analysis techniques. This is especially the case when the head of a pig is not maintained on the same straight line as the body of the animal. It was estimated that an additional 2.4% error is associated with sub-optimal posture of animals during weight estimation. To minimize weight estimation error as much as possible, the aim of this study was to identify the most suitable image analysis technique that can automatically select frames from video streams with optimum animal posture for accurate weight estimation. Four different techniques, namely reference line, length ratio, angular width and mid-line methods were investigated using images of pigs between 45 and 90 kg. All images were taken from above the animals at a height of 1680 mm. In this study, images of animals turning their heads more than 30 degrees from the body line either left or right were classified as suboptimal. Similarly, images were also classified as suboptimal if the angular placement of the pigs in the images were more than 30 degrees from the midline. Among the different methods, both the length ratio and angular width method were found to be most likely to identify images with suboptimal head position, while the midline method was the best at identifying pigs with a suboptimal body position. Thus overall the length ratio method appears to be the best to identify suboptimal images before further processing.

Keywords: Image analysis, posture, head turning, livestock, pig.

Introduction

Animal farming requires continuous monitoring of animal weight to ensure optimal nutrition, to potentially reduce environmental impact, prepare a marketing strategy and estimate profitability (Parsons *et al.* 2007). Traditional weighing systems for livestock are based on manually operated ground scales that are time consuming, costly and stressful to the animals (Kollis *et al.* 2007). Image analysis based weighing system can negate some of the difficulties associated with traditional weighing systems (Wang *et al.* 2008). The importance of image analysis in the agricultural sector increases day by day especially within the livestock industries due to the ability of machine vision applications to capture important information related to the competitiveness of the farm, such as the health, growth efficiency, weight and carcass compositions of animals (Banhazi and Black 2009; Banhazi *et al.* 2009; Doeschl-Wilson *et al.* 2005; Schofield 1990; Whittemore and Schofield 2000).
As technology has developed, it has become standard practice to obtain images from a video stream. However, video cameras capable of capturing 30-40 images per second might provide

excess amount of information that is not always useful. These high capture rates might increase the chance of obtaining the object of interest, but they also increase the need for reliable separation of useful images from the ones that are not optimal for information extraction. Therefore, it is necessary to develop a suitable method of filtering images continuously. An algorithm capable of automatically identifying and excluding redundant images is required. Only images that contain the complete object of interest in a desired orientation should continue on to further analysis stages.
Specifically in relation to animal measurement for weight prediction; one of the main problems identified was that both the head and tail areas are a source of measurement error (Brandl and Jorgensen 1996). Thus these areas have to be identified and removed from the images before further processing. However removing the head and tail sections from the images of pigs with suboptimal head or body position is much harder when compared to processing images of animals that are placed in an optimal position (Tscharke 2009, pers. com). In recent studies, it was found that if suboptimal images (pigs with head or body turned) were removed before processing; the precision of weight estimation could be improved by 2.4% and total area variance could be reduced by 8.6% (Tscharke 2009, pers. com). Therefore, that main aim of the study presented in this paper was to develop and compare image processing methods that can automatically identify suboptimal images (with the body or the head of the pig turned) and remove them from the image stream before any further processing.

Materials and methods

A flow chart presented in Figure 1 shows an overview of the image analysis approach used.

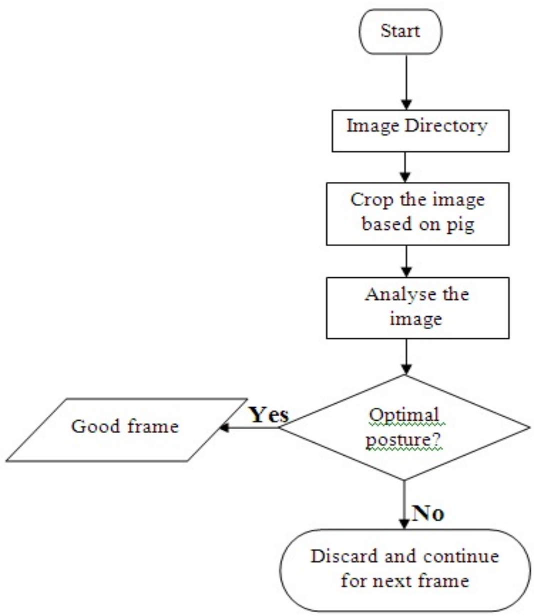
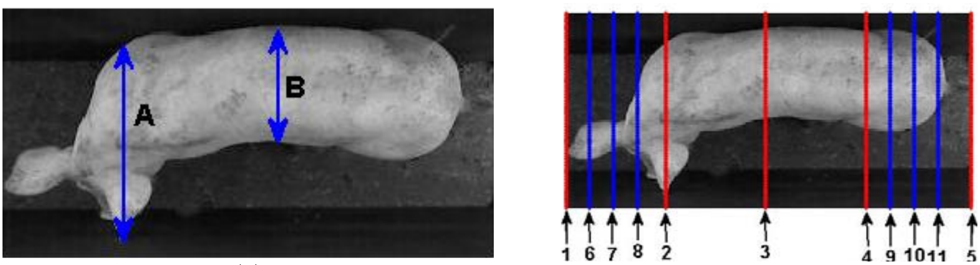


Figure 1. Flow chart of the overall methodology used

In this study, it was assumed that the image was incorrect (and thus may cause weight estimation error) if the head was turned more than 30 degrees either to the left or the right from the centre line of the animal. This 30 degree cut-off threshold value was measured by using a ruler and marking lines through the centre of the body and centre of the head on printouts of the images. The same manual method was used to identify the angular placement of the pig in the images. A total of 51 images were collected from the video stream which includes 28 images with incorrect posture and 23 images that were classified as correct images.
The image analysis procedure always started with the acquisition of the image that was automatically cropped before the four different image analysis methods (aimed at identifying incorrect head or body postures) were performed on the images to identify the most the reliable method. The four different methods used to identify incorrect postures of pigs in the frames were the (1) reference line, the (2) length ratio, the (3) angular width and the (4) mid-line angle methods.

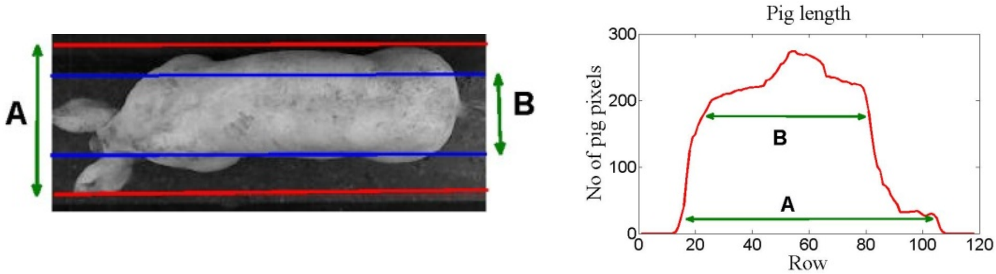
Reference line
First the image was divided into 4 portions by five vertical lines and then the first and last portion of the image were divided into another four smaller portions using three reference lines to identify whether the head was correctly placed (Figure 2.b). The concept assumed that if the head was turned left or right, the reference line would include more pig pixels (line A in Figure 2.a) compared to the main reference lines (line B in Figure 2.a) across the body of the pig. Figure 2 shows a sample pig image with head turned and it can be seen from the image that pig pixels along line A are greater than those along line B.



(a) (b)

Figure 2. Investigation of pig posture based on reference line length.

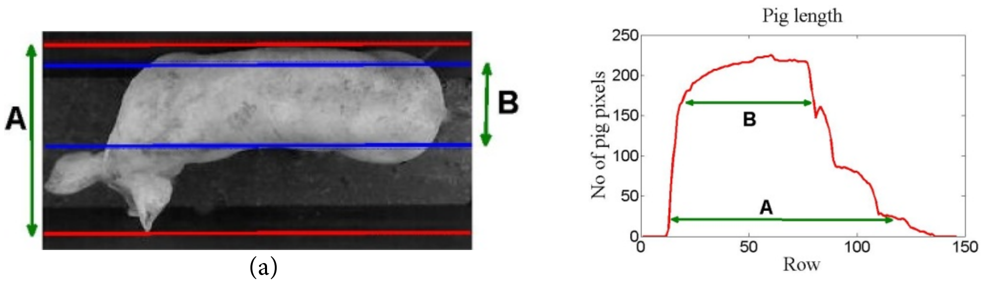
Length ratio
This method used a similar approach to the reference line method. However in this method, pig pixels were counted along row lines instead of column lines. First, the image data was changed into either 0 as non pig pixel or 1 as pig pixel and then pig pixels were counted in each row which actually indicated the approximate length of the pig. On the basis of these pig pixels a plot was drawn across row lines. A sample image of a pig with straight head (Figure 3.a) and plot of pixel variations across the rows can be seen in the figure 3b. The length of the pig was plotted across the rows where x axis represents the row and y axis represents the number of pig pixel on that row. Letter A indicates the number of rows that contain the complete pig where letter B represents the rows that form an envelope containing the maximum length of pig pixels (Figure 3).



(a) (b)

Figure 3. Length ratio of straight and corresponding intensity plot.

If the head is turned in either directions, length A would be much greater than the length B. Figure 4 shows a sample image of a pig with its head turned to the left side and corresponding length plot. As the head was turned left, the length fluctuation could be seen on the right side of the plot.



(a) (b)

Figure 4. Length ratio of pig with head turned and corresponding intensity plot.

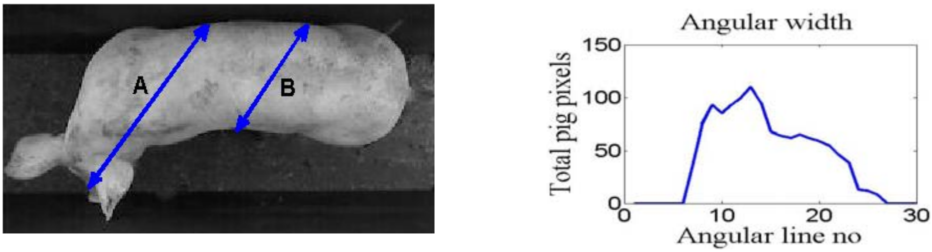
<u>Angular width</u>

In this method, the widths of a pig were calculated along angular lines instead of the vertical lines. Figure 5.a shows that for an image with head turned, line A was much greater than the line B. To analyse the resultant data, Equation 1 was generated to locate the position of pixels that occupied the same line.

$$r = \sqrt{2} \times d - c, \text{ where, } r = \text{row}, \ c = \text{column} \tag{1}$$

$d =$ vertical distance of the angular line from top left corner$(0,0)$ of the image

Initially, the angle of these lines was set at 45° to both sides of the centre line of the image and the distance between each angular line was 10 pixels. Along these lines, the total amount of pig pixels was computed and a plot was generated. The portion of the image with a pig with suboptimal head position would always contain more pig pixel than the rest of the body. Figure 5.a shows a sample image of a pig with head turned where letter A represents the angular width of the head area and letter B represents the angular width of the body area. The excess width within the head area would generate steepness in the overall angular width and thus would increase the difference between the maximum angular width and the average angular width. Figure 5.b shows the plot of angular width of the pig in image 5.a.



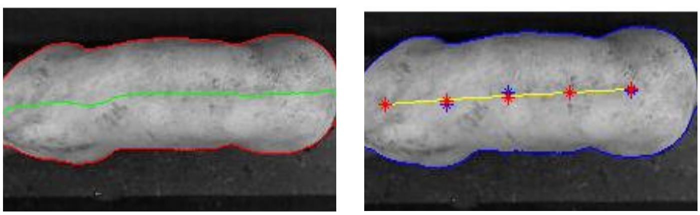
(a) (b)

Figure 5. Width of pig calculated across the angular line.

<u>Mid line</u>

Before calculating the midline, it was important to obtain the contour line of the pig accurately; otherwise incorrect countor detection would lead to incorrect mid points being generated. The edge line between the body of the pig and the background was identified based on the intensity changes as reported before (Banhazi *et al.* 2009).

It was obvious that if the pig was straight in the image the slope of the midline of the pig body would be close to zero and if it was at an angle in the frame the angle of the slope would also increase. After obtaining the contour of the pig, the midline point was found by dividing the top and bottom edge points by 2. Figure 6.a shows the midline obtained via this process.



(a) (b)

Figure 6. Angle of pig's midline.

To calculate the slope, a best fit linear line was drawn through equally distanced points (Figure 6.b). In addition to the slope of this linear line, the vertical distances from each midpoint and the best fit line were calculated. A geometrical equation that was used to calculate vertical distances is displayed in Equation 2.

$$d = \frac{|ax_1+by_1+c|}{\sqrt{a^2+b^2}} \quad \text{where, } ax + by + c = 0 \text{ is equation of the line and} \qquad (2)$$

$(x_{1,}y_1)$ is the midpoint from where distance was calculated

In this method, it was assumed that if the body was turned these midpoint distances from the best fit linear line would be greater in addition to the higher slope.

Results and discussion

Table 1 shows the results of the different methods used to determine the animal's posture in the images. All the methods used were able to identify the correctly positioned animals with optimal postures in the frame and accepted them for further processing, as shown in the table 1. As it can be seen, the "Length Ratio" method showed the best consistency at determining animals with incorrect postures when compared to the other methods. However, it misinterpreted some images when the head of the animal was pointing down so that the neck area could not be differentiated from the body which directly affects the algorithm. The second most reliable method found in the investigation was the "Angular Width" method that had problems identifying animals that turned their head and rear section at the same time. This occurred because pigs that turned their bodies reduced the difference between maximum angular width and the average angular width and therefore failed to pass the minimum threshold value to identify the head turning. The rest of the methods were less successful in identifying animals with suboptimal posture.

Table 1. Summary of comparative results

Method	Function	Correct Posture Images	Correctly Identified	% Identified	Incorrect posture Images	Correctly Identified	% Identified
Reference Line	HT	23	23	100	28	6	21
Length ratio	HT &BA	23	23	100	28	19	68
Angular width	HT	23	23	100	28	16	57
Midline	HT &BA	23	23	100	28	12	43

HT = Head Turning, BA = Body Angle

Reference line

Although the reference line method demonstrated some clear sensitivity on the head placement, it had some drawbacks as well. Because the ears of the pigs have an effect on the number of pixels that are counted as part of the pig as well as the position of the head, sometimes the head portion of the pig did not completely fall between the first and second reference lines and therefore could not be measured. In addition, when the head was turned more that 45 degrees, the ears of the pigs often fell outside the reference line section. Figure 7.a shows such a situation where the head is turned more that 45 degrees and only one ear is within the reference line section (between 1-2) that would result in a false identification of the image. Figure 7.c shows a sample where the head is turned less than 45 degrees and both ears are within the reference line section giving a correct indication of pigs with suboptimal head position. The complete width plot of the pig across columns of the image is shown in Figure 7. It is obvious from the results that turning in the front or rear portion of the pig created a much

higher width compared to the average width in the mid area. Under our specific experimental conditions, the threshold for head turning identification was found to be 15 pixels difference between the front and mid body width for a head turned more than 30 degrees.
Some problems were discovered with this algorithm including the reference line placement issue. As only three reference lines were used in the first section of the image; these reference lines sometimes missed the widest point of the pigs head giving incorrect indication of head position. However, this problem might be rectified by considering the whole image binary plot as shown in Figure 7 (b and d) which can highlight the widest part of the animal wherever it occurs.

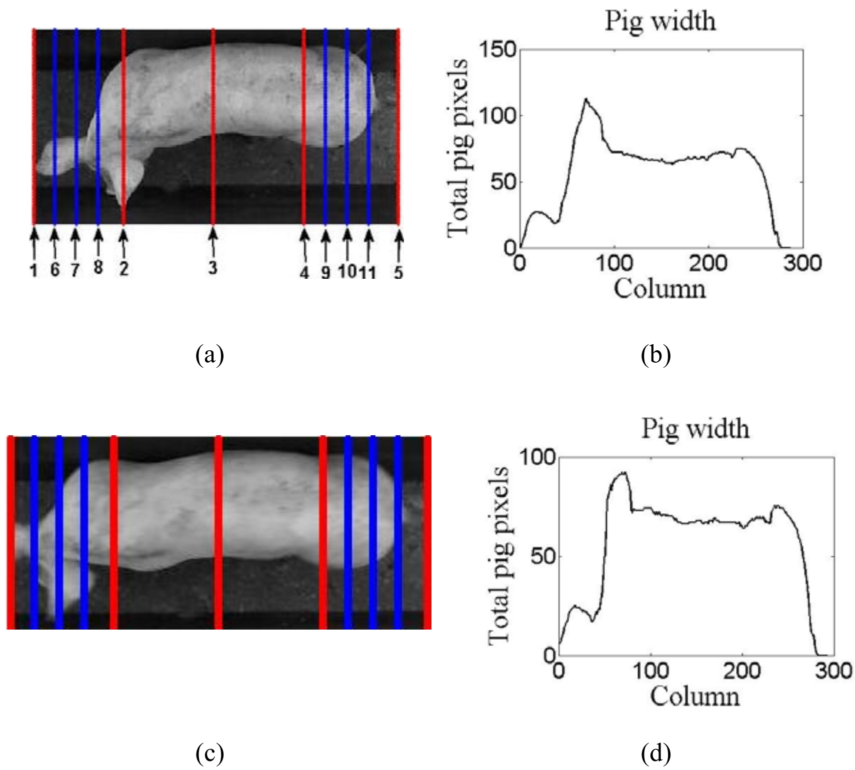


Figure 7. Reference line method used on images with pigs in suboptimal position

<u>Length ratio</u>
The most reliable results were obtained while analysing length and length ratio of the pigs. In addition to checking the head placement, this algorithm was also suitable for providing body angle information of the pig in the frame. Length plots of binary pig pixels are shown in Figure 8.b & d, where the x axis represents rows and the y axis represents total number of pig pixels on that row. It was found that for both suboptimal head or body postures, the number of rows that contain pig pixels [A] became much greater compared to the number of rows which contained the maximum pig length [B]. Furthermore, if the pigs head was in a suboptimal position, the ratio of A & B became greater than 2 and more fluctuations were observed. If the

pig was only angularly placed, the ratio was observed to be greater than 2 with minor or no fluctuations. Fluctuations were calculated by how many times the plot moved away from zero after a sudden drop off at either side of the main plot area. After analysis of several images, the threshold value for the differences and the fluctuations were found to be 50 and 5 respectively to identify images where the pig had its head turned more than 30 degrees.

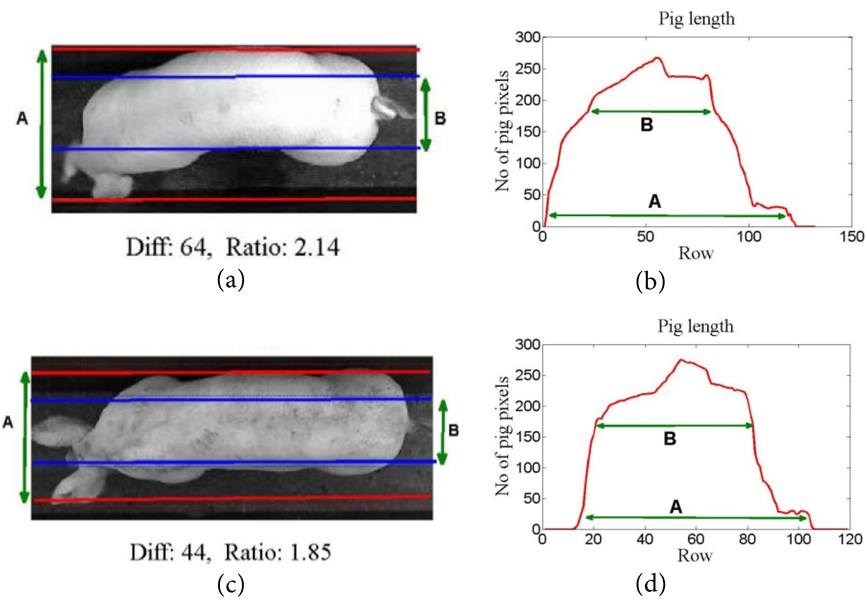


Figure 8. Images analysed using the length ratio method

<u>Angular width</u>

The angular width method used reference lines that were placed equidistant and aligned at 45° to both *x* and *y* axis on the image. The pig width was computed along each of the reference lines and analysed to determine if they identify the main characteristics of the pig's posture. As shown in Figure 9, for pigs with their heads turned a sharp and steep profile can be seen on the plot (Figure 9. a & b) whereas for a straight pig fluctuations and a wider spread plot were observed (Figure 9.c and d). Due to this sharp and steep plot characteristic, a larger difference was found between the average and the maximum pig pixels along angular lines. A threshold value for head turning was found to be 30 pig pixels difference. Therefore images with values greater than 30 pig pixel differences were considered to be images containing pig that had their heads turned. After such a relationship was found, investigation was continued into alternative angles of the reference lines, to determine if the 45 degrees reference lines were the best to use in this methodology. As a matter of fact, different threshold values were observed for different reference line angles (Figure 10). The threshold value followed a negative exponential relationship with the angle of reference line.

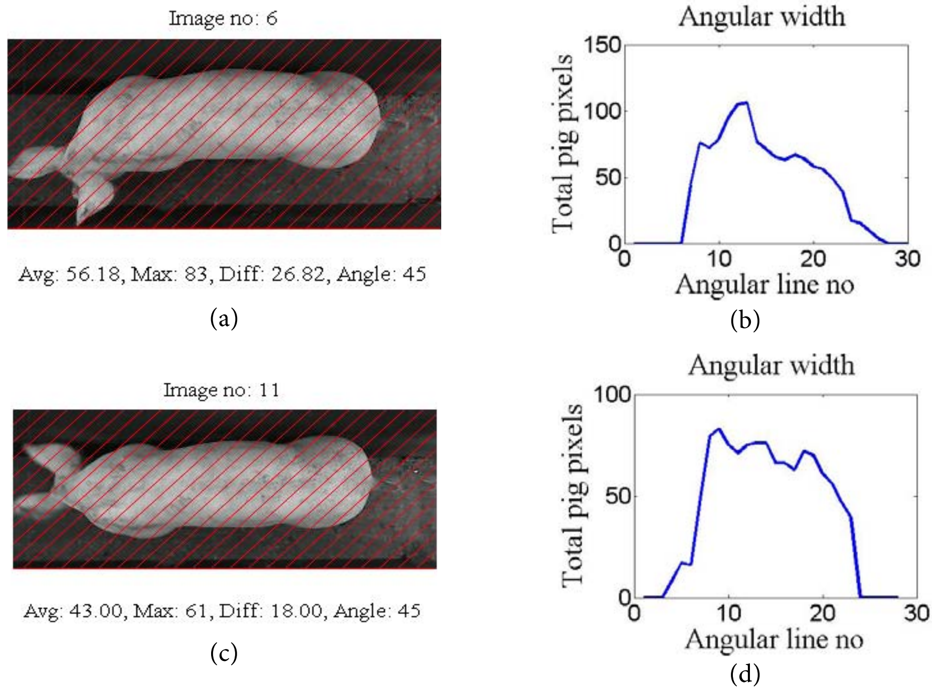


Figure 9. Angular width values across the 45° aligned lines

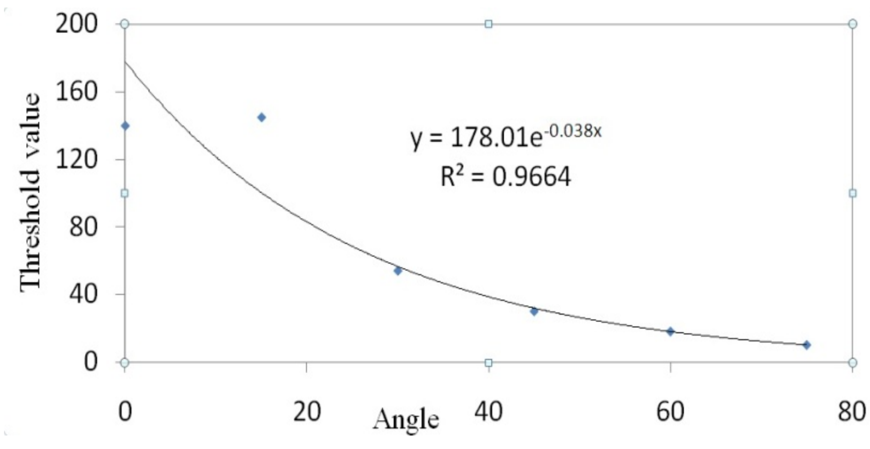
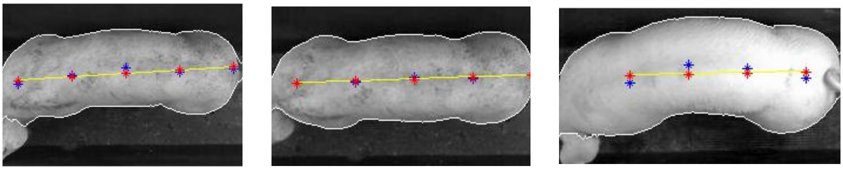


Figure 10. Relation between the angle of the lines and threshold values

Midline

The midline method computed and analysed both the angle of horizontal midline and the distance from the best fit line to the individual reference points (Figure 11). The distance between the midline and the individual reference points was usually more than four pixels if the body of the pig was not straight. In addition, if two or three points showed a value of greater than four pixels; the image usually contained a pig with suboptimal head placement. It was more difficult to determine when only the head was turned using this method. However, the absolute angle (only the value, not the direction) was found to be higher for pigs with sub optimally positioned head and body.



(a) (b) (c)

Figure 11. Point distance from the best fitted line in different pig posture

Conclusion

Interest in weight estimation using image analysis has increased rapidly over the past few years due to its practicality and cost effectiveness. As the process depends on accurately identified and extracted features of the pig images, better quality images containing animals in optimal posture are required for further processing. This study therefore investigated several approaches using pig images to obtain valuable information about the animal's posture such as the orientation of the head and the whole body of the animals. Amongst the approaches, both length ratio and angular methods were identified as capable of selecting images automatically that contained animals with suboptimal head position. However, the length ratio method was also suitable for identifying images that represented animals with suboptimal body position. Midline method was best used for body position identification.

Although individually the success rate of these methods to identify suboptimal head of body positions were modest; it is hypothesised that a combination of all these approaches might provide a more reliable and accurate output. This will be investigated as part of future research efforts.

Acknowledgments

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References

Banhazi TM, Black JL (2009) Precision livestock farming: a suite of electronic systems to ensure the application of best practice management on livestock farms. *Australian Journal of Multi-disciplinary Engineering* **7**, 1-14.

Banhazi TM, Tscharke M, Ferdous WM, Saunders C, Lee S-H (2009) Using image analysis and statistical modelling to achieve improved pig weight predictions. In 'SEAg 2009'. Brisbane, Australia. (Eds T Banhazi, C Saunders) p. CD publication. (SEAg).

Brandl N, Jorgensen E (1996) Determination of live weight of pigs from dimensions measured using image analysis. *Computers and Electronics in Agriculture* **15**, 57-72.

Doeschl-Wilson AB, Green DM, Fisher AV, Carroll SM, Schofield CP, Whittemore CT (2005) The relationship between body dimensions of living pigs and their carcass composition. *Meat Science* **70**, 229-240.

Kollis K, Phang CS, Banhazi TM, Searle SJ (2007) Weight estimation using image analysis and statistical modelling: a preliminary study. *Applied Engineering in Agriculture* **23**, 91-96.

Parsons DJ, Green DM, Schofield CP, Whittemore CT (2007) Real-time Control of Pig Growth through an Integrated Management System. *Biosystems Engineering* **96**, 257-266.

Schofield CP (1990) Evaluation of image analysis as a means of estimating the weight of pigs. *Journal of Agricultural Engineering Research* **47**, 287-296.

Wang Y, Yang W, Winter P, Walker L (2008) Walk-through weighing of pigs using machine vision and an artificial neural network. *Biosystems Engineering* **100**, 117-125.

Whittemore CT, Schofield CP (2000) A case for size and shape scaling for understanding nutrient use in breeding sows and growing pigs. *Livestock Production Science* **65**, 203-208.

Investigations of combining automatic milking system (AMS) with grazing

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Abstract

In this investigation the operation principle from an automatic milking system (AMS) in combination with grazing was analysed on an organic producing farm in North Rhine-Westphalia, Germany. The main objective of the project was the recording of milking and behaviour parameters like number of milkings per cow and day, milk yield per day, lactation stage, frequency of visiting feeding station per day, number of cows inside the barn to different times. Four different variations of cow comfort were offered on pasture.
By means of these factors a working plan for combining AMS and grazing was proofed. Furthermore incentives for dairy cows were emphasized to estimate the factors' highest influence on cows to come in the barn for milking voluntarily.

Keywords: automatic milking system (AMS), milk production, pasturing.

Introduction

Assuming that robotic milking systems are connected to all-season indoor housing of animals belongs to the past. Instead, cows are expected to go voluntarily to the milking unit several times daily to be milked during the grazing season (van Dooren *et al.*, 2002).

Due to the fact, that automatic milking systems (AMS) become more and more common, this investigation should provide information about optimal handling of an AMS in combination with grazing. Grazing has a positive impact on animal welfare and is a prerequisite for organic production.

Spörndly *et al.* (2004) describe that there is a high potential for improvement of dairy farms with low productivity during the grazing period. Furthermore, farmers with AMS often offer water only in the barn to stimulate the animals to return from the pasture to be milked (Spörndly and Wredle, 2002).

The following hypotheses were analysed in this investigation:

1. The number of milkings is affected by the number of cows inside the barn.
2. Increasing cow comfort on the pasture (offering water and shade) results in a decrease of number of milkings.

Materials and methods

The investigation took place on an organic dairy farm in North Rhine-Westphalia, Germany. The free ventilated cubicle house was build for 75 cows with one automatic milking system (figure 1). The adjacent pasture has an acreage of 20 ha. An automatic door handles the cow traffic outside the barn and keeps the cows with an entitlement to milking inside the barn.

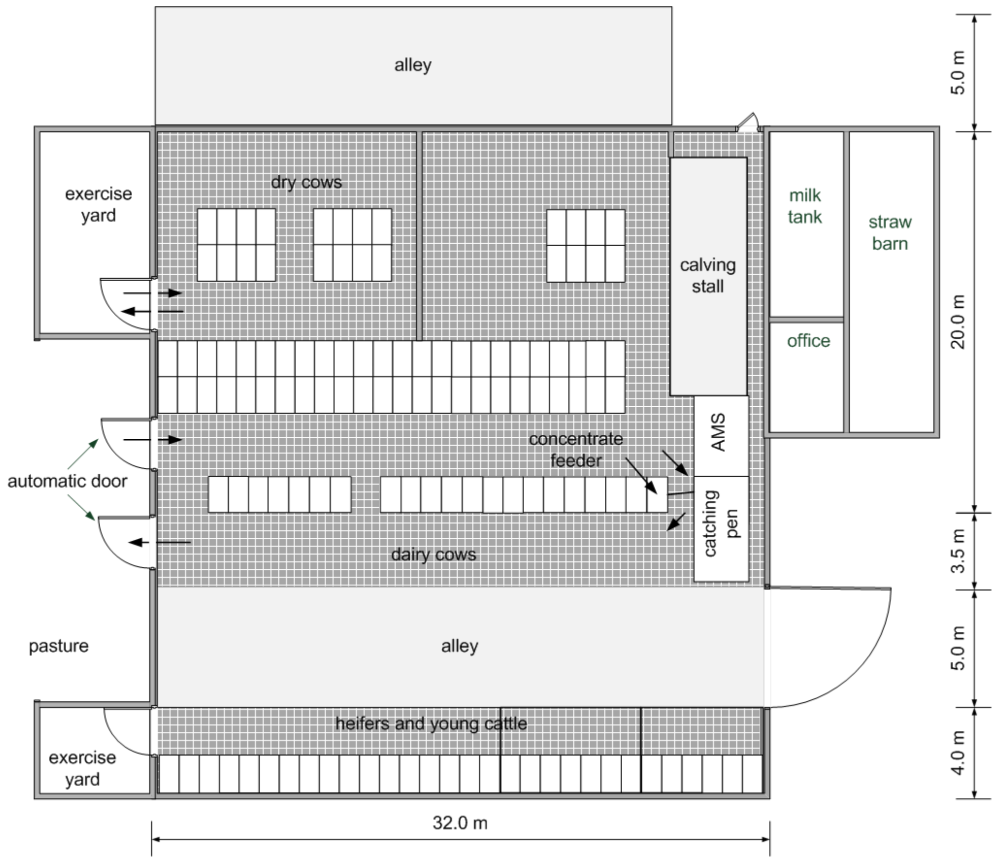

Figure 1. Layout of the dairy barn with adjacent pasture

First, the actual condition was described for several days. Therefore the following parameters were recorded: number of milkings per day and cow, milk yield per cow, number of cows in the barn at fixed times and number of cows which had to be collected for milking. Furthermore, these data were compared to the data of the four following parts of the study (table 1):

Table 1. Timetable of investigations

experimental period	start date	end date	experiment days	part of the study
1.	08.05.2010	16.05.2010	9	actual condition
	17.05.2010	20.05.2010	4	offering water in the barn and on the pasture
	02.06.2010	10.06.2010	9	offering shade on the pasture through another shed
	12.06.2010	17.06.2010	6	offering both water and shade on the pasture
2.	18.07.2010	20.07.2010	3	actual condition
	21.07.2010	24.07.2010	4	offering shade on the pasture through another shed
	31.07.2010	06.08.2010	7	offering water in the barn and on the pasture
	16.08.2010	20.08.2010	5	offering both water and shade on the pasture

Results

Figure 2 shows the number of milkings for both experimental periods. During the first experimental period, there were no significant differences between the four parts of the study. In the second experimental period the number of milkings varied in subject to the four parts of the study. It is striking that "offering shade on the pasture through another shed" has a higher influence on the number of milkings than "offering water in the barn and on the pasture". With regard to the "actual condition" there is a variaty between the first (2.1 number of milkings) and the second experimantal period (2.5 number of milkings). Considering the results in the part "offering water in the barn and on the pasture" of both experimental periods, the number of milkings was higher in the second period. The part "offering shade on the pasture through another shed" has a mean of 2.2 numbers of milkings for both experimental periods. On the last part "offering both water and shade on the pasture", the mean of 2.2 number of milkings for the first period and 2.3 number of milkings for the second period are close together. But the spread of the data is very different.

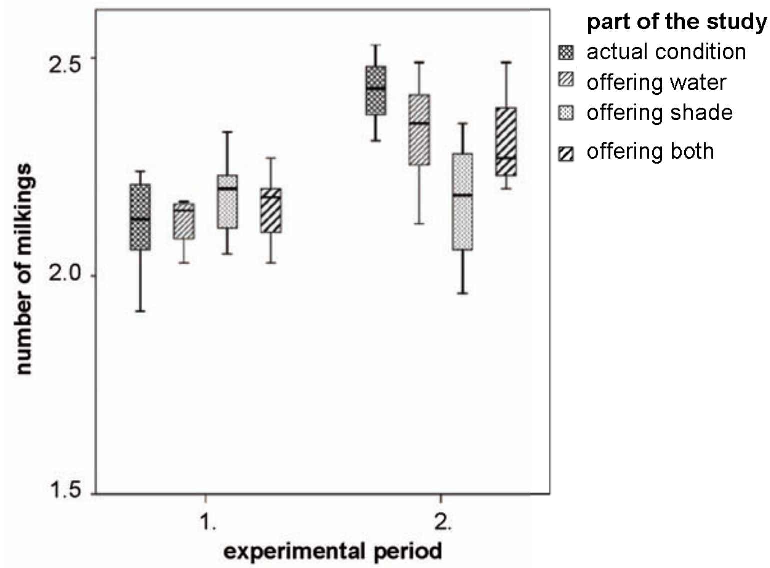

Figure 2. Boxplot of the number of milkings for both experimental periods

With increasing lactation stage the vistis of the AMS decreased (figure 3). Fresh cows (first 100 days) had a mean of 4.8 number of milkings per day. The statistical outliers of the visits of the AMS is 18. It is obvious that some cows vistis the AMS even though they have no entitlement to milking. These cows prevent the others to go inside the milking box.

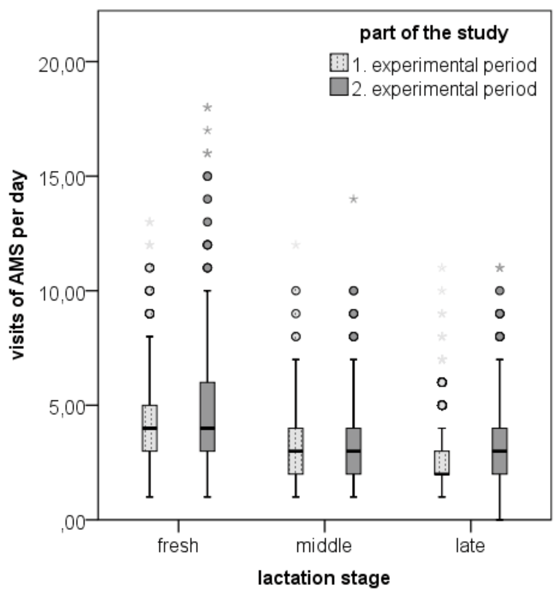

Figure 3. Visits of AMS as a function of lactation stage (fresh cows: first 100 days)

Discussion

In fact, the results demonstrate that robotic milking in an AMS, which is almost continuously available throughout the day can be combined with grazing. This was the conclusion reached by Ketelaar-de Laurence *et al.* (1999). Distances between barn and pasture up to a maximum of 360 m do not affect the number of AMS visits (Ketelaar-de Laurence *et al.*, 2000). In the present study the results are similar. Van Dooren *et al.* (2004b) were able to prove that there are no significant differences in water intake. It didn`t make any difference if the water was offered in barn or on pasture. Assuming this thesis for the own investigation, offering water on the pasture does not influence milk performance.

In the first experimental period there were significant differences between "actual condition" and "offering shade on the pasture through another shed". It can thus be concluded that offering water on pasture has no influence on milk production in this organic producing farm.

There are significant differences between the parts "offering shade on the pasture through another shed", "offering water in the barn and on the pasture" and "offering both water and shade on the pasture" for the second experimental period. However, there is no significant difference to "actual condition".

Van Dooren *et al.* (2004b) have found out that there is a significant higher number of milkings when water is only offered in the barn and the cows have a long way from pasture to the barn. In the first experimental period there is no influence on number of milkings by offering water on pasture. Whereas, in the second experimental period is a decrease to the number of milkings.

Based on the comparison of these experiments there were different conclusion between the first and the second experimental period of this investigation. Furthermore, based on the observations during the whole study the weather and temperature also seem to have an effect of the cow behavior. This factor has to be cleared in detail in a further investigation.

Conclusions

Finally AMS and grazing can be combined if a few rules are followed. The farms need a flexible manager with good observation skills. Some cows have to be taken off from pasture for milking just during the routine. Water should only be offered in the barn. An automatic door for the cows can handle the cow traffic outside the barn and keep the cows with an entitlement to milking inside the barn.

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References

Ketelaar-de Laurence, C., Ipema, A., Outwerkerk van, E., Hendriks, M., Metz, J., Noordhuizen, J., Schouten, W. 1999. Voluntary automatic milking in combination with grazing of dairy cows: Milking frequency and effects on behaviour. Applied Animal Behaviour Science 64: 2, 91-109

Ketelaar-de Laurence, C., Ipema, A., Metz, J., Noordhuizen, J., Schouten, W., Smits, A. 2000. Effect of sward height and distance between pasture and barn on cows` visits to an automatic milking system and other behaviour. Livestock Production Science 65, S. 131-142

Spörndly, E., Krohn, C., Dooren van, H., Wiktorsson, H. 2004. Automatic milking and grazing. In Automatic Milking- a better understanding, Hrsg. A. Meijering, H. Hogeveen und C. de Koning, S. 263 ff., Wageningen: Wageningen Academic Publishers

Spörndly, E., Wredle, E. 2002. Automatic milking and grazing—Motivation to visit themilking robot. Deliverable D26, EU project "Implications of the introduction of automatic milking on dairy farms" (QLK5-2000-31006). Online. Available http://www.automaticmilking.nl. Accessed Aug. 19, 2004.

van Dooren, H., Spröndly, E., Wiktorsson, H. 2002. Automatic milking and grazing. Applied grazing strategies. Deliverable D25, EU project "Implications of the introduction of automatic milking on dairy farms" (QLK5-2000-31006). Online. Available http://www.automaticmilking.nl. Accessed Aug. 19, 2004

van Dooren, H., Heutninck, L. Biewenga, G., Munksgaard, L., Krohn, C., Spörndly, E., Wredle, E., Wiktorsson, H. 2004b. Automatic milking and grazing. Grazing strategies and their effect on animal welfare and system performance D27. EU-Projekt: Implications of the introduction of automatic milking on dairy farms, http://www.automaticmilking.nl. Accessed Aug. 13, 2010, Uppsala – Schweden

Analysis of fertile eggs' surface temperature in the hatchery using infrared thermography

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Abstract

This research aimed to analyze the eggs' surface temperature variation in broiler multi-stage setter. The age of breeders was 42 and 56 wks. Ambient data and eggs' surface temperature were registered in six distinct sectors, at three heights from the floor (A = 0.10 m, B = 1.0 m. C = 2.0 m). The mean surface temperature at the lower trays (A) was higher than those at B and C. The surface temperature of the eggs from breeders with different age were different (P-value = 0.001), and the variation between the mean surface temperature was 0.3 °C and the thermographic images were efficient in assessing this difference.

Keywords: incubation, surface temperature, IR thermography.

Introduction

Brazilian poultry production has reached high standard nowadays due to investments in appropriate tropical technology (Marcolin, 2006; Martins *et al.*, 2006). According to current literature (Tazawa & Nakagawa, 1985; French, 1997; Gustin (2003a) fertile eggs' surface temperature is very close to actual embryo temperature, and small variations may affect chickling quality. Inside multiple phase setters embryos are maintained in distinct stages of growth, and this may affect the overall productivity due to distinct heat exchange between embryo and setter ambient (Yahav *et al.*, 2004; Lourens *et al.*, 2005; Piaia, 2005).

High ambient temperature may induce early embryo's development, and also cause dehydration and producing broilers of low quality (Yalçin & Siegel, 2003). According to Yahav *et al.* (2004) and Collin *et al.* (2005) the combination of egg's surface temperature (Tovo), the exposition period and length may determine embryo's development. Lourens *et al.* (2005) found that fertile eggs under temperatures below 37.8°C in the first week of incubation may require some adjustments in the subsequent two weeks. Fertile eggs need to be kept in the right temperature mainly during the first half of the incubation process, as the embryo starts to increase the production of metabolic heat after the first two weeks of incubation, and the excess of heat needs to be removed from the setter. In a multi stage setter it is common to have batches of eggs in distinct age of incubation and the challenge is to have the heat removed and air circulation well distributed in order to maintain embryos at appropriate level of metabolic heat inside eggs (Bittar Filho & Vieira, 2006).

This research had the objective of analyzing the surface temperature of fertile eggs inside a multi stage incubator using infrared thermographic images.

Materials and methods

The experiment was carried out in a commercial hatchery located in Southeastern Brazil (46º46' W, 22º43' S; altitude 683 m). The multi stage incubator (Figure 1) is widely used in Brazil (model CASPCMg 125 R/e, with multiple stages of incubation and capacity of 96 eggs in each tray).was divided in six areas and were select in eggs (14 days) and data of surface temperature of eggs were assessed using infrared thermography (Figure 2). Eggs from two distinct breeder's ages (42 and 46 days) were investigated with respect to theirs surface temperature.

Ambient data and eggs' surface temperature were registered in six distinct sectors, at three heights from the floor (A = 0.10 m, B = 1.0 m, C = 2.0 m). The images were analyzed using the Testo® software at 20 points inside the tray located in the described quadrants corresponding to the subdivision of the incubator, and the surface temperatures registered. Average temperatures for each quadrant and for each height were calculated and ANOVA was applied using the Minitab ® software.

Figure 1. Incubator CASP CMg 125 R

Figure 2. Termovisor Testo® 880-ST

Results and Discussion

Table 1 shows the mean of the eggs' surface temperature in the sectors and heights of the setter. Difference in both, sectors and heights were significant (P–Value = 0.001). Variations in temperature of the eggs are associated with different rates of embryonic development (Wilson, 1991).

Table 1. Mean of the surface temperature of the eggs in the sectors and heights.

Sectors	Height A	Height B	Height C	Mean	CV[1](%)
1	39.7	38.9	38.7	39.1ab ± 0.5	1.4
2	38.8	39.2	39.2	39.1ab ± 0.3	0.7
3	39.9	39.1	39.0	39.3a ± 0.5	1.2
4	39.7	39.0	39.2	39.3a ± 0.8	0.9
5	39.9	39.0	39.1	39.3a ± 1.2	1.3
6	39.3	38.6	38.6	38.8b ± 1.0	1.0
Mean	39.5a ± 0.5	39.0b ± 0.3	38.9b ± 0.4		
CV[1](%)	1.3	0.6	0.9		

[1]CV = coefficient of variation.

The surface temperature of the eggs shows significant difference (P-Value = 0.006) (Table 2). The main factor affecting hatching time was reported to be incubation temperature (Insko, 1949; Reinhart & Hurnik, 1984). High incubation temperatures between 37.5 °C and 39.0 °C have been found to accelerate embryonic development, and therefore cause chicks to hatch early (Romanoff, 1936) but with decreased hatchability. According to French (1997) eggs` temperatures above 37.8 °C ***reduced hatching*** (French, 1997), variations of ± 1°C may negatively impact hatching time (French, 1997; Wilson, 1991), Yalcin and Seigel (2003) found that variation in temperatures between 36.9 °C and 39.6 °C influenced the growth of the skeleton but a compensatory mechanism ensued to modulate those changes by the time of hatching.

The mean surface temperature at the lower trays was higher than those at B and C. The surface temperature of the eggs from breeders with different age were different (P-value = 0.001), and the variation between the mean surface temperature was 0.3 °C. When compared to breeders, it is observed a significant difference (P-value = 0.001).

Table 2. Mean of the surface temperature of fertile eggs for breeders and heights

Breeder' age	Height			Mean	CV[1](%)
(day)	A	B	C		
42	39.8	39.1	38.9	39.3a± 0.5	1.3
46	39.2	38.9	39.1	39.0b± 1.0	0.9
Mean	39.5a±0.7	39.0b±0.4	39.0b±0.4		
CV[1](%)	1.4	0.7	0.7		

[1]CV = coefficient of variation.

High incubation temperature (Christensen *et al*., 1999; Hassan *et al*., 2004) or low incubation temperature (Black & Burggren, 2004a; Yalcin & Siegel, 2003) had unfavorable effects on embryonic growth, as well as metabolic and physiologic adjustments. Incubation temperature has been known to modify the metabolic rate of the developing embryo and affecting nutrient utilization and oxygen consumption.

Conclusions

The thermographic images registered the variation on the surface of eggs from distinct ages of breeders, and it was possible to identify the lack of homogeneity in the incubation of eggs, that may lead to inefficiency in the process.

Acknowledgements

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References

Black, J. L., Burggren, W.W. 2004. Acclimation to hypothermic incubation in developing chicken embryos (*Gallus domesticus*) I. Developmental effects and chronic and acute metabolic adjustments. J. Exp. Biol. **207** 1543-1522.

Bittar Filho, I., Vieira, M. V. 2006. Condições de incubação e desempenho do frango. In: Revisão Técnica Agroceres Ross, pp 2.

Collin, A., Picard, M., Yahav, S. 2005. The effect of duration of thermal manipulation during broiler chick embryogenesis on body weight and body temperature of post-hatched chicks. Animal Research **54**, 105–111.

Christensen, V. L., W. E. Donaldson, Nestor, K. E. 1999. Length of plateau and pipping stages of incubation affects the physiology and survival of turkeys. British Poultry Science **40** 297-303.

French, N.A. 1997. Modeling incubation temperature: the effects of incubator design, embryonic development, and egg size. Poultry Science **76** 124-133.

Insko, Jr., W. M. 1949. Physical conditions in incubation. In: Taylor, L. W (Ed.). The Fertility and Hatchability of Chicken and Turkey Eggs. John Wiley and Sons, Inc., London, pp 210-243

Hassan, S. M., A. A. Siam, M. E. Mady, Cartwright, A. L. 2004. Incubation temperature for ostrich (*Strutbio camelus*) eggs. Poultry Science **83** 495-499.

Lourens, A., Van Den Brand, H., Meijerhof, R., Kemp, B. 2005. Effect of eggshell temperature during incubation on embryo development, hatchability and post-hatch development. Poultry Science **84** 914–920.

Marcolin, S.D. 2006. Processos de tratamento para reutilização da cama de aviários: Aspectos econômicos. In: Conferência APINCO 2006 de Ciência e Tecnologia Avícolas, Santos. Anais... Campinas: FACTA, 2006. pp. 25–31.

Martins, F.M., Talamini, D.J.D., Novaes, M. 2006. Avicultura: situação e perspectivas brasileira e mundial. Ave World **20** 21-30.

Reinhart, B. S., G. I. Hurnik, G.I. 1984. Traits affecting the hatching performance of commercial chicken broiler eggs. Poultry Science **63** 240-245.

Romanoff, A. L. 1936. Effects of different temperature in the incubator on the prenatal and postnatal development of the chick. Poultry. Science **15** 311-315.

Piaia, J.C. 2005. Aplicação da inteligência artificial no monitoramento do processo de incubação. Florianópolis.UFSC. Dissertação (Mestrado em Engenharia) – Engenharia Química, Universidade Federal de Santa Catarina. pp 90.

Tazawa, H., Nakagawa, S. 1985. Response of egg temperature, heart rate and blood pressure in the chick embryo to hypothermal stress. Journal of Comparative Physiology **155**B 195–200.

Yahav, S., Collin, A., Shinder, D., Picard M. 2004. Thermal Manipulations During Broiler Chick Embryogenesis: Effects of Timing and Temperature. Poultry Science **83**1959-1963.

Yalçin S., Siegel P. B. 2003. Exposure to Cold or Heat During Incubation on Developmental Stability of Broiler Embryos. Poultry Science **82** 1388-1392.

Wilson, H. R. 1991. Physiological requirements of the developing embryo: Temperature and turning. Avian Incubation. S. G. Tullett, ed. Butterworth-Heinemann, London, pp 145–156.

Drinking behaviour of suckler-cow herds of dual-purpose breed during winter indoor period

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Abstract

Water is the most important nutrient for cattle. Automatic recording of water intake (in addition to other behaviour and performance parameters) could be an useful tool for the herd management and control of individual animals. The aim of this study was to evaluate drinking behaviour of suckler-cow herd of two dual-purpose breeds (German Simmental and German Yellow) during winter indoor period. The free water intake of dual purpose breed cows and pregnant heifers seems to be higher than in typical beef cows. The youngest calves (first 12 postnatal weeks old) appear to cover most of their water requirement via milk. In all animal categories, very short as well as very long intervals could be observed between two drinking events. Similarly as in dairy cows, relative frequency distribution of drinking intervals can be used to define drinking events as separate drinking bouts.

Keywords: drinking behaviour, suckler cow herd, winter indoor period

Introduction

Water supplies for both humans and livestock are becoming a subject of increasing importance (Cardot *et al.,* 2008). Water is the most important nutrient for cattle, and unrestricted availability of qualitatively good water is essential for health, behaviour, and performance of animals. Cattle require large amounts of water every day (NRC, 2001). They cover the greatest proportion of their requirement via drinking (free water intake (FWI) and ingestion of water contained in feed (NRC, 2001). Factors influencing daily water intake and requirement include stage of production, physical activity, age, body weight, body weight gain, animal health, dry matter intake, percent dry matter of the diet, water quality, sodium intake, and ambient temperature (Adams & Sharpe, 1995; Beede, 2005; Dahlborn *et al.,* 1998; Holter & Urban, 1992; Lardy & Stoltenow, 1999; Looper & Waldner, 2002; Mahlkow-Nerge, 2004; Meyer *et al.,* 2004; Murphy *et al.,* 1983). The same animal consumes different level of water in different physiological stage. The water requirement of cows is higher during lactation than during dry period. Drinking water can satisfy 70 to 97 % of a dairy cow's total water needs (NRC, 2001). When feeds with high relative humidity such fresh forages are consumed, FWI can be considerably reduced. Lactating dairy cows grazing pasture consumed only 38 % of total water consumption as free drinking water (Stockdale & King, 1983). During the liquid feeding stage, calves receive most of their water via milk or milk replacer (NRC, 2001).
The importance of drinking water is frequently underestimated, since it takes only a small part in the behaviour of cattle (Bahr, 2007). Daily FWI can be described in term of number of drinking events per day, drinking time, and rate of drinking. In dairy cows, it was reported that cows received water in so called bouts, i.e. drinking events clustered in time. Cumulative

and relative frequency distribution of log-transformed intervals between drinking events were used in dairy cows to determine of the minimum interbout interval, i.e. the minimum time between two of the same activities required to consider these two periods as separate events (Dado & Allen, 1993; Melin *et al.*, 2005).

In the last years a lot of new electronic sensors were developed and introduced in livestock husbandry to record different parameters with the aim to detect any deviations from normal behaviour and/or performance, health problems and etc. as soon as possible (Wendl, 2008). Also in extensive forms of animal husbandry, e.g. the calf rearing by suckler cows, the automatic recording of water intake in addition to other parameters (activity monitoring, recording of feed intake and performance characteristics) could be an useful tool for the herd management and control of individual animals. In dairy cows, drinking behaviour has been and is still intensively studied. Little information is available on water intake of suckler-cow herds. In the last years, moreover, dual-purpose breeds are more frequently used for rearing of beef cattle. They have better potential for milk production than typical beef breeds. Therefore, it can be expected that the water requirement of suckler cows and also calves of dual purpose breeds could differ not only from requirement of dairy cattle but also from requirement of typical beef cattle. To meet the water requirements of dual purpose breed animals in suckler cow herds or to be able to appraise the information of water intake the knowledge of "normal" water intake and drinking behaviour are required. The aim of this study was to evaluate the water intake and drinking behaviour of suckler-cow herds of two dual-purpose breeds during winter indoor period.

Material and methods

Animals, housing, and feeding

The data were collected in one herd of German Simmental breed (group 1) and one herd of German Yellow breed (group 2) during one winter indoor period (since 09.11. 2005 until 26.04. 2006). The animals (cows, calves, young cattle over one year, and pregnant heifers) were housed in the loose cold housing system (uninsulated, naturally-ventilated building) separately according to groups. All animals of each group were kept together in one herd area (Figure 1). Only around calving time, calving animals were kept in calving pen of appropriate group. In group 2 the herd area and calving pen were permanently divided, whereas in group 1 mostly only around calving time of one of animals. Moreover, the calves of group 1 had permanent access to the calving pen trough a fence opening for calves.

Average number of animals was 44.8±9.6 (mean±SD) in group 1 and 35.2±8.0 animals in group 2 during experimental period. Thereof, the number of cows was 25.2±1.0 and 21.5±3.6, calves 16.6±12,1 and 9.3±8.3, heifers 2.5±2.6 and 6.4±3.7, and young cattle over one year 0.5±0.5 and 0.7±0.8 in group 1 and 2, respectively. Calves remained usually with their mothers for first 43 to 44 weeks of their life. During experimental period, the first calves were separated from their dams already in age of 31 weeks and latest in age of 52 weeks. Altogether the data of 61 cows (13 with calves, 7 without calves and 41with and also without calves), 16 pregnant heifers, 9 young cattle and 71 calves (40 in first 12 weeks of life, 12 in weeks 13 to 24, 29 in weeks 25 to 36 and 27 older than 36 weeks) were recorded during experimental period.

Animals of both groups were fed with grass silage and hay for ad libitum intake once daily between 0700 and 0800 h. When necessary, the feed was pushed towards the feeding fence few times per day, the last time between 1600 and 1700 h. Animals had free access at least to one

individual drinking bowl (DB) Model S41A, Texas Trading®). Two DB were installed in the herd area and one in the calving pen of each group. The maximum volume of DB was 1.9 l and maximum filling rate 11.4 l/min.
Average maximum outside daily temperature was 4.2±6.8 °C (between -8.5 and 23.1 °C) during experimental period (November 4.0±5.3, December 1.4±3.2, January -1.6±3.6, February 2.1±4.0, March 6.4±6.3, April 14.2±5.6). The temperature was measured by a meteorological station placed around 100 m from stable.

Recording of water intake

To record the water intake, DB were fitted with in-line flow meters (BIOTECH®). All animals were tagged with electronic ear tags (Daisy 530, AGRIDENT®) in the left ear. The animal identification at DB was performed by an antenna. The antenna was fixed on the left side of U-form frame positioned around DB (Figure 1). A special program (developed in cooperation with company Data Scale/Bonn) was used for recording of data. One drinking event was recorded when at least one impulse was recorded by flow meter. Two separate events were recorded when interruption in drinking was longer than 5 s. Each recorded drinking visit to DB produced a data log consisting of animal identification, time of visit, drinking time, and amount of water consumed.
The adjustment of DB (the frame around DB (enabling the animals to drink just from one side and thereby leading the head of animals to the correct position for identification), recording program, used type of DB) for recording of water intake has proven successful to monitor the drinking behaviour of cattle (except the youngest calves (≤ 12 weeks old) in our study. Identification reliability of system with approx. 95 % is good (in average 5.3±1.6 % of recorded drinking events and 4.7±1.3 % of consumed water per day were recorded without identification of drinking animal), but should be optimized for further investigations (e.g. by optimisation of antenna position and the antenna form).
A rest of water could stay in the DB, whose amount could not be proofed. If animals drunk just this small amount of water, this was not recorded. This could be relevant by recording of data in animals with low drinking water requirement, i.e. in the youngest calves. To achieve higher reliability of recorded data also for the youngest calves, improvements of system have to be done to assure that animals will not drink rest water from DB without recording.

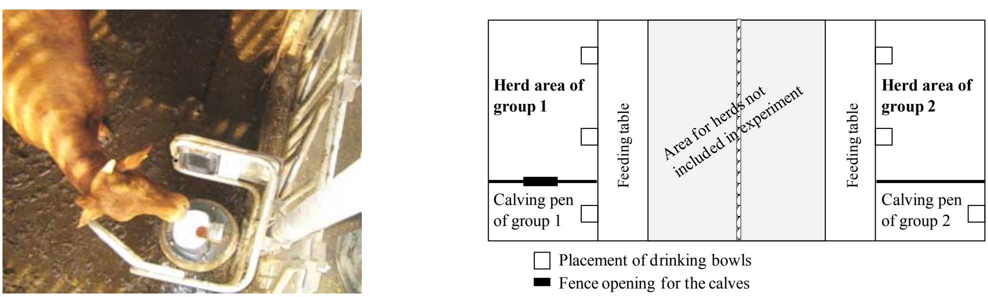

Figure 1. Photo of individual drinking bowls adjusted for recording of water intake and sketch of the stable with view of housing of individual groups and drinking bowls placement.

Data evaluation and statistical analysis

The drinking behaviour could be evaluated during 169 days in group 1 and 166 days in group 2. Data of both groups were evaluated together. The recorded data were used to calculate the following data for each animal: daily FWI (amount of water consumed on DB per day), daily drinking time (sum of duration of drinking events per day), daily number of drinking events (number of DB visits per day with recording of at least one impulse and interruption in drinking not longer than 5 s), and daily number of drinking bouts (number of drinking bouts per day). Relative frequency distribution of LN-transformed (i.e. logarithmized to the base e) intervals between drinking events was used to determine the minimum interbout interval to define one drinking bout (the method described by Melin *et al.* (2005). Relative frequency distributions of intervals were plotted as bar charts with width of 0.5 LN units. The minimum interbout interval was estimated visually as interval length where two LN population cross. Mean values for each parameter were calculated by averaging daily values for each animal according to animal category (cows, calves, young cattle, and heifers) and animal subcategory by cows (cows with calves and cows without calves) and calves (according to age (≤ 12 weeks old, 12.1-24 weeks old, 24.1-36 weeks old, > 36 weeks old). Because data of most parameters were not normally distributed, the Kruskal-Wallis and Wilcoxon tests (a=0.05) were used for statistical analyses.

Results

During the experiment, a total of 142,947 intervals between drinking events were obtained from the database. Interval lengths varied widely in all animal categories. Very short as well as very long intervals could be observed in all animal categories. In 39 % of all drinking events, the next drinking followed in less than 60 s. In cows, it was in 39 % of events, in calves in 43 %, young cattle in 24 %, and in heifers in 35 %.

Table 1. Daily free water intake, daily drinking time, daily number of drinking events, and daily number of drinking bouts (median (mean±SD) in cows with and without calves, and calves in different age groups. [1]Free water intak.

animal category animal subcategory	n	daily FWI[1] (l)	daily drinking time (min)	daily number of drinking events	daily number of drinking bouts
cows	61	40.0 (42.5±13.0)	8.9 (9.9±5.8)	10.8 (13.4±8.8)	6.9 (8.1±4.0)
cows, with calves	54	48.0 (51.0±14.0)	9.5 (11.2±6.3)	11.5 (14.7±9.6)	8.1 (9.3±4.6)
cows, without calves	48	30.1 (32.7±13.4)	6.8 (8.4±6.2)	9.2 (12.2±9.0)	5.6 (6.5±3.4)
calves	71	1.1 (5.0±5.6)	0.6 (1.8±2.0)	1.3 (3.6±3.9)	1.0 (1.9±2.0)
calves, ≤ 12 weeks old	40	0.3 (0.5±0.6)	0.1 (0.2±0.2)	0.4 (0.6±0.8)	0.3 (0.4±0.4)
calves, 12.1-24 weeks old	12	1.7 (2.3±2.3)	1.0 (1.3±0.8)	3.3 (4.4±4.3)	1.9 (2.2±1.4)
calves, 24.1-36 weeks old	29	10.8 (10.8±3.2)	3.6 (3.9±1.4)	6.7 (7.4±2.9)	3.9 (4.0±1.4)
calves, > 36 weeks old	27	9.5 (9.8±3.9)	3.2 (3.5±1.4)	6.7 (7.1±3.0)	3.7 (3.7±1.3)
young cattle	9	14.4(17.1±11.5)	3.9 (4.3±2.5)	6.0 (7.0±4.0)	4.5 (4.9±2.4)
heifers	16	24.0 (25.0±6.0)	5.6 (6.5±3.6)	8.4 (10.4±7.2)	5.5 (6.4±3.5)

Figure 1 shows the frequency distribution of LN-transformed drinking intervals of all animals and Figure 2 of animals according to individual animal categories. Relative frequency distributions of LN-transformed intervals between drinking events were distributed as at least two populations (i.e. at least two peaks (every representing one population) could be observed) when all data and also data of individual animal categories were plotted. This enable to distinguish between very short drinking intervals, i.e. intervals within drinking bouts (first peak representing first population) and longer drinking intervals, i.e. intervals between drinking bouts (second peak representing second population).

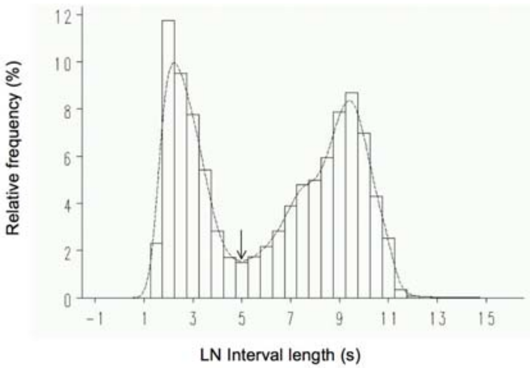

Figure 2. Relative distribution of LN-transformed intervals between drinking events of all animals (n=142,947). LN=natural logarithm. ↓ visually estimated minimum interbout interval.

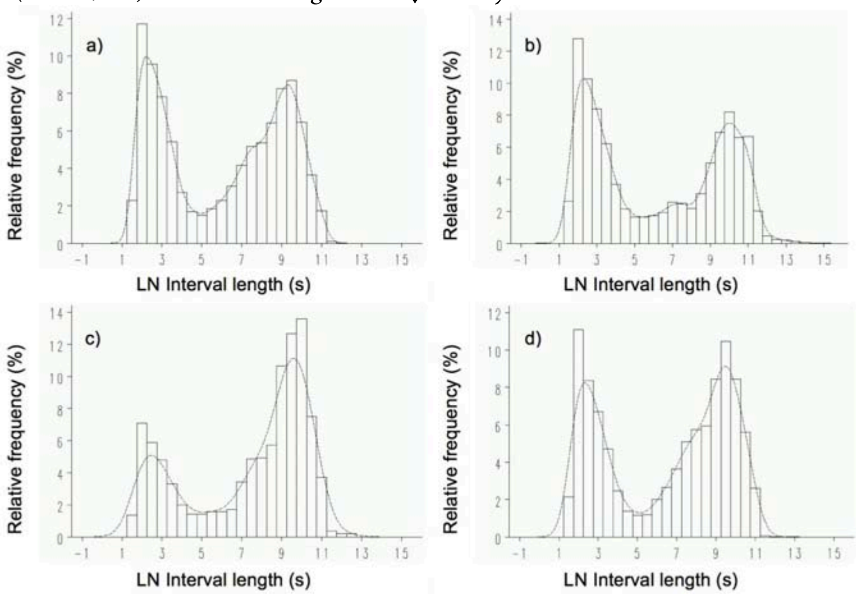

Figure 3. Relative distribution of LN-transformed intervals between drinking events of a) cows (n=106,658), b) calves (19,410), c) young cattle (1,398), d) heifers (15,481). LN=natural logarithm.

Visually estimated cross-point (i.e. minimum interbout interval) between first and second population (from all recorded data (Figure 1) was around 5 (LN-transformed intervals in s), i.e. 2.5 min.

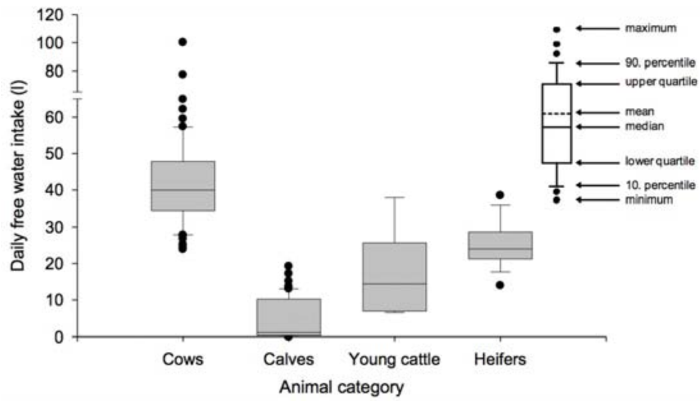

Figure 4. Daily free water intake per animal according to animal category.

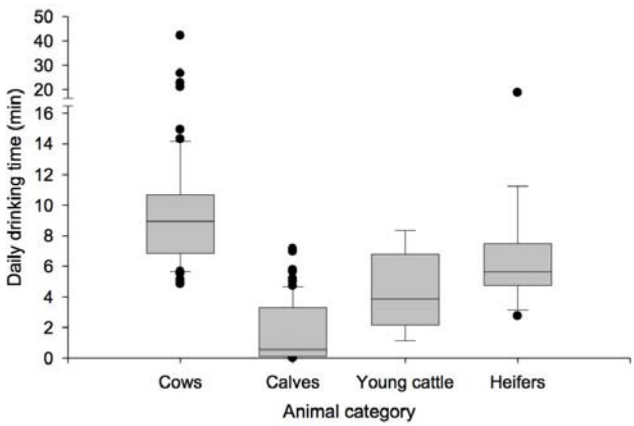

Figure 5. Daily drinking time per animal according to animal category (for explanation of box plots see Figure 4).

Daily FWI, daily drinking time, daily number of drinking events, and daily number of drinking bouts per animal according to animal category are shown in Figure 4 to 7 and Table 1. Animal category had a significant effect on all these parameters ($P<0.0001$). The highest levels per animal were, as expected, observed in cows, followed by pregnant heifers and young cattle. The lowest values were observed in calves. Daily FWI of individual animal categories (cows, calves, young cattle and heifers) differed significantly ($P\leq0.05$) among each other. By the other three parameters, values of individual animal categories differed significantly between each other except between young cattle and heifers (by daily drinking time, daily

number of drinking events and bouts) and between cows and heifers (by daily number of drinking events).
In cows, calves, young cattle and heifers, 71±6, 68±18, 55±21, and 69±7 %, respectively daily drinking events and 74±6, 70±20, 64±28, and 74±4 %, respectively of FWI took place between 0800 and 2000 h.
The values of tested parameters (Table 1) differed significantly ($P<0.05$) between cows with calves and cows without calves. In calves, age of animals had a significant effect on the tested parameters (all parameters $P<0.0001$). The lowest levels were observed in calves in the first 12 weeks of life, higher, but still relatively low, in weeks 13 to 24. Considerably higher levels were observed in 25 to 36 weeks old calves. However, they did not differ from levels of calves older than 36 ($P>0.05$).

Discussion

In average, every DB was not used longer than 2.5 h per day and 12.6 min per hour. Therefore, it can be expected that all animals could express normal drinking behaviour.
Similarly as in dairy cows (Dado & Allen, 1993; Melin *et al.,* 2005), very short as well as very long drinking intervals were recorded in all animal categories in our study. The relative frequency distributions of LN-transformed intervals from all animals (Figure 2) and also interval lengths from individual animal categories (Figure 3) were allotted at least as two populations as it was observed in dairy cows (Melin *et al.*, 2005). 4 min were estimated in the study of Dado & Allen (1993) and 3.7 min in the study of Melin *et al* (2005) as minimum interbout interval in dairy cows. In our study, the minimum interbout intervals of 2.5 min (LN interval length of 5 s) was visually estimated from all recorded data (Figure 2) and applied for all animal categories.

As expected, the animal category influenced significantly all tested parameters. In cows, the presence of calf and in calves, the age had also significant effect on the tested parameters. Values of the tested parameters were higher in cows with calves than in cows without calves. In calves, all tested parameters increased with age. However, no differences were observed between 24.1 to 36 weeks old calves and older then 36 weeks.

Daily FWI as well as other tested parameters were highest in cows with calves. Average daily FWI of cows with calves was 51.0 l (median 48.0 l). This is lower than in lactating dairy cows yielding around 21.5 to 25.7 kg with FWI between 58.4 and 65.2 l (Woodford *et al.,* 1984; Mahlkow-Nerge, 2004). Little information is available on FWI of nursing cows. Estimated daily total water intake (FWI include the water contained in feed), frequently published for the nursing beef cows in the first three to four months of lactation, is 42, 49, 61 and 68 kg by maximum daily temperatures between 1.7, 10.0, 18.3 and 26.7 °C, respectively (Guyer, 1977; Landefeld & Bettinger, 2002; Lardy *et al.,* 2008). Unfortunately, without reference to body weight of animals. Compared with these data, already the FWI (i.e. water intake without water contained in feed) of cows with calves in our study seems to be higher than estimated total water intake when temperature is considered.

Average maximum daily outside temperature was 4.2±6.8 °C during experimental period. The animals were kept in cold stable. Therefore, it can be expected that temperature in the stable closely followed outside temperature. By similar average maximum daily temperature (4.4 °C), estimated daily total water intake is around 43 kg (Winchester & Morris, 1956; Lardy *et al.*, 2008). In the study of Winchester & Morris (1956), reference to body weight between 408 to 499 kg could be found for that estimated value. Average body weight of cows with calves was around 790±93 kg n=29 (data are not available for all cows) in our study. The estimated total water intake is around 50 and 55 kg for cows of comparable body weight (726 kg) by average temperature 4.4 and 10 °C, respectively. This suggests that the water requirement of nursing dual-purpose cows would be underestimated by applying recommended values for nursing beef cattle. Higher water requirement could be attributed to better milk production of dual-purpose breeds.

Daily FWI of cows without calves was slightly lower than in dry dairy cows 35.6 l (Woodford *et al.*, 1984) and 36.6 l (Holter & Hurban, 1992). In this case, the estimated daily total water intake for dry dairy cows (39.4 and 42.4 kg by 726 kg by average maximum daily temperature of 4.4 and 10 °C, respectively (Winchester & Morris, 1956) could meet the water needs of the dry cows of tested breeds in our study.

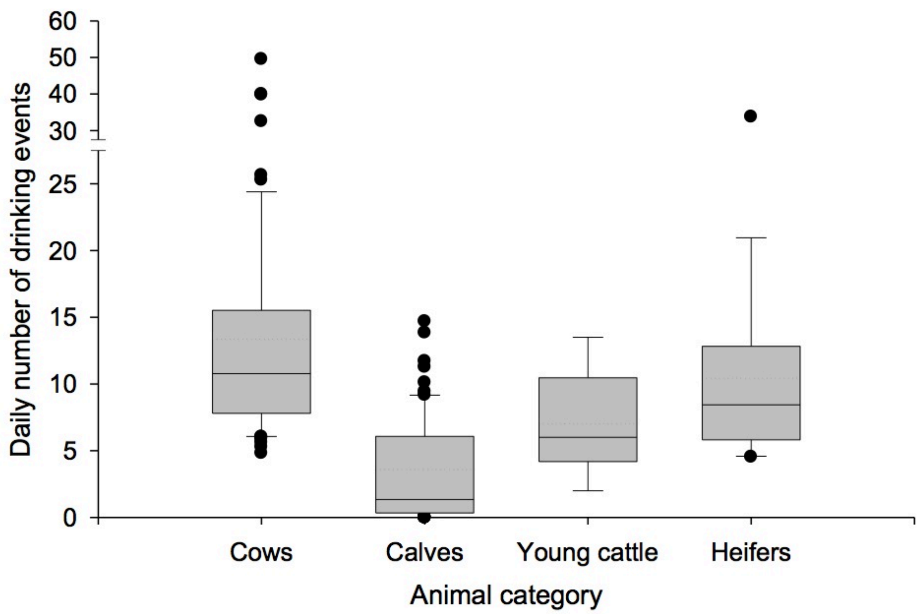

Figure 6. Daily number of drinking events per animal according to animal category (for explanation of box plots see Figure 4).

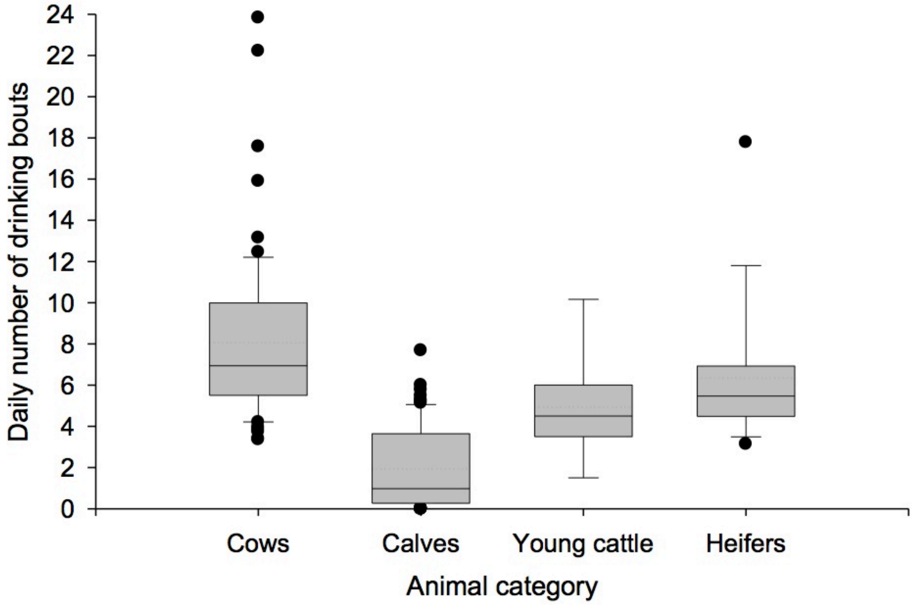

Figure 7. Daily number of drinking bouts per animal according to animal category (for explanation of box plots see Figure 4).

However, not in case of applying the values estimated for dry beef cows. Estimated total daily water intake is only 22.7 and 24.6 kg for beef dry cows by average maximum daily temperature of 4.4 and 10 °C, respectively (Guyer, 1977; Lardy *et al.*, 2008). The same values are applied also for heifers in both publications. However, also in heifers, FWI was already in the range of estimated total water intake.

FWI of youngest calves (≤ 12 weeks old), was mostly notably lower than in Holstein calves fed with restricted amount of milk or milk replacer or ad libitum (Atkeson *et al.*, 1934; Pettyjohn *et al.*, 1963; Jenny *et al.*, 1978; Kertz *et al.*, 1984; Thomas *et al.*, 2007). No regularity was observed in drinking during first 12 postnatal weeks. Also in 12. postnatal week, some calves were not daily recorded by drinking. Even if not all drinking events would be recorded (when calves would drink only rest water in drinking bowls, what was not proofed in our study), it seems that calves in early age can cover their daily water requirement via liquid feed by ad libitum liquid feeding. Atkeson *et al* (1934) show that calves covered 99 % their water requirement via milk when 4 weeks old and milk intake of 5.4 to 7.3 kg. In 12 weeks old calves, it was only 61 %, but by the same milk offer. By feeding of higher amount of milk or ad libitum milk intake, it can be expected that calves can cover large proportion of water intake via milk also in higher age. In one Simmental herd, it was observed that nursing cows produced up to 18 kg milk per day (average 12.4 kg per day in 9 lactation month) (Steinwidder *et al.*, 2006). This is considerably more than dairy calves get offer. Unfortunately, in age of 16 to 24 weeks were only single or even no calves in herd. However, just in that age, FWI seems to increase notably from week to week (data not shown). It can be supposed that milk of dam cannot cover increasing water requirements from certain age of calves; also it can be expected that from certain age milk cannot cover increasing energy requirement and intake of solid feed starts to increase. With increasing solid feed intake and body weight the water requirement increases.

By average maximum daily temperature of 4.4 (10 °C), estimated total water requirement in kg for growing calves is 15.1 (17.0), 20.8 (22.7), and 24.6 (26.5) by body weight of 181, 272, and 363 kg (Winchester & Morris, 1956; Guyer, 1977; Lardy *et al.*, 2008). In calves observed in our study, similar average body weights were observed in 14 to 15 (176 to 190 kg), 27 to 28 (260 to 287 kg), and 35 to 36 (356 to 368 kg) weeks old calves. The FWI with water intake via milk could correspond to estimated requirement values in calves 14 to 15 and 27 to 28 weeks old. However, in 25 to 40 weeks old calves, no effect of age (week) could be observed on FWI, i.e. FWI did not differ even the body weight continuously increased (Mačuhová *et al.*, 2009). The reason therefore were unclear.

In cows, calves, and heifers, around 70 % daily drinking events and daily FWI took place between 0800 and 2000 h. In young cattle, also more than a half of drinking events and FWI (55 and 64 % respectively) occurred between 0800 and 2000 h, but the difference to rest hours was not so notable (mainly by drinking events) than in other categories. Similar results were observed also in dairy cows. More FWI occurred in daylight resp. working hours (Nocek & Braun, 1985; Cardot *et al.*, 2008).

FWI was performed in 5.6 and 8.1 bouts in cows with and without calves, respectively. This is lower than in dairy cows in study of Dado & Allen (1994) (14.0 bouts by 77.6 l daily FWI) but comparable with observations in study of Cardot *et al* (2008) (7.5 bouts by 83.6 l). In both studies, the same criteria (4 min) were used for the definition of drinking bouts. However, whereas the animals were housed in tie stalls in the first mentioned study, in the second study they were kept in a free stall-barn. It can be expected that when animals have to walk to drinking place the number of visits can be reduced and in consequence also the number of drinking bouts can be affected.

The daily drinking time was 9.5 min in cows with calves, 6.8 min in cows without calves, 5.6 min in pregnant heifers, 3.9 min in young cattle, and 3.2 to 3.6 min in calves older than 24 weeks (all median values). The youngest calves (≤ 12 weeks old) spent with drinking daily only 0.1 min. Drinking time of cows with calves was notably lower than in dairy cows with daily FWI of 74.0 or 77.6 l (15.0 and 18.5 min, respectively) (Mahlkow-Nerge; 2004, Dado & Allen, 1994). There is not a lot of information of drinking time of beef cattle. One study of Wagnon (1963) shows that beef cattle drinking water from a trough spent with drinking between 3 to 6 min per day and cow. This would be comparable with our results. Only cows with calves spent more time and younger calves (≤ 24 weeks old) less time with drinking in our study. However, the drinking time can be strongly affected by filling rate of drinking facility. Therefore, the results of different studies can vary strongly.

Conclusions

Drinking is not a random process. The relative frequency distribution of LN-transformed intervals between drinking events can be used for estimations of bouts criteria in suckler cow herds. The often published estimated water intake for beef cattle can underestimate really water requirements of some animal categories of dual purpose breeds during winter period. Mainly, FWI of nursing dual purpose cows appears to be higher than in typical beef cows. The youngest calves (first 12 postnatal weeks old) seem to cover most of their water requirement via milk.

There is further work to be done investigating the water intake also during other seasons (only indoor winter period could be evaluated in this study) and in different stages of production by individual animal categories. Moreover, the effect of different feed types (e.g. grazing) should be examined. In this study, it was not possible because the feed type did not change during experimental period.

References

Adams, R. S. and Sharpe, W.E. 1995. Water intake and quality for dairy cattle. Penn State Extension Publication DAS 95-8, 8 pp.

Atkeson, F. W., Warren, T. R. and Anderson, G. C. 1934. Water requirement of dairy calves. Journal of Dairy Science **17** 249-256.

Bahr, C. 2007. Sensorbasierte Analyse und Modellierung ausgewählter Verhalternsparameter von Mutterkühen. Dissertation, Humboldt-Universität Berlin, 2007, 250 pp.

Beede, D. K. 2005. The most essential nutrient: water. Proceedings of 7th Western Dairy Management Conference, 9-11 March, 2005, Reno, NV, pp. 13-31.

Cardot, V., Le Roux, Y. and Jurjanz, S. 2008. Drinking behaviour of lactating dairy cows and prediction of their water intake. Journal of Dairy Science **91** 2257-2264.

Dado, R. C. and Allen, M. S. 1993. Continuous computer acquisition of feed and water intakes, chewing, reticular motility, and ruminal pH of cattle. Journal of Dairy Science **76** 1589-1600.

Dado, R. C. and Allen, M. S. 1994. Variation in and relationships among feeding, chewing, and drinking variables for lactating cows. Journal of Dairy Science **77** 132-144.

Dahlborn, K., Akerlind, M. and Gustafson, G. 1998. Water intake by dairy cows selected for high of low milk-fat percentage when fed two forage to concentrate rations with hay or silage. Swedish Journal of Agricultural Research **28** 167-176.

Guyer, P. Q. 1977. Water requirements for beef cattle. File G372 under: BEEF, C-4, Beef Management, http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1329&context =extensionhist (online available 20.01.2011).

Holter, J. B. and Urban, W. E. Jr. 1992. Water partitioning and intake prediction in dry and lactating Holstein cows. Journal of Dairy Science **75** 1472-1479.

Jenny, B. F., Mills, S. E., Johnston, W. E. and O'Dell, G. D. 1978. Effect of fluid intake and dry matter concentration on scours and water intake in calves fed once daily. Journal of Dairy Science **61** 765-770.

Kertz, A. F., Reutzel, L. F. and Mahoney, J. H. 1984. Ad libitum water intake by neonatal calves and its relationship to calf starter intake, weight gain, feces score, and season. Journal of Dairy Science **67** 2964-2969.

Landefeld, M. and Bettinger, J. 2002. Water effects on livestock performance. ANR-13-2, http://ohioline.osu.edu/anr-fact/pdf/0013.pdf (online available 10.01.2011).

Lardy, G. and Stoltenow, Ch. 1999. Livestock and water. North Dakota State University Agriculture and University Extension, Morril Hall, Fargo, AS-954, 12 pp., http://www.ag.ndsu.edu/pubs/ansci/livestoc/as954w.htm (online available 10.01.2011).

Lardy, G., Stoltenow, Ch. and Johnson, R. 2008. Livestock and water. NDSU Extension Service, North Dakota State University, AS_954, 7 pp. http://www.ag.ndsu.edu/pubs/h2oqual/watanim/as954.pdf (online available 19.01.2011).

Looper, M. L. and Waldner, D. N. 2002. Water for dairy cattle. Cooperative Extension Service, College of Agriculture and Home Economics, Guide D-107, Las Cruces, NM, 8 pp., http://cahe.nmsu.edu/pubs/_d/D-107.pdf (online available 10.01.2011).

Mačuhová, J., Jais, Ch., Oppermann, P. und Wendl, G. 2009. Wasseraufnahme von Kälbern in Mutterkuhhaltung (Water intake in suckler beef calves). In: KTBL-Schrift 479, Aktuelle Arbeiten zur artgemäßen Tierhaltung 2009, 41. Internationale Arbeitstagung Angewandte Ethologie bei Nutztieren, 19.-21. 11. 2009, Freiburg, pp. 193-195.

Mahlkow-Nerge, K. 2004. Ohne Wasser keine Milch (Without water no milk). Nutztierpraxis aktuell 10, 8 pp., http://www.ava1.de/pdf/artikel/rinder/2004_04_mahlkow-nerge.pdf (online available 10.01.2011).

Melin, M., Wiktorsson, H. and Norell, L. 2005. Analysis of feeding and drinking pattern of dairy cows in two cows traffic situations in automatic milking system. Journal of Dairy Science **88** 71-85.

Meyer, U., Everinghoff, M., Gädeken, D. and Flachowsky, G. 2004. Investigations on the water intake of lactating dairy cows. Livestock Production Science **90** 117-121.

Murphy, M. R., Davis, C. L. and McCoy, G. C. 1983. Factors affecting water consumption by Holstein cows in early lactation. Journal of Dairy Science **66** 35-38.

Nocek, J. E. and Braun, D. G. 1985. Effect of feeding frequency on diurnal dry matter and water consumption, liquid dilution rate, and milk yield in first lactation. Journal of Dairy Science **68** 2238-2247.

NRC. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. National Academy Press. Washington DC: USA, 408 pp.

Pettyjohn, J. D., Everett, JR., J. P. and Monchrie, R. D. 1963. Responses of dairy calves to milk replacer fed at various concentrations. Journal of Dairy Science **46** 710-714.

Stockdale, C. R. and King, K. R. 1983. A note on some of the factors that affect the water consumption of lactating dairy cows at pasture. Animal Science **36** 303-306. In: NRC. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. National Academy Press. Washington DC: USA, 408 pp.

Steinwidder, A., Häusler, J., Schauer, A., Maierhofer, G., Gruber, L., Gasteiner, J. and Podstatzky, L. 2006. Einfluss des Absetztermins auf die Milchleistung und Körpermasse von Mutterkühen sowie die Zuwachsleistung von Mutterkuh-Jungrindern (Influence of duration of suckling period on milk yield, body weight and weight gain of suckler beef cattle). In: Tagungsband, Zadravec-Erjavec Tagung, 09.-10.11.2006, pp. 284-289.

Thomas, L. C., Wright, T. C., Formusiak, A., Cant, J. P. and Osborne, V. R. 2007. Use of flavoured drinking water in calves and lactating dairy cattle. Journal of Dairy Science **90** 3831-3837.

Wagnon, K. A. 1963. Behavior of beef cows on a California range. California Agricultural Experiment. Station (Bulletin) 799 58 pp, In: Larsen, R. E. Manure loading into streams from direct fecal deposits. Fact Sheet No. 25, http://danr.ucop.edu/uccelr/h25.htm (online available 27.01.2011).

Wendl, G. 2008. Machinery and techniques for cattle husbandry. In: Harms, H.H. and Meier, F. (Ed.): Yearbook Agricultural Engineering, Band 20, pp. 197-205.

Winchester, C. F. and Morris, M. J. 1956. Water intake rate of cattle. Journal of Animal Science **15** 722-740.

Woodford, S. T., Murphy, M. R. and Davis, C. L. 1984. Water dynamics of dairy cattle as affected by initiation of lactation and feed intake. Journal of Dairy Science **67** 2336-2343.

Evaluation of milkability and udder morphology in Tsigai, Improved Valachian ewes in conditions of Slovakia

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Abstract

The purpose of this paper is to present the results of the research works undertaken on the evaluation of physiological and morphological factors affecting the milkability of Tsigai, Improved Valachian and Lacaune breeds which are bred in Slovakia. Physiological aspects of milkability have been assessed according to milk flow kinetics of and the udder morphology traits. Tsigai and Improved Valachian (most used breeds in Slovakia) had worse milkability than Lacaune. The crossing of Tsigai and Improved Valachian with Lacaune had positive effect on milk yield and occurrence of milk ejection. However, the teat position was negatively affected.

Keywords: udder morphology, milk flow kinetics, Tsigai, Improved Valachian, Lacaune

Introduction

Rearing of sheep has a long tradition in Slovakia. The management is primarily based on pasture during summer season and indoor housing during winter period. In summer period we still have unused areas which are suitable for sheep, though they are in remote parts. In Slovakia the machine milking started already since 1960. Introduction of milking machines required data related to the milkability of ewes and as well as a searching the best milking machine parameters. The most experiments related to milkability were done within 70 and 80s years of last century (Mikuš, 1974; Mikuš, 1973; Mikuš & Masár, 1985). But machine milking was not spread to farms in a larger extent. In those time all breeds in Slovakia, were bred for dual – purpose with progressive differentiation to give two types: meat – wool type or milk – wool type. Recently, meat – milk type is mostly required. In Slovakia, the mostly reared breeds are Tsigai and Improved Valachian which belong to autochthonous and locally adapted breeds.

Tsigai and Improved Valachian are very similar in milk production potential. To improve their milk production, milkability, and prolificacy, Tsigai and Improved Valachian are crossed with dairy breeds as Lacaune and East Friesian at present (Capistrak *et al.,* 2001; Margetín *et al.*, 2005).

In last decades, the number of farms with machine milking or interest to milk the sheep with machine is increasing. This fact evokes the question, if the breeds kept in Slovakia are suitable for machine milking. This can be found out by evaluation of the milking characteristics. Milkability can be evaluated by analysis of the milk flow curves (Labussière, 1988; Mayer *et al.,* 1989; Bruckmaier *et al.,* 1997; Caja *et al.,* 2000) and measurement of udder morphology (Labussière, 1988; Fernández *et al.,* 1995; Milerski *et al.,* 2006). Knowledge of milk yield, milking time, and udder conformation is useful for optimization of the milking routine and milking machine parameters to the needs of the ewes. Machine milkability can be also estimated by fraction of milking – machine milking, machine stripping, and residual milk (Such *et al.,* 1999).

Milk stored in the udder before milking can be divided into two fractions: the cisternal fraction and the alveolar fraction. The cisternal milk comprises milk, which has already been transferred from alveoli to the cistern or large ducts during interval between milkings and is immediately obtainable by milking machine without milk ejection only by simply surmounting the teat sphincter barrier (Bruckmaier & Blum, 1998). The cisternal milk can represent more than 40% of milk stored in the udder of dairy ewes (Marnet & McKusick, 2001; Mačuhová *et al.,* 2008). The alveolar milk (milk stored in the alveoli and small ducts) can be removed from the udder only in response to milk ejection during the milking (Bruckmaier & Blum, 1998). Milk partitioning between both compartments varies according to species, breed, age, stage of lactation, and milking interval (Bruckmaier *et al.,* 1997; Davis *et al.,* 1998; Castillo *et al.,* 2008). The milk distribution in the udder before milking was not studied in detail in Tsigai and Improved Valachian.

Milk flow

Milk flow is one of the most interesting criteria for studying milkability in the machine milked dairy ewes and its main traits are considered to be relevant for design of milking machines and for adaptation the optimal milking routine in each breed (Caja *et al.,* 2000). Dairy ewes with the ideal milk flow are quickly and completely milked out, with a high milk flow rate and an effective ejection of alveolar milk (Bruckmaier *et al.,* 1997; Marnet *et al.,* 1998). The milk flow is related to udder morphology (cistern depth), teat (position, size) and neuro-hormonal reaction of the dairy ewes on machine milking (Labussière, 1988; Bruckmaier *et al.,* 1997; Marnet *et al.,* 1998).

In older studies, the milkability has been assessed according to kinetics of milk flow measured by manual recording of milk volume increments in 10-second intervals at first (Mikuš, 1974; Mikuš & Masár, 1985; Milerski *et al.,* 2005). Since 2005, the recording of milk volume was performed by electronic jars in one–second intervals in our studies (Mačuhová *et al.,* 2007, 2008; Tančin *et al.,* 2009, 2011). Within each jar, there is a 2-wire compact magnetostrictive level transmitter connected to the computer. Milk level in the jar is continuously measured by a transmitter with recording signals on computer. These results are used to create the curve of milk flow.

In the 1980-s years milk flow curves of ewes were divided into three groups according to their course: one peak, two peaks and unidentified curve (milk flow with three or four peaks). In population of Tsigai ewes predominated ewes with two peaks – 86% (Mikuš & Masár, 1985). Ewes with one peak milk flow (10%) were mainly on the first lactation (Mikuš & Masár, 1985). One peak milk flow curve could represent milk flow without alveolar milk ejection when only cisternal milk fraction is removed in response to machine milking. On the other hand, the milk flow curves with two peaks show alveolar milk ejection after the cisternal milk is removed. An efficient milk ejection reflex is still of primordial importance and helps to explain the adaptation to machine milking in small ruminants (Marnet *et al.,* 2001). In consequence of the genetic selection for higher milk production or decreased average milk flow rate, the occurrence of two peaks milk flow curve is rarer now (Marnet *et al.,* 1998; 1999). Thus the second peak is masked because at the time of milk ejection, the cistern fraction has not yet been completely removed from the udder when alveolar fraction descends into cistern for removal (Marnet *et al.,* 1998). Therefore, the second peak is not observed even though it is known that milk ejection has occurred in some ewes (Marnet *et al.,* 1998; Rovai *et al.,* 2002). This type of milk flow was named plateau (Rovai *et al.,* 2002). We named this type of milk flow as plateau I (Mačuhová *et al.,* 2008). Then Bruckmaier *et al.,* (1997) found out another type of milk flow curve. This type of milk flow has also the steady milk flow, but at low level rate (< 0.04 l/min). It is supposed, that the ewes with this type of milk flow have extremely weak or totally absent oxytocin release during milking (Bruckmaier *et al.,* 1997). We named this type of milk flow as plateau II (Mačuhová *et al.,* 2008).

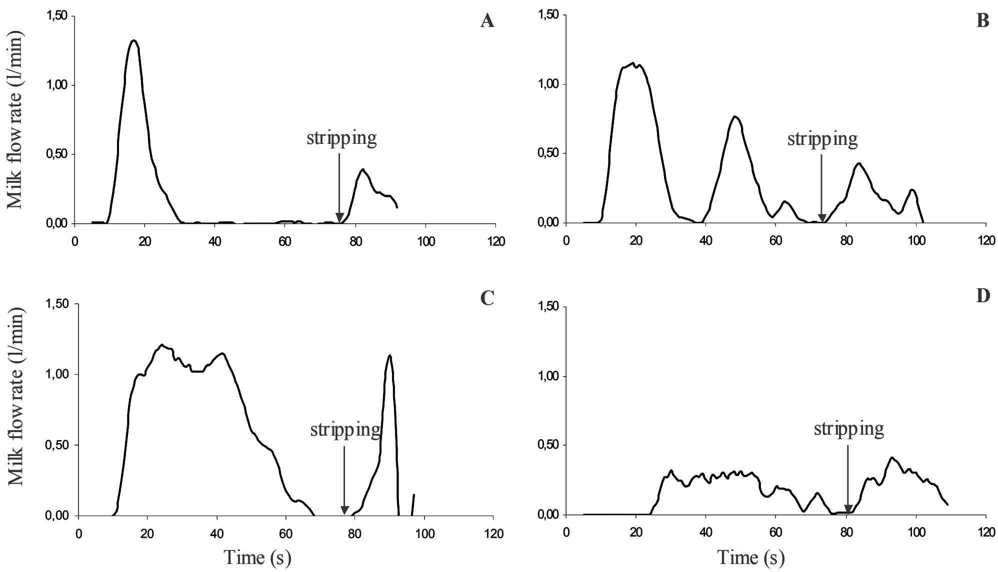

Figure 1. Different milk flow patterns present during machine milking of Tsigai, Improved Valachian, Lacaune, Tsigai x Lacaune, Improved Valachian x Lacaune. (A): one peak; (B): two peaks, (C) plateau I, (D) plateau II (Mačuhová et al., 2008).

Finally in our studies, the milk flow curves are classified into four groups: one peak (1P), two peaks (2P), plateau I (PLI) and plateau II (PLII) (Fig. 1). The frequency of occurrence of different milk flow patterns (1P : 2P : PLI : PLII) was found out 43 : 50 : 7 : 0% in Tsigai and 47 : 47 : 6 : 0% in Improved Valachian. Better results were found out in crossbreds Tsigai and Improved Valachian with Lacaune, when in Improved Valachian x Lacaune had 0 : 67 : 22 : 11% and in Tsigai x Lacaune 30.5 : 39 : 30.5 : 0% (1P:2P:PLI:PLII; respectively) (Mačuhová *et al.,* 2008).

Milk flow kinetic of individual ewes was very stable during short period of lactation but a pattern of milk flow changed throughout lactation in breeds Tsigai, Improved Valachian and Lacaune. The ewes with stable milk flow patterns over lactation presented 69% (Tančin *et al.,* 2009). The highest stability of occurrence of the same milk flow type throughout lactation showed ewes with 1P milk flow. Unfortunately in such animals, only cisternal milk is removed because of missing milk ejection in response to machine stimulation (Labussière, 1988). Cisternal, alveolar and stripping milk yield represented 59.8 ± 5.3, 0, 40.2 ± 5.3% and 54.2 ± 3.0, 26.5 ± 2.6, 19.3 ± 1.9% of total milk yield by 1P and 2P type of milk flow curves. The percentage of machine milk fraction (cisternal plus alveolar fraction) was clearly higher during milkings with 2P type of milk flow (~ 79%) than with 1P type of milk flow (~ 60%). Moreover, the percentage of cisternal milk fraction was quite similar in both types of milk flow curves. During milkings with 2P type of milk flow, the bimodality (the start of the second increase of milk flow) was observed at around 39 ± 2 s in breeds traditionally bred in Slovakia (Mačuhová *et al.,* 2008). The duration of machine milking in ewes with 1P type of milk flow was only 45 ± 4 s (Mačuhová *et al.,* 2008). This confirms that the 1P type of milk flow curves occurred in ewes without alveolar milk ejection in our observation (Mačuhová *et al.,* 2008) as observed previously in other study (Bruckmaier *et al.,* 1997) too. High stability of 1P milk flow type occurrence (100%) during lactation shows that ewes with 1P type of milk flow did not adapt to machine milking in the course of lactation. In these animals, milking conditions cause stress induced inhibition of oxytocin release or machine stimuli do not evoke the release of oxytocin. Ewes with PLI type of milk flow had the least stability (55%). PLI changed in later lactation to 1P or 2P. The change of PLI to 1P indicates that the former plateau was probably caused of limitation of milk flow through teat canal (Tančin *et al.,* 2009). The change of PLI to 2P was caused with lower milk yield in later stage of lactation. So, we could remove all milk from cistern before alveolar milk was ejected to the cistern in response to milk ejection. The results of occurrence of single milk flow types and the time of ejection reflex could help by the evaluation of the labour input during machine milking with regard on welfare of ewes during milking (Mačuhová *et al.,* 2010).

There was confirmed relationship between type of milk flow curve and milk yield (Mikuš & Masár, 1985; Mačuhová *et al.,* 2007, 2008; Mačuhová, 2009; Tančin *et al.,* 2011). The breeds Tsigai and Improved Valachian had high occurrence of 1P milk flow (how it was mentioned), where the milk ejection during milking is not supposed as well as the lowest milk yield (Mačuhová *et al.,* 2008).

From milk flow curves, it can be identified latency time and maximal milk flow rate. Latency time is the time between teat cup attachment and the start of recording of milk flow. Latency time and maximal milk flow rate depend on the vacuum required to open the teat sphincter (Mikuš, 1973; Marnet *et al.,* 1999) and on milk recording system. The milk recording systems consist of some electronic jars. Each jar is equipped with electronic sensors able to follow and record the milk volume that is progressively collected during the milking. Each jar has some minimal volume which has to be filled to allow the starting of milk yield recording. The time needed to fill this space is latency time. Short latency time and early occurrence of maximal milk flow indicate a rapid response of an animal to the stimulus of the milking (Casu *et al.,* 2008). Average values of latency time were between 22-24 % of machine milking time in our experiments (Mačuhová, 2009). In Sardinian x Lacaune backcross ewes latency time represented only 13% of machine milking time (Casu *et al.*, 2008). This is notably lower than in our study despite fact that latency time in that study lasted until volume of milk 160 ml in jar was reached and in our study only 30 ml.

Evaluation by partitioning of milk

Milkability can be evaluated also by partitioning of milk collected during milking (machine milk, machine stripping milk), and amount of residual milk (remains in the udder and is only removed after administration of supraphysiological doses of oxytocin) (Labussière, 1988; Mačuhová, 2009). Higher amounts of residual milk may result from incomplete milk ejection associated with poor milking routines, frightened or nervous animals or uncomfortable milking equipment. The Slovak breeds Tsigai and Improved Valachian had higher percentage of residual milk than Lacaune breed. Values of milk fraction (machine milk : machine stripping milk : residual milk) were 63 : 23 : 14%, 65 : 19 : 16% and 69 : 24 : 7% for Tsigai, Improved Valachian and Lacaune ewes, respectively (Mačuhová, 2009). Such *et al.,* (1999) observed higher values of residual milk in Lacaune breed (11%), but lower machine stripping fraction (21%) than it was in Lacaune reared in Slovak condition. In breed Tsigai, percentage of residual milk was similar like in the study from 80s years, when its value was 13.1% (Labussière, 1983). Animals with 2P and PLI type of milk flow had lower residual milk percentage from total milk yield than animals with 1P type of milk flow (Mačuhová, 2009).

Morphological properties of the udder and correlations

The removal of milk during milking can be affected also by morphology of the udder. The udder morphology traits have been gained objectively by measurement or subjectively by assessment using the linear scores (Mikuš, 1978) and also by the ultrasound technique (Milerski *et al.,* 2006). Ultrasonography is carried out from the side of the udder according to methodology of Ruberte *et al* (1994) and from below in a water bath as described by Bruckmaier & Blum (1992).

The udder morphology might be influenced by several factors, such as genotype, lactation number, lactation stage, and breeding system (Mikuš, 1985; Apolen *et al.,* 2000; Čapistrák *et al.,* 1997; Milerski *et al.,* 2006).

The forming of the udder has not been receiving adequate attention in a flock where ewes were milking by hand. The milker adjusted manner of milking to the udder of individual ewes. This problem promoted researchers to action with the advent of machine milking (Mikus, 1978). The first measurements done in Tsigai, Valachian and Merino breeds showed differences in the dimensions of the udder and teats between these breeds. The results indicated, that it was impossible recommend the same criteria for all sheep breeds in selection for udder suitable for machine milking (Mikus, 1978). With aim to improve milk production and the "create" optimal udder for machine milking, Tsigai sheep have been crossed with East Friesian sheep (Mikuš, 1985). The udder depth, udder length and udder width were larger in crossbreeds than in purebred Tsigai sheep and teat angle did not change (Mikuš, 1985). From results published by Labussière (1983) and Milerski *et al.,* (2006) we can see increase of the values of the udder depth (from 107.4 to 133.7; mm), teat length (from 27.0 to 35.3; mm) and teat angle (from 34.5 to 37.5; °) in breed Tsigai from the 80 s years.

First sheep of breed Lacaune had been imported to Slovakia in order to improve milk production since 1993 -1994. The crossbreeds had higher milk production than purebred breeds. But Lacaune as well crossbreeds with Lacaune had more horizontally positioned teats than purebred breeds Tsigai and Improved Valachian (Mačuhová *et al.,* 2008; Apolen *et al.,* 2000; Milerski *et al.,* 2006). This show that, the crossing with Lacaune can negatively

influenced the teat position in Tsigai x Lacaune and Improved Valachian x Lacaune (Mačuhová *et al.,* 2008). This should be taken in regards for future breeding programmes. Lacaune had higher cistern than Tsigai and Improved Valachian (Milerski *et al.,* 2005). Positive effect of crossing with Lacaune was observed in area of cisterns, e.g. Improved Valachian x Lacaune had by about 32% larger area of cistern than Improved Valachian ewes (Margetín *et al.,* 2002). However, ewes with deeper cisterns (i.e. more udder volume below the teat canal exit) take longer to milk than ewes with shallower cisterns. It is not surprising because ewes with taller cisterns produce more milk (McKusick, 2000).
Total milk yield and machine milk yield were significantly correlated with maximal milk flow rate, milking time, cistern depth, teat angle, and teat position, but no with machine stripping and milk flow latency (i.e. time when milk flow started after claw attachment). Milk flow latency showed positive correlations with milking time and negative correlations with maximal milk flow rate (Mačuhová *et al.,* 2008). The positive and significant correlation between milk yield and milk flow rate suggests that high producing animals have fast milk removal (Dzidic *et al.,* 2004). The positive and significant correlation was found also between teat position and cistern depth (estimated by linear score) in Tsigai, Improved Valachian and Lacaune (Milerski *et al.,* 2006; Mačuhová *et al.,* 2008). It means that ewes with deeper cistern had more horizontally positioned teats. The same effect was also observed between teat angle and cistern depth when these udder traits were measured in the same breeds (Milerski *et al.,* 2006; Mačuhová *et al.,* 2008) and also in Manchega (Rovai *et al.,* 1999) as well as East Friesian ewes (McKusick *et al.,* 2000). However, the udders with deeper cisterns and bigger teat angle can have problem with falling off the cups during milking (Labussière, 1988) and increasing of stripping milk yield by a part of the cisternal milk which is located below the orifice into the teat canal and cannot be reached without machine stripping (Bruckmaier *et al.,* 1997). This can prolong the milking time and thereby reduce the efficiency of machine milking. Moreover, ewes with more horizontal teat position and larger teats had greater problems with milk output, greater probability of subclinical mastitis inception (Margetín *et al.,* 2005). Therefore, it is necessary to put greater attention to udders with more horizontal teat position at machine milking (Margetín *et al.,* 2005). The average udder size of Lacaune ewes was larger than in Improved Valachian and Tsigai (Milerski *et al.,* 2006). The larger cistern of Lacaune ewes and their low proportion of residual milk help this breed to tolerate the extremely simplified milking method. Moreover, they have predisposition to adapt to long intervals between milkings (Labussière, 1988). These ewes have more storage volume which is one of the components keeping intrammary pressures low and more easily avoids over distension of the alveoli between milkings (McKusick, 2000). Improved Valachian and Tsigai ewes do not belong to really high producing ewes. However, already in these sheep positive correlations of total milk yield with cisternal depth and position of teat could be observed (Mačuhová *et al.,* 2008). This could indicate that other breeding for higher milk production could lead to worsening of udder morphology (as it is observed in high producing ewes in other studies).

Conclusion

The results of occurrence of single milk flow types and the time of ejection reflex could help by the evaluation of the labour input during machine milking with regard on welfare of ewes during milking (Mačuhová *et al.,* 2010). The occurrence frequency of milk flow types could be also impacted by breeding conditions and breeding performance too.

Milk flow kinetics of individual ewes were very stable during short period of lactation but a pattern of milk flow changed throughout lactation. The highest stability of milk flow curve occurrence throughout lactation showed ewes with one peak milk flow, e.g. milk flow, where the milk ejection during milking is not supposed and the lowest milk yield was observed. There was confirmed relationship between type of milk flow curve and milk yield. The breeds Tsigai and Improved Valachian had high occurrence of one peak milk flow, and higher levels of residual milk than Lacaune breed. The results indicate worse adaptability of Tsigai and Improved Valachian breeds to machine milking. In crossbreds Tsigai and Improved Valachian with Lacaune, there was higher milk yield and occurrence of plateau I milk flow curves than in purebred Tsigai and Improved Valachian.

A positive effect of crossing Tsigai and Improved Valachian with Lacaune has been proved in cistern depth, but the opposite effect has been found in teat position. The milkability traits can be used for evaluation of the biological needs of ewes in relation to different milking routines in parlour and to adjust the machine milking parameters.

Our results show a good potential for machine milking of these breeds. However, strategies for improvement of milkability (machine improvement and genetic selection) need to be taken up as it was done for Lacaune breed 20 years ago.

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References

Apolen, D., Čapistrák, A., Margetín, M. and Špánik, J. 2000. Vzťah medzi tvarom vemena a produkciou mlieka oviec [Relation between udder shape and milk production in sheep]. Journal Farm of Animal Science, **33** 223-228.

Bruckmaier, R. M. and Blum, J. W. 1992. B-mode ultrasonography of mammary gland of cows, goats and sheep during α-and β-adrenergic agonist and oxytocin administration. Journal of Dairy Research **59** 151-159.

Bruckmaier, R. M. and Blum, J. W. 1998. Oxytocin release and milk removal in ruminants. Journal of Dairy Science **81** 939-949.

Bruckmaier, R. M., Paul, G., Mayer, H., and Schams D. 1997. Machine milking of Ostfriesian and Lacaune dairy sheep: udder anatomy, milk ejection, and milking characteristics. Journal of Dairy Research **64** 163-172.

Caja, G., Such, X. and Rovai, M. 2000. Udder morphology and machine milking ability in dairy sheep. In: Proceedings of the 6th Great Lakes Dairy Sheep Symposium November 2-4, 2000. Guelph, Ontario, Canada, pp. 17-40.

Capistrak, A., Margetin, M., Apolen, D. and Spanik, J. 2001.Milk production and prolificacy of purebred Tsigai and Improved Valachian sheep and their crosses with Lacaune breed. In: Book of abstract of the 52nd annual meeting of the EAAP, Budapest, Hungary, p. 264.

Casu, S., Marie-Etancelin, C., Robert-Granié, C., Barillet, F. and Carta, A. 2008. Evolution during the productive life and individual variability of milk emission at machine milking in Sardinian x Lacaune back-cross ewes. Small Ruminant Research **75** 7-16.

Čapistrák, A., Margetín, M., Špánik, J. and Bachyncová, T. 1997. Produkcia mlieka a morfologické vlastnosti vemena oviec plemena cigája a ich kríženiek s plemenom Suffolk. [Milk production and morphological properties of udder in sheep of Tsigai breed and their crosses with Suffolk breed]. Journal Farm of Animal Science **30** 110-118.

Castillo, V., Such, X., Caja, G., Salama, A. A. K., Albanell, E. and Casals, R. 2008. Changes in alveolar and cisternal compartments induced by milking interval in the udder of dairy ewes. Journal of Dairy Research **91** 3403-3411.

Davis, S. R, Farr, V. C., Copeman, P. J. A., Carruthers, V. R., Knight, C. H. and Stelwagen, K. 1998. Partitioning of milk accumulation between cisternal and alveolar compartments of the bovine udder: Relationship to production loss during once daily milking. Journal of Dairy Research **65** 1-8.

Dzidic, A., Kaps, M. and Bruckmaier, R. M. 2004. Machine milking of Istrian dairy crossbreed ewes: udder morphology and milking characteristics. Small Ruminant Research **55** 183-189.

Fernández, G., Allvarez, P., San Primitivo, F. and de la Fuente, L. F. 1995. Factors affecting variations of udder traits of dairy ewes. Journal of Dairy Science **78** 842–849.

Labussiere, J. 1983. Etude des aptitues laitières et de la facilité de traite des quelques races de brebis de Bassin Méditerranéen. Résultats preliminaires obtenus au 16 mai 1983. III Symposium internacional de ordeño mecánico de pequeños rumiantes. Valladolid, España, pp. 780-803.

Labussière, J. 1988. Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livestock Production Science **18** 253-274.

Mačuhová, L. 2009. Fyziologické a anatomické predpoklady bahníc plemien chovaných na Slovensku pre strojové dojenie. [Physiological and anatomical preconditions of dairy sheep breeds bred in Slovakia]. PhD. Thesis. CVŽV Nitra, pp. 132.

Mačuhová, L., Uhrinčať, M., Mačuhová, J., Margetín, M. and Tančin, V. 2008. The first observation of milkability of the sheep breeds Tsigai, Improved Valachian and their crosses with Lacaune. Czech Journal of Animal Science **53** 528-536.

Mačuhová, L., Uhrinčať, M., Marnet, P. G., Margetín, M., Mihina, Š. and Tančin, V. 2007. Reakcia bahníc na strojové dojenie: hodnotenie priebehu toku mlieka. [Response of ewes to machine milking: evaluation of the milk flow curves]. Slovak Journal of Animal Science, **40** 89-96.

Mačuhová, L., Mačuhová, J., Uhrinčať, M., Tančinová, D. and Tančin, V. 2010. Organizácia práce pri strojovom dojení a welfare bahníc. [Labour input during machine milking and welfare of ewes]. Potravinárstvo **4** 179-188.

Margetín, M., Milerski, M., Apolen, D., Čapistrák, A., Špánik, J. and Margetínová, J. 2002. Veľkosť cisterny vemena dojných oviec zisťovaná využitím ultrazvuku. [Mammary cistern size of dairy ewes determined by ultrasound techniques]. Journal Farm of Animal Science **35** 97-105.

Margetín, M., Milerski, M., Apolen, D., Čapistrák, A. and Oravcová, M. 2005. Morphology of udder and milkability of ewes of Tsigai, Improved Valachian, Lacaune breeds and their crosses. In: Physiological and technical aspect of machine milking. Nitra, Slovak Republic, pp. 259-263.

Marnet, P. G., Combaud, J. F. and Dano, Y. 1999. Relationships between characteristics of the teat and milkability in Lacaune ewes. In: Milking and milk production of dairy sheep and goat. F. Barillet and N. P. Zervas, EAAP Publication No.95, Wageningen pers., Wageningen, The Netherlands, pp. 41–44.

Marnet, P. G. and McKusick, B. C. 2001. Regulation of milk ejection and milkability in small ruminants. Livestock Production Science **70** 125-133.

Marnet, P. G., Negrao, J. A. and Labussière J., 1998. Oxytocin release and milk ejection parameters during milking of dairy ewes in and out of natural season of lactation Small Ruminant Research **28** 183-191.

Mayer, H., Weber, F. and Segessemann, V., 1989. A method to record and define milk flow curves of ewe during routine machine milking. In: Proceedings 4th International Symposium on Machine Milking of Small Ruminants, Tel Aviv, Israel, pp. 564–573.

McKusick, B. C. 2000. Physiologic factors that modify the efficiency of machine milking in dairy ewes. In: Proceedings of the 6 th Great Lakes dairy sheep symposium, Guelph, Ontario, Canada, pp. 86-100.

Mikus, M. 1978. Study of the mutual relationships between dimensions of the udder with regard to improvement of sheep for machine milking. In: Proceedings of the 2nd International Symposium of Machine Milking of Small Ruminants, Alghero, Italy, pp. 102 – 112.

Mikuš, M. and Masár, M. 1985. Die milchemission bei Zigajaschafen während des maschinellen milkens. [Milk emission during machine milking in Tsigai breed]. In: 36th Annual Meeting of European Association for Animal Production, Kallithea – Kassandra, Halkidiki, Greece,pp. 1-6.

Mikuš, M. 1973. Spúšťanie mlieka pri strojovom dojení oviec počas laktácie. [Milk ejection by machine milking throughout the lactation]. Živočíšna výroba **18** 469-474.

Mikuš, M. 1974. Vplyv rôzneho podtlaku na spúšťanie mlieka pri strojovom dojení oviec. [Effect of different vacuum at milk emission during machine milking]. Živočíšna výroba **19** (6) 463 – 470.

Mikuš, M. 1985. Morfologické a funkčné vlastnosti vemena a produkcia mlieka krížencov F1 generácie bahníc plemena cigája s baranmi východofrízskeho plemena [The morphological and functional properties of udder and milk output in the F1 crossbreds of the ewes of the Tsigai breed with East-Friesian rams]. Živočíšna výroba **19** (6) 463 – 470.

Milerski, M., Margetin, M., Capistrak, A., Apolen, D., Spanik, J. and Oravcova, M. 2005. Udder cistern size and milkability of ewes of various genotypes. In: Physiological and technical aspect of machine milking. Nitra, Slovak Republic, pp. 63-69.

Milerski, M., Margetín, M., Čapistrák, A., Apolen, D., Špánik, J. and Oravcová, M. 2006. Relationships between external and internal udder measurements and the linear scores for udder morphology traits in dairy sheep. Czech Journal of Animal Science **51** 383-390.

Rovai, M., Such, X., Caja, G. and Piedrafita, J. 2002. Milk emission during machine milking in dairy sheep. Journal of Dairy Science **80** (Suppl. 1) 58.

Rovai, M., Such, X., Piedrafita, J., Caja, G. and Pujol, M. R. 1999. Evaluation of morphology traits during lactation and its relationship with milk yield of Manchega and Lacaune dairy sheep. In: Milking and milk production of dairy sheep and goat. F. Barillet and N.P. Zervas, EAAP Publication No.95, Wageningen pers., Wageningen, The Netherlands, pp. 107-109.

Ruberte, J., Carretro, A., Fernández, M., Navarro, M., Caja, G., Kirchner, F. and Such, X. 1994. Ultrasound mammography in the lactating ewe and its correspondence to anatomical section. Small Ruminant Research **13** (2) 199-204.

Such, X., Caja, G. and Pérez, L. 1999. Comparison of milkability between Manchega and Lacaune dairy ewes. In: Milking and milk production of dairy sheep and goat. F. Barillet and N.P. Zervas, EAAP Publication No.95, Wageningen pers., Wageningen, The Netherlands, pp. 45-50.

Tančin, V., Mačuhová, L., Kováčik, J., Kulinová, K. and Uhrinčať, M. 2009. Stability of milk flow kinetics in sheep during machine milking. Slovak Journal of Animal Science 42 (Suppl. 1) 110-114.

Tančin, V., Mačuhová, L., Oravcová, M., Uhrinčať, M., Kulinová, K., Roychoudhury,S. and Marnet, P.-G. 2011. Milkability assessment of Tsigai, Improved Valachian, Lacaune and F1 Crossbred ewes (Tsigai x Lacaune, Improved Valachian x Lacaune) throughout lactation. Small Ruminat Research (in press).

Predicting calving time of dairy cows by behaviour sensor

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Abstract

Predicting approaching calving enables proper supervision and work planning in the dairy.
Behavior parameters monitored automatically for each cow (Afiact Plus®), were used to construct a model to predict calving time as a categorical variable. Visual analysis indicated significant changes in most of the parameters on the day before calving.
The model's performance measures were maximum true positives (calving took place within 24 hours) and minimum false alarms. The best results were achieved by the Discriminant Function using as the minimizing variance transformation the ratio between successive days difference to the standard deviation of the average of the previous three days. This yielded 80.95% true positives and 22.80% false alarm. Extending prediction to 48 hours increased accuracy to 90.48% true positives and 15.60% false alarms indicating that automatically recorded behaviour parameters can be used to predict approaching calving.

Keywords: behaviour, lying time, calving, dairy cow

Introduction

The issue of identifying the onset of calving is of growing concern for large dairy farms where adequate labour resources, in terms of man hours and skills, may not be available to adequately supervise cows during calving so that timely intervention can be provided in cases of dystocia. It is common knowledge that the behaviour of the cow changes prior calving and several attempts were carried out to monitor cows' behaviour prior to and during calving in order to characterize changes that can lead to a system that predicts calving. However, these attempts were carried out in individual pens monitoring behaviour by video cameras (Miedena *et al.,* 2009). On dairy farms in Israel as well as in may countries around the world, cows are kept in groups before calving and transferred to individual pens (if at all) after visual observation that calving has started. Therefore, for these dairy farms a different approach is needed to detect approaching calving to assist in herd management. This can be a device that monitors behavioural parameters which is attached individually to each cow and transmits the in a way that on-line analysis of the data can take place.
The capabilities and significance of a behaviour sensor attached to the cow's leg to indicate welfare, health and physiological status was described in several works (Livshin *et al.* 2005, Arazi *et al.,* 2010). It is logical to use such devices for additional management purposes such as an indication of approaching calving. Indeed, preliminary studies suggested just that (Maltz & Antler 2006, 2007, 2008). These studies were based on data acquired by a newly developed behaviour sensor that measures in addition to activity associated with oestrous detection,

accumulating lying time and lying bouts and transmits the data every time the sensor is in the vicinity of an antenna (S.A.E. Afikim®, Kibbotz Afikim, Israel). The first attempt to record behaviour of dry cows prior to calving involved bringing dry cows, fitted with this sensor, once daily to an antenna (in the milking parlour) to download the behaviour data (Maltz & Antler, 2006). In this trial it was demonstrated that behavioural changes could indicate approaching calving up to 24 hours after the last data recording. The capability of this sensor was improved when an antenna was installed in two passages between two parts of the dry cows' pen (Maltz & Antler, 2007). The work was performed so far on small scale in a research dairy and behaviour data were analysed on a diurnal basis. The results achieved, justify an attempt to build a model based on data recorded in a commercial dairy with refined analysis differentiating between day and night behaviour.
The objective of this study are to build a model based on behaviour data recorded by a commercial sensor operated in a commercial dairy to indicate automatically approaching calving under normal commercial conditions.

Materials and Methods

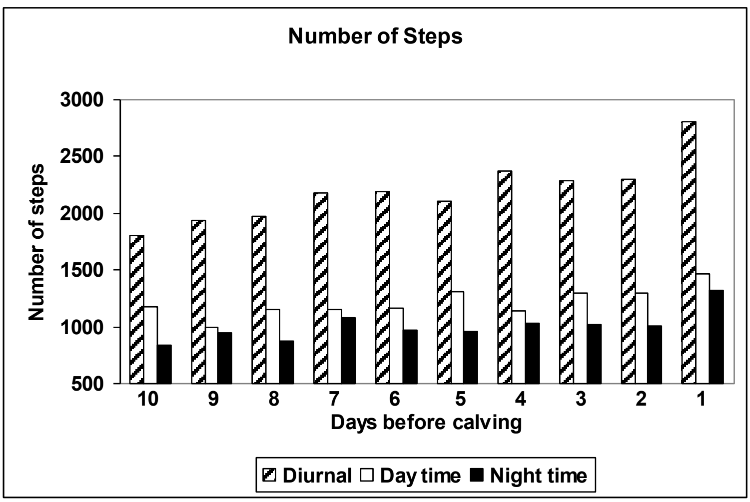
The trial was performed in a commercial dairy in Kibbutz Gezer in Israel milking about 250 cows. The cows are routinely dried off 50-60 days before expected calving and transferred from the milking-cows pen to a dry-cow fully roofed shed. About 2 weeks before expected calving the cows were transferred yet again to the preparation-cow shed which is actually the extension of the dry cows shed. This shed was divided into two sections of different areas linked by two passages. The small part included the feeding alley and was about 1/3 of the total area, and the larger one, about 2/3 of the total area, included the drinking troughs. The cows tended to rest in the larger part and moved to the smaller one when wanting to feed, but lying down in the small yard was not uncommon. The animals were fed a special preparation-cow mixture every second day in the morning and the scattered food was cleaned up twice daily.
The cows were fitted with behavior sensors (AfiactPlus®). Each passage between the two parts of the shed was equipped with an antenna and every time a cow crossed from one yard to the other (either direction), the accumulated number of steps, lying time and number of lying bouts were downloaded and the cross-over between the different sections was registered. A routine check of the preparation-cow shed (day and night) enabled to record the calving time.
The first stage was visual analysis after enough data was recorded to characterize behaviour trends. This was done after accumulating records of 22 cows and 11 heifers. Paired t-test was applied for differences of successive days. Then the model was constructed on records of 44 cows. The visual analysis and model construction were performed on data recorded 10 days before calving day. There was no difference in behaviour patterns between cows and heifers, therefore the results are presented together for both. The data were analyzed for each cow diurnally and separately for day time (between 07:00 – 19:00) and night time (19:00 – 07:00). This could be done because time of crossing was recorded. In the vast majority of the records it was possible to get the record within ±1 hours of the times defining day and night (see below).

Visual Analysis

The data were analyzed visually and the contribution of each variable to the calving "yes" or "no" decision making was tested separately. The behaviour patterns of cows indicate quite clearly a significant difference in behaviour during the day before calving (Fig. 1,2) in all variables save number of lying bouts (Fig. 2). However, detailed analysis of the lying bouts reveals a more complicated picture of this variable (see discussion). Nevertheless, at this stage we excluded the lying bouts from the model. It can be seen clearly that the biggest change the day before calving is in the ratio between number of steps to lying time (Fig.1) diurnally as well as during day and night time.

Model Design and Performance

Three different classification models were tested to predict approaching calving, Logistic Regression, Linear Discriminant Analysis (LDA), and Decision Tree. Four types of minimization variance transformations were examined, using a training data set which included 70% of the observations. The performance measures were maximum true positives and minimum false alarms. Final comparison was based on the validation data set which included the remaining 30% of observations.
The best model was achieved by LDA using SPSS 17 software (PASW statistics 17.0 release 17.0.2 (March 2009). This model produces dichotomy results for each day i.e. is calving expected "yes" or "no". The model was trained on 70% of the data and tested on the remaining 30%.
At the first stage the decision was taken diurnally after the "night" data were collected for the next 24 hours.



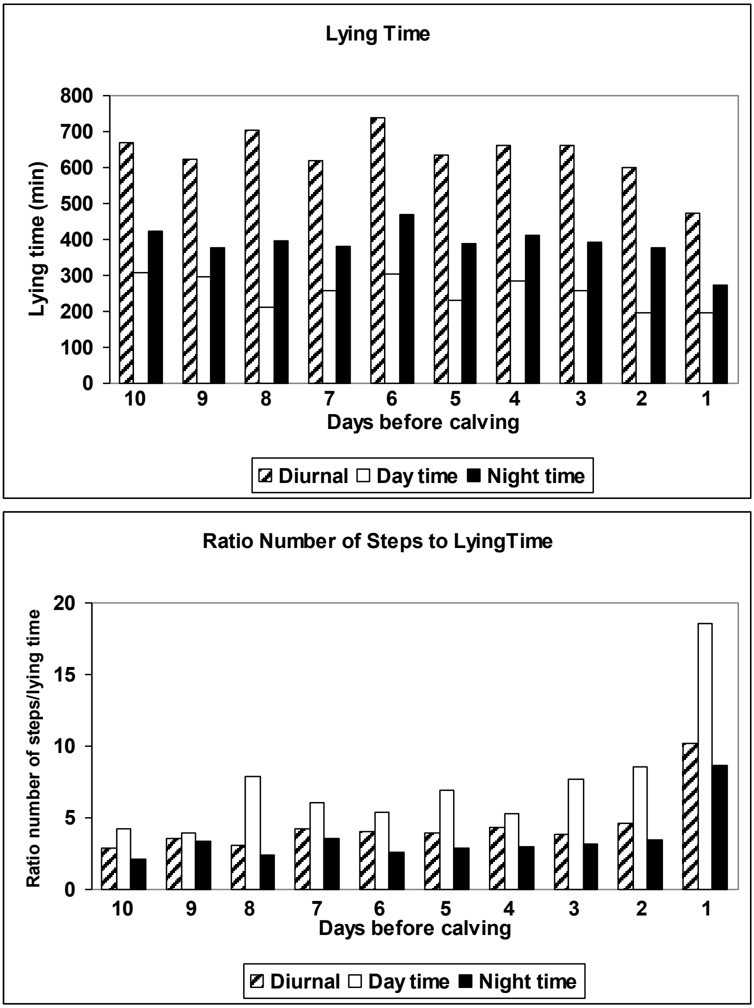


Figure 1. Number of steps, lying time (min) and the ratio between them for 22 cows and 11 heifers during day time, night time and diurnally 10 days prior to calving. The differences between day 1-2 are significantly different (P<0.05) for all variables and all periods.

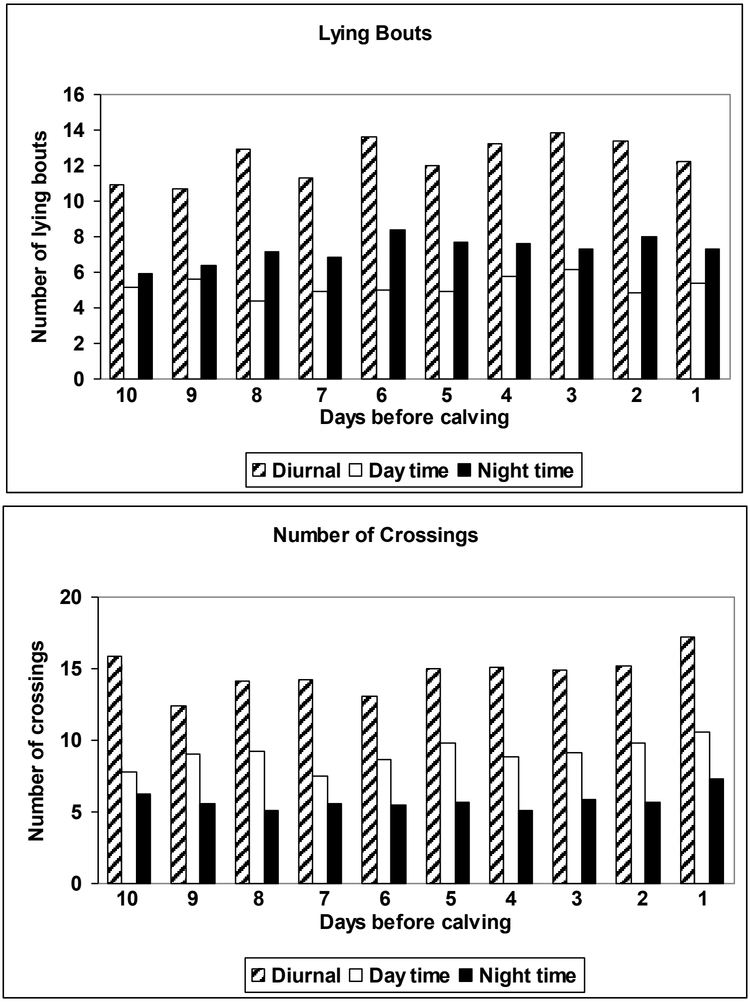


Figure 2. Number of lying bouts, and crossings between the two parts of the shed for 22 cows and 11 heifers during day time, night time and diurnally 10 days prior to calving. The differences between day 1-2 are significantly different (P<0.05) for number of crossings diurnally and night time.

The independent (explanatory) variables were:
$X_{1,day}$ – number of steps during the day
$X_{1,night}$ – number of steps during the night
$X_{2,day}$ – number of lying bouts during the day
$X_{2,night}$ – number of lying bouts during the night
$X_{3,day}$ – lying time(min) during the day
$X_{3,night}$ – lying time(min) during the night
$X_{4,day}$ – number of crossings between the two yards during the day
$X_{4,night}$ – number of crossings between the two yards during the night
$X_{5,day}$ – ratio between number of steps to lying time during the day
$X_{5,night}$ – ratio between number of steps to lying time during the night

Two formulas were produced:

$$-0.182(X_{3,night}) + 0.245(X_{4,night}) + 0.206(X_{5,night}) + 0.124(X_{1,day}) + 0.008(X_{5,day}) - 1.957 \quad (1)$$

$$0.008(X_{3,night}) + 0.04(X_{4,night}) + 0.021(X_{5,night}) + 0.022(X_{1,day}) - 0.707 \quad (2)$$

If (1) ≥ (2) then calving is expected the next 24h.

It can be seen that the variables $X_{2,day}$ and $X_{2,night}$ were not included in the model. Cross validation for the observations left out of the calibration process yielded 61% true positive and 17.6% false positives.
The attempt to apply the LDA for two diurnal decisions one for day time and one for night yielded 60.9% true positive for day time calvings (night time data were used) and 44.4% for night time calvings (day time data were used). This low proportion of true positives is not surprising considering the fact that for each of the two diurnal decisions making only half of the data were used.
The minimizing variance transformation that yielded the best results was the one that actually includes the individual temperament of each cow i.e. the daily differences of each behaviour variable X related to the standard deviation of the average of three days prior to the current day (X_i) as follows:

$$X_i = (X_i - X_{i-1})/std_{\,i-1;i-4} \quad (3)$$

The relative change in the cow's behaviour is a beter predictor than the actual behaviour measurement.
Extending the calving prediction time to 48 hours improved the model's performance for predicting approaching calving to 90.48% to true positives and only 15.58% false positives.

Discussion

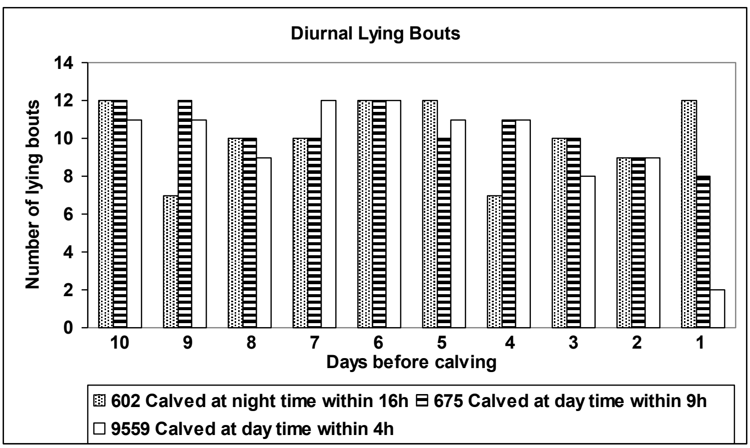
The potential of the behaviour sensor to perform as an approaching calving predictor was demonstrated in several studies (Malts & Antler 2006, 2007, 2008). Increasing activity prior to calving was also demonstrated by Bahr *et al.,* (2007) using pedometers in calving suckling cows. Until now these studies were performed on a small scale in a research dairy. This is the first study carried out in a commercial dairy under commercial routine conditions. The routine practice of this dairy, regarding calving cows, is to transfer calving cows from the dry-cow and preparation-cow accommodation areas to individual straw bedded pens. Unable to predict the calving time, the herdsmen are routinely inspecting the dry and preparation cows and when they see that calving starts they move the calving cow to the individual pen. This is a normal practice in many dairies in Israel and around the world because it is recommended to allow the calving cow a clean and undisturbed environment for the calving process. It is also easier to attend to the cow when there are no other cows interfering with the calving process. However, under the current management conditions it is no wonder that a big proportion of the calves are born in the common dry or preparation-cow shed, especially those that are born at night. Undoubtedly, these dairies will benefit a lot from being able to predict calving for the next 24 or even 48 hours moving all cows expected to calve to the individual pens at their convenience. After all, there is no harm if a calving cow stays additional 24 hours in the individual pen before calving.

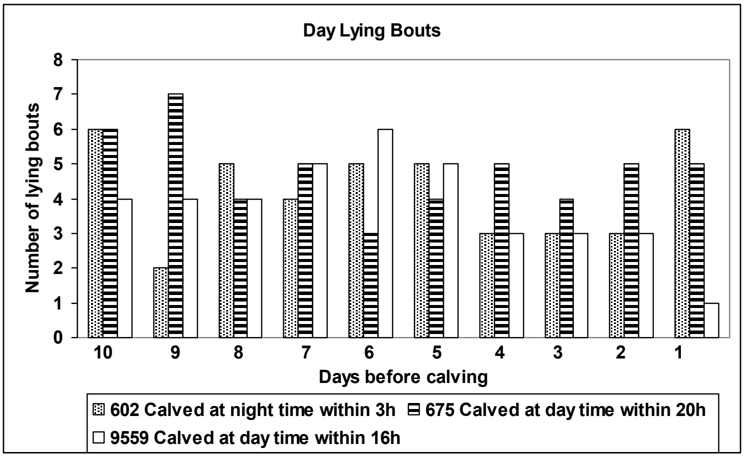
The behaviour data to predict calving have to be analyzed individually in relation to the normal (history) behaviour pattern of each cow. This normalizes the data for individual temperament and social hierarchy. The cows vary in their behaviour patterns of all variables as can be seen in the large standard deviations of the averages as well as in Figures 3 and 4. The solution that was taken in this study was to relate successive days differences to the standard deviation of the previous three days is likely to be a good solution but it was taken because of the routine in the dairy to transfer cows from the dry-cow pen to the preparation-cow pen about 1-2 weeks before expected calving. In this case the transfer itself affects behaviour and taking more than three days as “normal behaviour” might include “adjustment” to the new environment, thus influencing the results. However, in dairies where the cows stay all the dry period in one pen, four or even five days may be used for “normal behavior” evaluation to be used for the minimization variance transformation.

The results obtained individually for day and night time behaviour suggest that this system (sensor-model-software) can be improved considerably. The results of the twice daily decision making suggest that a bigger weight should be put on the night time behaviour data. More data may well improve the model for the twice daily decision making especially for those using night time data for day time prediction of calving as well as for one diurnal decision and that a more sophisticated analysis may incorporate efficiently the “lying bouts” variable into the decision making process.

Behaviour variables of 3 individual cows that are described in Figures 3 and 4 demonstrate the variability between animals in both, routine behaviour and response to approaching calving as well as the problematic attitude to lying bouts. These individual cow data also demonstrate the possibilities that a more sophisticated analysis may be achieved that takes into consideration individual differences in temperament on one hand and individual response to calving on the other. The number of diurnal lying bouts (Figure 3) show that in the day before calving, in one cow (602) it increased from 9 to 12 the second cow (675) decreased from 9 to 8 and in the third cow (9559) dropped from 9 to 2. Obviously these results demonstrate why the number of lying bouts were not included in the decision making process of the model. However, the day time lying bouts, for cow 602 is double in day time than that of the previous three days while that of cow 675 did not change and cow 9559 lay down only once (Fig. 3). For night time yet again a change. Cow 6020 that so far demonstrated an increase in number of lying bouts now (night time day 1 before calving) it is similar to that of the previous night while that of cow 675

decreased. This inconsistency can be explained by two facts: (1) Lying time. We see that for cow 9559 lying time dropped to about 20 minutes (Fig. 4) which reduced dramatically the average lying time of a single bout (Fig. 5) despite the fact that number of lying bouts was reduced the same, to a lesser extent, happened in cow 602 for night time and diurnally. (2) The proximity between the time that the data are analyzed to actual calving time. For cow 602 number of lying bouts was doubled from 3 to 6 because the day data time data were summarized 3 hours before actual calving (Fig 3) while for cow 9559 approaching calving affected the cow entirely different, not lying down at all. The fact that lying bouts is a behaviour variable that is increasing prior to calving in individual pens was already indicated by Miedema *et al.,* (2009). We can conclude that some behaviour variables have to be analyzed in relation to complementary ones such as lying bouts and lying time as well as giving more weight to the period i.e. day time or night time that the data are analyzed.
The need for a downloading antenna dictated the requirement for a passage where the antenna could be located. This allowed an additional behaviour variable indicating restlessness of "crossing" between one side of the pen to the other to be collected. However, this variable is a problematic one. The problem is that the cow might restrict itself just before calving mainly to one side of the accommodation so her restlessness may be expressed in the number of steps but not in the number of "crossings". This happened in several cows even in this study (data not shown) though as a whole cows tended to move from one side of the pen to the other in a way that showed a significant increase during the day before calving. Therefore the weight of this variable in the decision making should be limited taking number of steps as the superior one to indicate restlessness. Anyway, in the case of wireless data transmission this variable will not exist anyhow unless individual computerized concentrates self feeders are used for preparation cows (Maltz & Antler 2008).





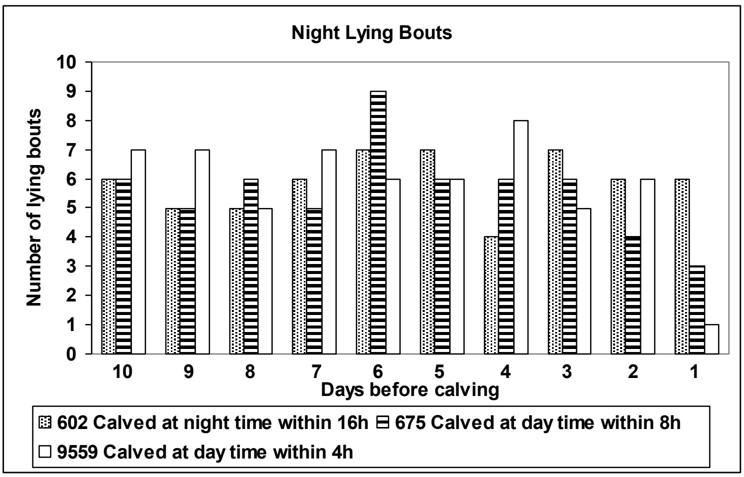


Figure 3. Number of diurnal, day time and night time lying bouts of three cows (602, 675, 9559) in the last 10 days before calving.

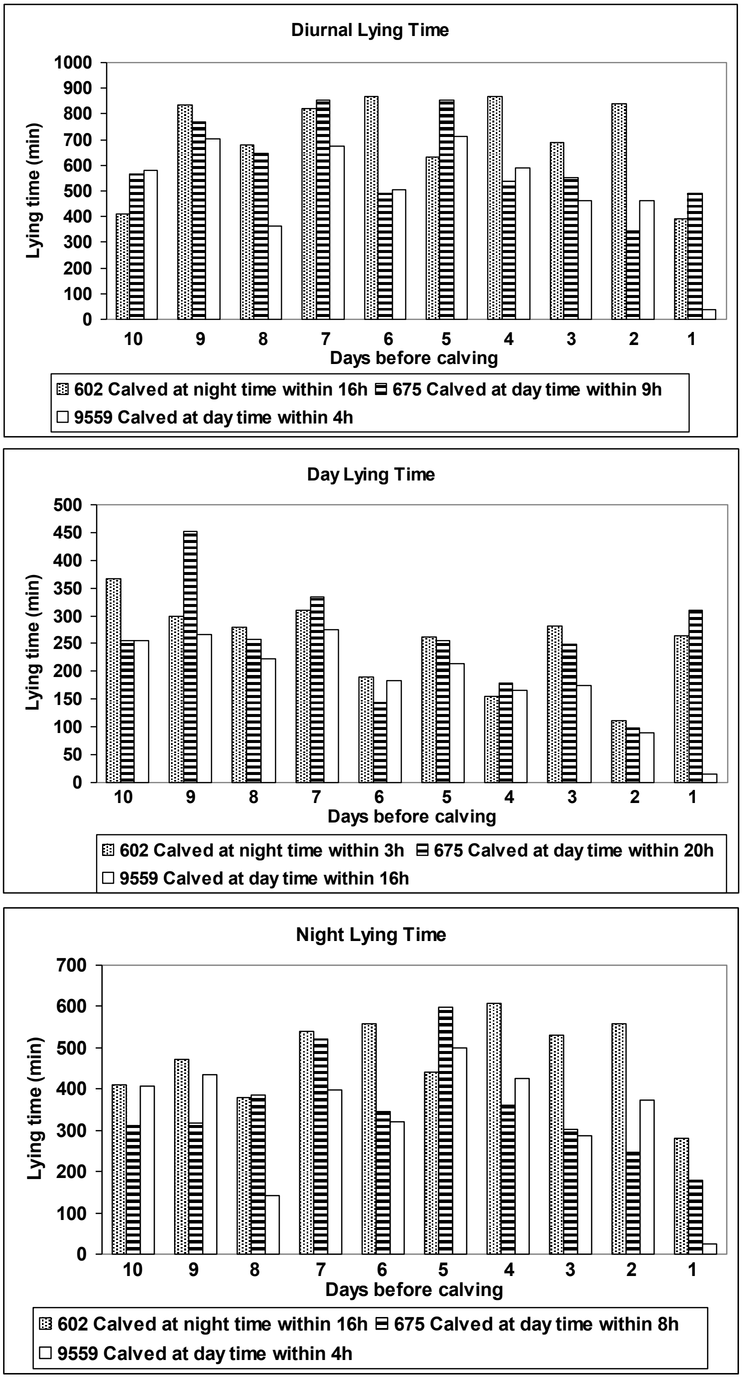


Figure 4. Lying time diurnally, during day time and night time of three cows (602, 675, 9559) in the last 10 days before calving.

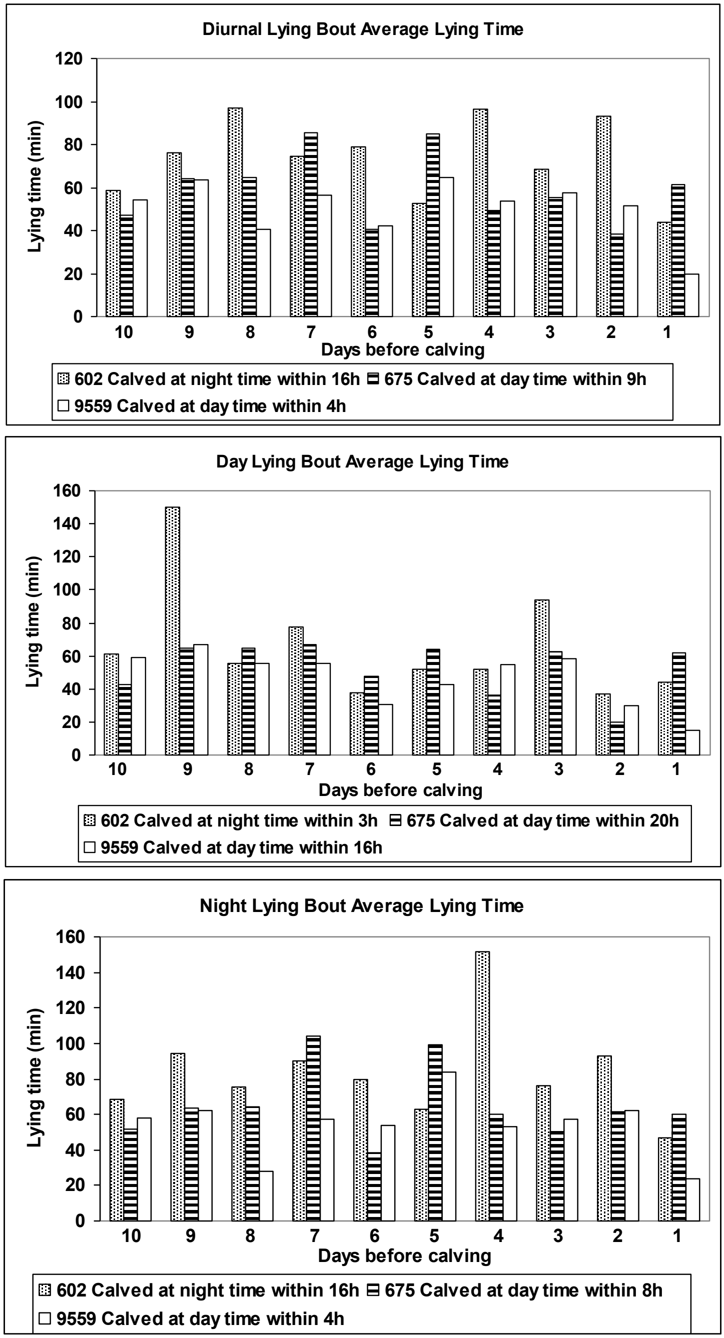


Figure 5. Average lying time of a single lying bout diurnally, during day time and night time of three cows (602, 675, 9559) in the last 10 days before calving.

Conclusions

This study shows that the individual cow behaviour sensor can provide the data required to construct a model that predicts approaching calving of dairy cows kept in a group taking into consideration specifically night or day time behaviour as well as diurnal behaviour. More data and a more sophisticated data analysis may improve this model.

References

Arazi, A., E. Ishay and E. Aizinbud. 2010. The use of a new sensor (Behaviour tag) for improving heat detection, health and welfare monitoring in different rearing conditions. ICAR 37th Annual Meeting, Riga, Latvia 31 May - 4 June, 2010

Bahr, C., Kaufman, O. and K. Schebe. 2007. Sensor based analysis and modeling of moving and resting behaviour in suckler cows before, during and after calving. Proc. Precision livestock farming '07, Edited by: S. Cox, Wageningen Academic Publishers, pp. 269-275.

Maltz, E. and Antler, A. 2006. Behaviour sensor to detect approaching calving of the dairy cow. EurAgEng 2006 World Congress, Bonn, Germany, September 3-7, pp507-508.

Maltz, E. and Antler, A. 2007. A practical way to detect approaching calving of the dairy cow by a behaviour sensor. Proc. Precision livestock farming '07, Edited by: S. Cox, Wageningen Academic Publishers, pp. 141-146

Maltz, E. and Antler, A. 2008. Detecting calving time of dairy cows by analyzing activity and feeding behaviour in computer controlled self-feeders management. Proc. CIGR international conference of agricultural engineering, xxxvii congresso brasileiro de engenharia agrícola – conbea 2008, Brazil, August 31 to September 4, 2008.

Miedema, H.M., Macrae, A.I., Dwyer, C. and Cockram, M.S. 2009. Identifying changes in dairy cow behaviour to predict calving. Proc. Precision livestock farming '09, Edited by: C. Lokhorst and P.W.G. Groot Koerkamp

Design and Development of an Automated Radio Frequency Identification Based Sheep Sorting System

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Abstract

An automated radio frequency identification based sheep sorting system prototype was design and developed. Due to high technology improvement and quality demand in livestock farming and today's rapid population increase better animal handling management and production systems are required to support and sustain food production. Automated sheep sorting system provides up to date information of the flock's health and growth rates thus providing the farmer with a tool from which better management decisions can be made. The overall goal of this study was to design and develop a mobile RFID based sheep sorting system to identify, weigh and separate sheep into four different camps (Medical attention, Ready for market, Require Feed, Faulty ear tags). A data acquisition system (RFID) was developed to collect and monitor health and growth status of 200 flocks of sheep. The results indicated that the time to identify, weigh, a sheep is five (5) seconds and on average the system sort 857 sheep in an hour. Each time a sheep goes through the sorting systems, information is captured and recorded in the system, to assist in making future managerial decisions.

Keywords: RFID, Data acquisition, Sorting systems.

Introduction

An animal handling facility is a collective name for structures and activities where livestock are kept, controlled, fed and safely gathered (Grandin, 1997a). There are five essential components commonly found in animal handling facilities: sorting pens, working area, loading platform, crush passage and crush pens (Hargreaves and Hutson, 1997). According to Grandin (1997b) each component of the animal handling facilities should be designed to manage and control livestock with little or no stress.

Hargreaves and Hutson (1997) define animal drafting as an activity or process whereby animals are sorted into different categories as desired by a farmer. Drafting is a technique used in animal handling as a managerial tool used to identify animal needs, record and keep information in livestock production processes (Grandin, 1997b). This technique is also referred to as sorting. Animals are sorted into categories of similar characteristics, for example animals ready for market, animals which need medical attention, mature and young animals.

Manual animal drafting involves labourers sorting one animal at a time into the desired category (Anderson and Edney, 1991). This procedure of drafting is not only tiring and time consuming, it may cause serious injuries to sheep and handlers. Hence the labour required is intensive and not comfortable for both animals and handlers (Maton *et al.*, 1985).

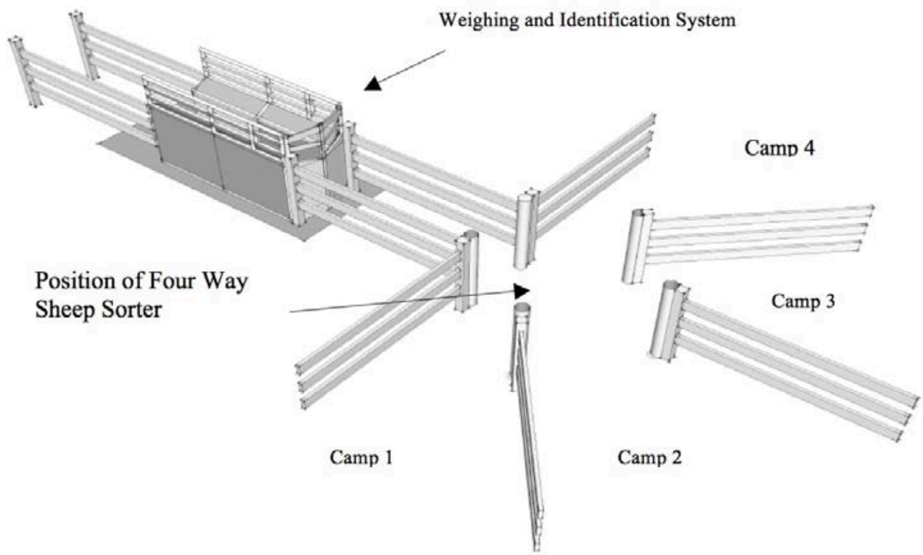
Over the years the manual sorting technique has advanced to automatic sorting systems (Pinna *et al.*, 2006). An automatic drafting system is a combination of devices that operates independently in response to an input. Drafting systems are commonly developed for precision livestock farming to make collection of data easier, less labour intensive and more accurate with the use of Radio Frequency Identification (RFID) technology (Hecton, 2009).

According to Ngai *et al.* (2008), RFID technology was developed as part of an internet organization system with a mission of positive influence to the supply chain processes. This technology is used in various areas for different purpose (Ngai *et al.*, 2008). For the purpose of this document application of RFID technology in animal handling will be demonstrated.

This document will focus on the sorting mechanism of the above mentioned animal handling components. The main objective of this project was to design, develop and evaluate an automated radio frequency identification based sheep sorting system.

Materials and methods

Figure 1 depicts an overview of the complete sorting system. The four way sheep sorter will be positioned as shown in Figure 1. With an idea of how the system will look it was possible to design and develop a layout configuration which fit into the system.



Technical requirement

The technical requirements of the sheep sorter design were broken down into the following:

- Receive a command sent from Radio Frequency Identification (RFID) and weighing system.
- The compressor power supply unit requires 220 V mains.
- The sorting system should occupy an area less than 1 400 × 1 400 mm.
- The total time taken to sort the sheep should be 5 seconds.
- The sorter should be lifted by at least two farm labourers. Assuming that a farm labourer can dead lift at least 50 kg (Men's Fitness, 2009). The sorter should not weigh more than 100 kg.
- The pressure exerted by the pneumatic cylinder should be less than the yield stress of bone, 113 MPa (Reed and Brown, 2001).
- The highest point of the gate should be at least 900 mm high.
- The width of the path through which the sheep moves should be between 500 mm to 640 mm.
- The structural parts of the sorter should be able to support a 150 kg person sitting on it. This utilises an average mass of humans of 87 kg and a safety factor of 1.7 (NHANES, 2009).

Steel design and Works

The design considerations and the technical requirements of the system were taken into account during the design phase. This section provides the background to the assumptions made and the summary of steel types and sizes decided upon for construction purposes. refer to

Layout Configuration Design

The layout configuration was designed to ensure correct dimensions and to give shape to the sorter. The physical and behavioural characteristics of the sheep played a vital role in this layout design. The sheep sorter covers an area of about 1.4 m^2 and distance of 640 mm between posts, which will ensure ease of transport of the complete structure.

Gate and Mountings

The sorter consists of three gates of 1045 × 800 mm, and two identical 600 × 800 mm, to facilitate the opening and closing of the desired camp. Detailed structural design and analysis is presented in this section. A 42 × 2 mm round steel pipe is satisfactory and was used to construct the gate frames.

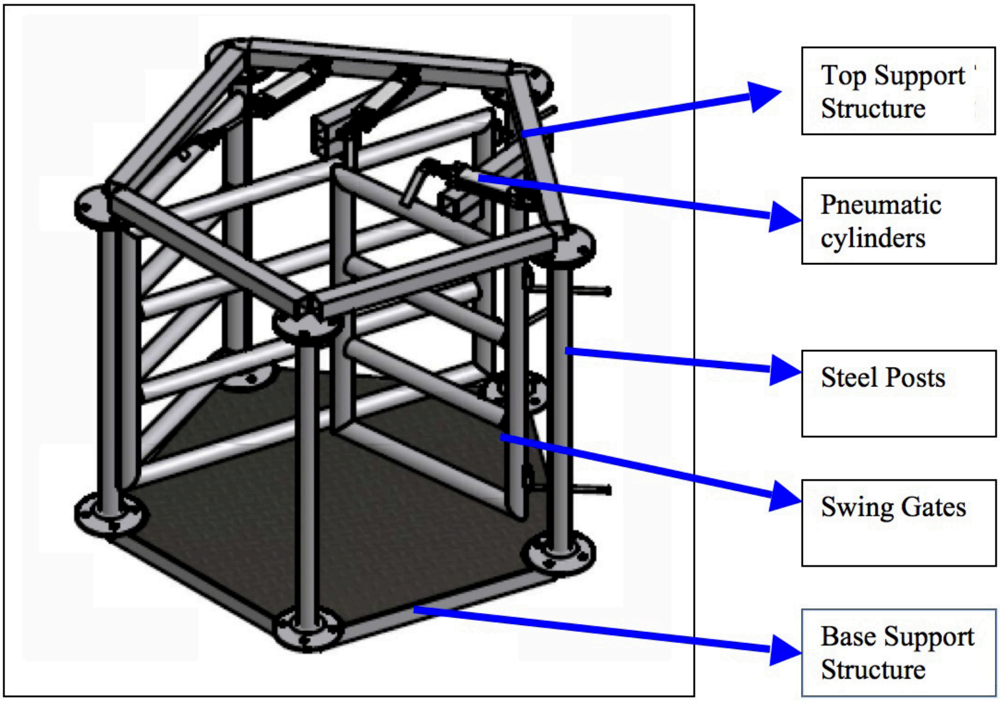


Figure 1. Isometric view of the sheep sorter

<u>Base and Top Support Structure</u>

The support structure is divided into two elements, the top support and the base support. To create symmetry and simplicity, the two elements were designed as similar as possible. The maximum load experienced by either the top or base support structure was used in the sizing of the square tubing sections. The design attributes of the base and top support structure are as follows.

- Load: 1500 N vertical plane, 2000 N horizontal plane.
- Steel Section: 50 × 50 × 2 mm square tubing
- Tread plate: 4.5 mm diamond patterned tread plate
- Welds: 8 mm
- Cylinder mounts: M6 bolts onto the inside of the square tubing
- Panel mount: M6 bolts onto the square tubing and shelving steel, above gates

Electronic Design

Sensors

To ensure safety of the sheep though the sorter, sensors are incorporate in the sorter. A rector reflective sensor was recommended and was used to detect the presence of the sheep in the sorter.

Pneumatics

Pneumatic cylinders were used to drive the gates of the automated sheep sorter. The moment of inertia of the gates and the required speed of the gates were used to check the suitability of the suggested cylinder size. Autodesk Inventor was used to determine the stoke lengths of the cylinders for each gate. Air Consumption V 1.5.0, supplied by FESTO was used to determine the air consumption of the three cylinders. A summary of the pneumatic system is listed as follows

- 2 × 32 mm bore, 200 mm stoke pneumatic cylinders (short gates)
- 1 × 32 mm bore, 150 mm stoke pneumatic cylinders (long gate)
- > 5 L compressor
- 1 × filter pressure regulator
- 3 × double acting valves

Control interface

A Programmable logic control (PLC) was used to automate the sheep sorter. The PLC comes with protective external and internal device. The selection of the PLC and it protective devices was based on the information on the number of inputs and outputs commands from the sorting systems. These are the types and specification of each protective device:

- 20in and 14out programmable logic control,
- SBVS 08042 24 V DC power supply,
- G2RV SL700 24 V DC interfaces Relay,
- single pole circuit breakers,
- end terminals, and
- Power consumption including compressor = 1.676 kW.

Procedure for measuring weight

Sheep are weighed for many different purposes in addition to recording growth. Sale price is based on weight and live weight has a direct relation to the profitability of the enterprise. Knowledge of animal weight is also essential for determining the dosage level of some drugs and the amount of feed to be given to the animal. For this research a manual scale was used to determine the weight of the sheep and it was manually punched into the sorter controller as an input into the PLC.

Method of Evaluation

During the test the following parameters and objectives were tested:

- The steel structure of the automated sheep sorter will be examined to ensure that there are no sharp or protruding edges that could cause serious injuries to either sheep or handlers.
- The pressure exerted by the gates closing on the animal was measured.
- The time taken to move the gates was measured to determine the rate of sheep sorting.

Results and discussion

The field test was conducted at Ukulinga Research Farm of University of KwaZulu-Natal (UKZN) in September 2009. The test took place at the Livestock handling facilities of the farm, where ten sheep were requested. The team was given a go-ahead of using those sheep by Mss Marion Young from the School of Animal Sciences.

The sorter was placed and connected to a sheep handling facility which had an automated lift gate at the exit point of the race. The lift gate was used to ensure that only one sheep can enter the sorter at a time.

<u>Safety check</u>

The sorter detects the presence of the sheep as it enters as well as it leaves. The field safety check confirms that stressed sheep try to escape through the smallest passage as quick as possible. As results some of the sensors were knock by the sheep and the communication between the transceiver and receiver was disturbed in the initial tests. However Dr Marion Young from School of Animal Science (UKZN) confirmed the contentedly flow of Marino sheep through the sorter at the end.

Figure 2. Field experimental set-up for sorting sheep

Sorting time

The time taken for a sheep to enter and leave the sorter is depended on the release of the sheep into the sorter. It took four to five seconds for a sheep to enter the sorter after the camp was selected and ready for a sheep. As a result the total time to sorter a sheep is calculate by adding the time measured to move the gates and the time for a sheep to enter and leave the sorter.

It takes a sheep 0.72 seconds for a sheep to enter and leave the sorter. The total to sort a sheep is calculated by summing the time taken to open camp 4, time to release a sheep and time for a sheep to enter and leave the sorter. Camp 4 is only camp where both the long gate and short will move to open the camp, so it takes the longest time compared to the other three camps to sort a sheep into camp 4, hence is used for calculations. The total time to a sort a sheep is 4.17 seconds, as shown in Table 1. This sorter sorts 857 sheep in an hour.

Table 1. Total time to short a sheep

Total Time To:	Open Long Gate	Open Short Gate	Release Sheep	Enter and Exit sorter	**Sort Sheep**
Time (s)	0,80	0,67	2,00	0,70	**4,17**

Social and environmental impact

The automated sheep sorter may change the dynamics of sheep handling facilities. An activity that used to occupy at least two farm labourers can now be fully automated and at the same time provide comprehensive up to date information, increasing the efficiency of production. The relatively small scale of the automated sheep sorter means that the environmental impacts associated with it will not cause serious damage. The impacts however should be identified and attempts should be made to minimise them.

A positive social impact of the sheep sorter is the potential increase in the productive capacity of a sheep farm. This increase in production may increase competition in the mutton industry and thus help to decrease the price of mutton.

The environmental impacts associated with the automated sheep sorter are noise pollution developed by the pneumatic compressor and the use of fossil fuels in is construction and operation. The pneumatic compressor should be installed in a sound proof box so as to minimise the noise during operation. To reduce the carbon foot print of the sheep sorter future models should use recycled and environmentally friendly materials. In the case of a sheep feedlot the farmer should consider using the sheep faeces to produce biogas and hence environmentally friendly electricity to power the automated sheep sorter.

Conclusion and Recommendations

The automation of sheep sorting may become an essential aspect of sheep handling facilities in the future. Automated sheep sorting provides up to date information of the flock's health and growth rates thus providing the farmer with a tool from which better management decisions can be made. The automated sheep sorter that was designed, constructed and tested in this

report has attempted to meet the requirements of the ARC as well as the technical requirements of automated sheep sorters.
It was found that the four way automated sheep sorter was able to sort 857 sheep per an hour.

There are however areas which will require further adjustments and changes. These have been recommended to the people involved in the future of the project. The integration of the weighing and identification device will most certainly provide further design challenges. With the use of a PLC in the electronic control of the automated sheep sorter these challenges should be more easily overcome while remaining cost effective.

The client and engineering requirements of the project were met however there are some areas of the project which can be further looked at and improved for future research. The following are recommendation to those identified areas:

- The sheep sorter is constructed of large steel sizes and it is believed that the size of the steel can be reduced and still maintain the project requirements much better. This will result in weight and size reduction of the sorter; therefore it will be easier to transport.
- The hinging mechanism of the gates can be changed to reduce friction when opening and closing. Less friction and weight when opening the gates will result in less force to drive the gates, hence less power consumption. Bullet hinges can be a solution to this area.
- The gate cylinders of the sorter are driven by single acting pneumatic valves, In case of power failure the gates will move back to their default positions irrespective of the presence of a sheep inside the sorter, this can result in a sheep being knocked and hurt by the gates. This can be avoided by the use of a double acting pneumatic valve.
- Entry and exist sensors must be better protected against being knock by a sheep.

Acknowledgements

This project was funded by the Agricultural Research Council-Institute for Agricultural Engineering and RG Burton Controls. Resource availability and smooth flow of the research was made possible through HOD of School of Bioresources of Engineering and Environmental Hydrology (BEEH) Prof JC Smithers and Senior lecturer Mr LF Lagrange of BEEH at University of KwaZulu-Natal. Without the above mentioned contributions the project would not have been realised

References

Anderson, RS and Edney, ATB.1991. Practical Animal Handling. Library of Congress Cataloging-in-Publication Data, Toronto, Canada.

Breedt, HT. 2004. Manual on Sheep Facilities. ARC- Institute of Agricultural Engineering.

Grandin, T. 1997a. The design and construction of facilities for handling cattle. Livestock Production Science 49:103-119.

Grandin, T. 1997b. Mangement and Economic Factors of Handling and Transport. In:ed. Grandin T, Livestock Handling and Transport, Chapter one, 1-9. CAB International, New York. USA.

Grandin, T. 2004. Sheep Housing and Handling. In:ed/. Grandin T, Farm Resources, Facilities and Equipment, Chapter two, 10-20. CAB International, New York. USA.

Halstead, P and Collins, P. 2002. Sorting the Sheep from the Goats. Archaeological Science 29(2002): 545-553.

Hargreaves, AL and Hutson, GD. 1997. Handling systems for sheep. Livestock production science 49:121-138.

Hecton. 2009. Hecton Products Ltd - Weigh Crates. Available from: http://www.hecton.co.nz/index.php?pageLoad=9. [Accessed 3/1/2009].

La G Matthee, JF. 1990. Farm Fencing. ARC- Institute of Agricultural Engineering. South Africa.

Lambooij, E. van't Klooster, CE. Rossing, W. Smits, AC and Pieterse, C. 1999. Electronic Identification with Passive Transponders in Real Calves. Computers and Electronics in Agriculture 24:81-90.

Maton, A. Daelemans, J, and Lambrecht, J. 1985. Housing of Animals. Elesevier Science Publishing Company INC, New York, USA.

Ngai, EWT. Moon, KKL. Riggins, FJ and Yi, CY. 2008. RFID research: An academic literature review (1995-2005) and future research directions. Production economics 112:510-520.

Pinna, W. Sadda, P. Moniells, G and Ribo, O. 2006. Electronic Identification of Sarda Goats Under Extensive Conditions in the Island of Sandinia. Small Ruminant Reserch 66: 286-290.

Grandin T, Livestock Handling and Transport, Chapter one, 1-9. CAB International, New York, USA.

Indoor concentrations of CO_2 and NH_3 in a pig fattening barn in Beijing, China

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Abstract

In order to extend the information about greenhouse gases and ammonia (NH_3) originating from pig farms in peri-urban areas of Beijing, China this study quantified the indoor gas concentrations of carbon dioxide (CO_2) and NH_3 in a pig fattening barn from an intensive pig farm situated in the Shunyi District, Beijing. Indoor CO_2 and NH_3 concentrations as well as temperature (T°) and relative humidity (RH) were continuously measured by using a multiple data acquisition device with a data logger. The results showed moderate diurnal fluctuations of CO_2 and NH_3 concentrations. CO_2 ranged from 1762 to 2556 ppm and NH_3 ranged from 19 to 29 ppm, respectively. T° and RH diurnal patterns did not show a significant influence on the concentration changes of CO_2 and NH_3.

Keywords: Carbon dioxide, ammonia, pig farm, China.

Introduction

China is the largest pig production country in the world, with approximately 50% of the world pig output (Mendoza-Huaitalla, *et al*., 2010). China can be divided into six pig production zones: Middle and lower reaches of the Yangtze River, North China, Northeast China, Southeast China, municipalities such as Beijing, Tianjin and Shanghai and other 10 provinces (Wang & Xiao, 2008). In Beijing, 16 districts are found and livestock husbandry is mainly practiced in 12 of them. Shunyi District represents a significant share (43%) of the total Beijing's pig production and it is well-placed as the dominant county in animal husbandry (Sun, 2009).
The fast development of livestock farms has brought environmental burdens through the accumulation of animal wastes and especially it has increased the problems of air pollution in the animal buildings affecting human and animal health and welfare (Wang & Zhang, 2001; Hinz & Linke, 1998). As a fact, indoor / outdoor air quality in animal farms has declined and currently, it is far beyond the thresholds established by the health standards for livestock and farmers (Wang & Zhang, 2001). The effects of NH_3 and CO_2 concentrations on man and livestock are important parameters to consider within the livestock buildings. NH_3 production in the animal houses is mainly emitted from the manure while the main sources of CO_2 production includes CO_2 produced by the animals and CO_2 also emitted from manure. CO_2 production from livestock can be derived from its energy metabolism rate, which is related to feeding level and nutrient composition of the diet (Pedersen, *et al*., 2008).
This study aimed to obtain preliminary results regarding the concentrations of CO_2 and NH_3 in a barn for growing-finishing pigs during the summer days in order to extend the information concerning gases concentrations in an intensive pig farm from Beijing.

Material and methods

Housing

The pig barn dimensions were of 50 m long, 8 m wide and 2,4 m high extending from west to east with two rows of pens separated by a central hall of 1 m wide. The ventilation system was of natural type in which 16 windows on both, southern and northern walls were found. During the measurement 260 fattening pigs (ca. 100 kg each) were housed in the barn. The pig farm was characterized by the manure management system denominated "gan qing fen" or "cleaning the manure dryly", in which the pig manure was manually collected twice a day. Feeding and watering regimes were basically adlib (unrestricted access). Feeding followed a phase structure due to the change in nutrients requirements when pigs grow. Pig diets consisted of corn, wheat, soybean meal, fish powder, compound premix and lysine. For further detailed descriptions see a previous publication (Mendoza-Huaitalla, *et al.*, 2010).

Measurements

A BABUC instrument with its data logger (LSI LASTEM s.r.l., Italy) was employed.
The instrument was provided with 11 channels in where it was possible to connect different thermo-hygrometric sensors. For the aims of this study, CO_2, NH_3, T° and RH sensors were adopted. Operative ranges for CO_2 and NH_3 probes were 0-3000 ppm and 0-50 ppm, respectively. Data on CO_2 and NH_3 were recorded every 1 minute and 3,5 minutes respectively on 16-17 April, 2010. The device was placed at 2 m height in the center of the pig barn. The main sampling point was the center of the building as shown in Figure 1.

Figure 1. BABUC device installed in the center of the pig fattening barn.

Results and discussion

Figures 2 and 3 show the diurnal patterns of the indoor CO_2 and NH_3 concentrations and T° and RH. CO_2 and NH_3 concentrations showed strong fluctuations; while on the contrary; RH and T° presented very low fluctuations. The descriptive statistics of the different variables are given in Table 1.

Table 1. Descriptive statistics of NH_3, CO_2 concentrations, T° and RH in the pig barn.

Items	Range	Mean	Median	SD
NH_3 concentration (ppm)	18,0-28,5	23,7	23,8	2,03
CO_2 concentration (ppm)	1762-2556	2039	1966	221,66
Temperature (°C)	23,0-26,7	25,1	25,5	0,98
Relative Humidity (%)	44,7-60	52,6	52,6	2,79

Two peaks in CO_2 concentrations were observed between 17:30-18:30 pm (see Figure 2) and might be related to the excitement of the pigs during the cleaning events that took place at these times during the two days of measurements. After 18:30 pm a continuous drop in the CO_2 concentrations was appreciated and it may be associated to decrements in pig activity. Indeed, from 23:00 pm (16 April) until 11:00 am (17 April), the CO_2 concentrations remained almost constant and it can be correlated to the fact that pigs were mainly sleeping during the night and very inactive during the following morning.

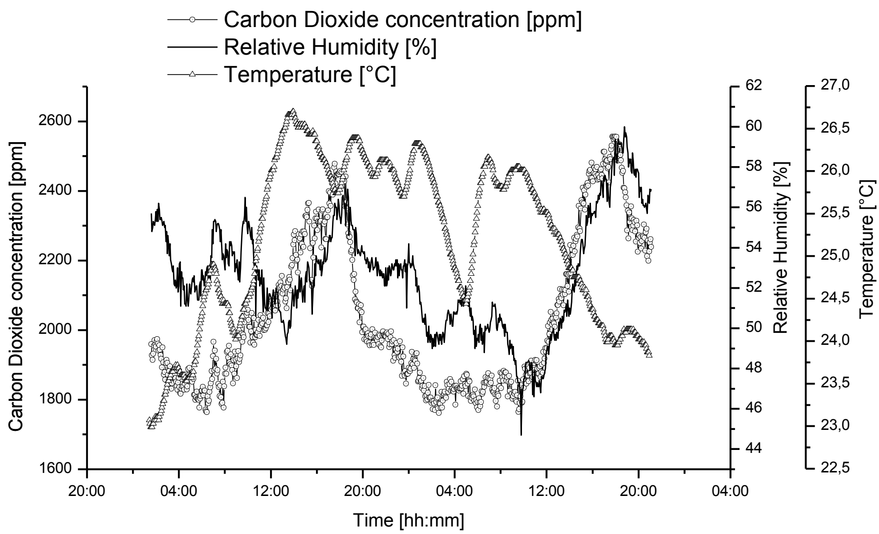

Figure 2. Indoor CO_2 concentrations, T° and RH in the pig barn.

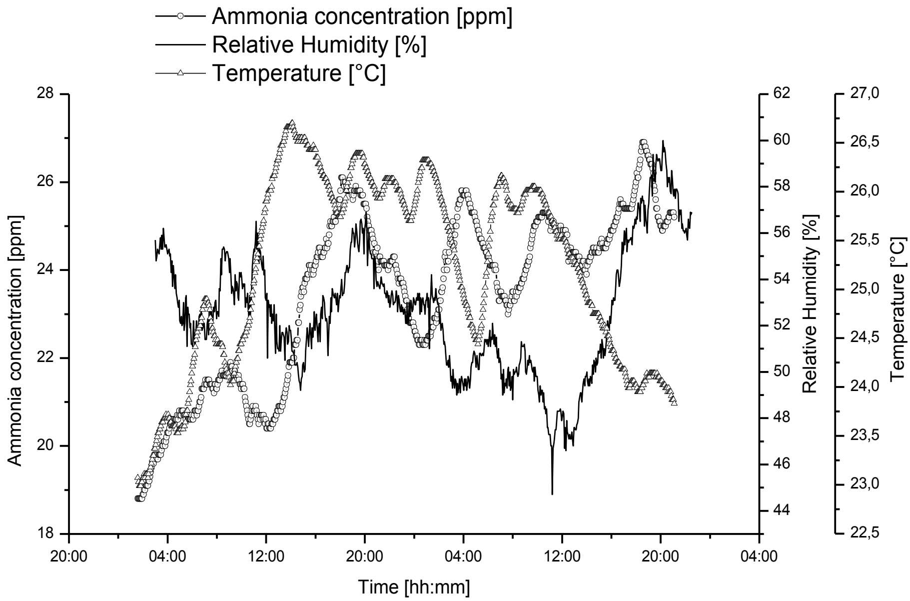

Figure 3. Indoor NH_3 concentrations, T° and RH in the pig barn.

Further, NH_3 concentrations presented similar peaks as appreciated in the CO_2 diurnal pattern. Indeed, peaks between the 17:30-18:30 pm can be also observed in Figure 3. Additionally, a main peak in the NH_3 concentrations was observed from 7:00 to 9:00 am, followed by a drop of NH_3 concentrations from 9:00 am onwards, which might be the result of the manure cleaning or "gan qing fen" performed by the farmers at this time as recorded during the measurements on site. Indeed, the cleaning practice is related to the property of the gases to be water soluble and consequently gases can be rapidly removed from the air as noticed by Chang, *et al.*, 2001.

In general, the continual fluctuations in the NH_3 indoor concentrations during the 2 days of measurements might be related to the constant loading and accumulation of manure on the floors that provided new substrates for biological decomposition as also found by Ni, *et al.*, 2000 from deep pits. Nevertheless, there is a quite difference between NH_3 concentration at the beginning and at the end of the measurements, and between day 1 (16 April) and day 2 (17 April) in contrary to CO_2. In the afternoon of day 2, temperature was falling, all other parameters were increasing. To find some explanations for the measured parameters some knowledge (measurements) of the outside conditions / incoming air / air exchange seems to be implicitly necessary.

Otherwise, T° and RH showed constant fluctuations during the measurements and it is inferred that these variations might be the result of the influence of the outdoor wind, T° and RH patterns which have not been taken into consideration. In fact, it seemed like there is not a close correlation between the gases concentrations and the T° and RH diurnal variations. Though, especially during 17:30-18:30 pm, when the two peaks of NH_3 and CO_2 were identified, high values of RH were also recorded.

Conclusions

CO_2 and NH_3 fluctuations were mainly influenced by pig activity, manure accumulation and cleaning. In order to draw more certain conclusions, it is required to perform long term gas concentrations measurements, to consider the outside conditions such as incoming air / air exchange and the influence of pig respiration, manure decomposition, animal characteristics as well as to replicate the measurements in full and empty barns.

Acknowledgements

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References

Chang, C. W., Chung, H., Huang, C. F. and Su, H. J. J. 2001. Exposure assessment to airborne endotoxin, dust, ammonia, hydrogen sulfide and carbon dioxide in open style swine houses. The Annals of Occupational Hygiene 45(6) 457-465.

Hinz; T. and Linke, S. 1998. A Comprehensive Experimental Study of Aerial Pollutants in and Emissions from Livestock Buildings. Part 1: Methods. Journal of Agricultural Engineering Resources 70, 111-118.

Mendoza-Huaitalla, R., Gallmann, E., Zheng, K. and Hartung, E. 2010. Pig husbandry and solid manures in a commercial pig farm in Beijing, China. International Journal of Biological and Life Sciences (6) 107-116.

Ni, J. Q., Heber, A. J., Diehl, C. A. and Lim, T. T. 2000. Ammonia, hydrogen sulphide and carbon dioxide release from pig manure under-floor deep pits. Journal of Agricultural Engineering Resources, 1(77) 53-66.

Pedersen, S., Blanes-Vidal, V., Joergensen, H., Chwalibog, A., Haeussermann, A., Heetkamp, M.J.W. and Aarnink, A.J.A. 2008. Carbon Dioxide Production in Animal Houses: A literature Review. Agricultural Engineering International: CIGR Ejournal. Manuscript BC 08 008, Vol. 10.

Sun, Z., 2009. Environmental impact assessment (EIA) and developmental strategies on animal husbandry in Beijing. Mid-Term Workshop of the Sino-German project on Recycling of organic residues from agriculture and municipal origin in China. Yangling, China.

Wang, C. F. and Zhang, Y. H. 2001. Elimination of harmful gases at scale pig farms and pig cleaner production implementation. Ecology of Domestic Animal, 22(1) 52-53. (In Chinese)

Wang, J. and Xiao, H. 2008. Pork Production in China - A Survey and Analysis of the Industry at a Lewis Turning Point. Chapter 1: Development of The Hog Industry and its Integration in China, ASEDP. Institute of Developing Economies, Japan External Trade Organization.

Validation of an automatic detection system for lameness in sows

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Lameness in sows is an important issue from a welfare and economic point of view. Early detection of lameness is required to impede unnecessary distress of sows and to avoid huge financial losses due to medical costs and early culling. In general, lameness in sows is evaluated by visual scoring of the gait. However, visual assessment is a subjective technique with low reproducibility especially when performed by observers unfamiliar with the scoring system. The natural stilted locomotion of sows and their instinct to suppress clinical signs of lameness, makes detection even more difficult. Considering the importance of lameness in sows, the need arises for more accurate and objective methods with a high sensitivity/specificity to enable an early and correct detection of this disease. Therefore, a detection system was developed, based on force plate analysis and image processing. The construction, basically a transportable cage, is built in aluminum. After a sow entered, the box is closed and a static measurement is performed. The bottom of the cage contains load cells to analyze the force exerted by each of the four legs. By use of a camera and through calculating specific angles on the derived pictures the posture of the hind legs can be assessed. Based on the data derived from the force plates and camera, specific parameters will be defined and their value in drawing a conclusion regarding lameness will be evaluated. Validation of the detection method is still going on and these preliminary results will be presented at the conference.

Sensor-based monitoring as a predictor of the moment of parturition of dairy cows

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Abstract

This study was carried out to monitor the behaviour in the prepartum period of 76 Holstein dairy cows in the last week of pregnancy by using a sensor-based technology. The reviewed behaviour indicators were lying behaviour and moving activity.
Cows showed differences in their behaviour especially in the last 24 hours before calving.
The change point analyzing, Chow-Test and CUSUMQ-Test method proofed that there is a significant difference in the behaviour between 72 h. to 24 h. a.p. and 24 h. to the time of calving.
It can be assumed that a sensor-based technique combined with different data analyzing methods can be used to predict the time of calving.

Keywords: Sensor / ALT-Pedometer, Monitoring, Prediction, Parturition, Dairy cow

Introduction

An increasing importance has to be attributed to birth monitoring in today's dairy cows. There already exist some systems which are about to alarm the owner of the beginning birth. These, however, have a disturbing effect on the cows and cannot secure a 100 per cent security.
This study was carried out to monitor the behaviour in the prepartum period of 76 Holstein dairy cows in the last week of pregnancy by using a sensor-based technology. The reviewed behaviour indicators were lying behaviour and activity.
The aim of the present study is to find out if the ALT-pedometer is suitable to be employed as birth alarm by measuring the activity and the lying position of dairy cows. ALT is the synonymous from the parameters Activity, Lying and Temperature registered on the animals' ankles.
Cows showed differences in their behaviour, especially in the last 24 hours before the calving.
The change point analyzing, Chow-Test and CUSUMQ-Test method proofed that there is a significantly different behaviour between 72 h. to 24 h. a.p. and 24 h. to the calving.
It is assumed that a sensor-based technique combined with different data analyzing methods can be used to predict the moment of parturition.

Material and methods

Data were collected between the 7^{th} day ante partum and the time of calving from seventy six high-producing dairy cows (22 primiparous and 54 multiparous) in the Centre of Research for Animal Husbandry and Technology of the Regional Office for Agriculture and Horticulture

(Sachsen-Anhalt, Iden). The cows were housed in a free-stall barn. The Indicators lying behaviour and activity were registered using ALT-pedometers.
ALT is the synonymous for the parameters Activity, Lying and Temperature registered on the animals´ ankles. The pedometer fitted on the animal ankles measure changes in activity, the rest periods of the cows, and the outside temperature on the leg. Continuous measurement of animal data is a decisive condition in herd management of dairy cows and plays an important role for statements in oestrus detection and determining animal health. This system plays a central role in the measurements of animal data (Brehme et al. 2008).
Analyses were carried out on the individual animal as an observational unit using the statistical program SPSS 13, Microfit 4 and the methods of Chow-test and CUSUMQ-test (Hashem and Pesaran, 1997).

Results and Discussion

Figure 1 shows the mean (± SD) of daily activity steps for the last 7 days before parturition for primiparous und multiparous cows. The average (± SD) of activity steps during the last week before parturition was 3635 ± 1269 step/d. in all cows.

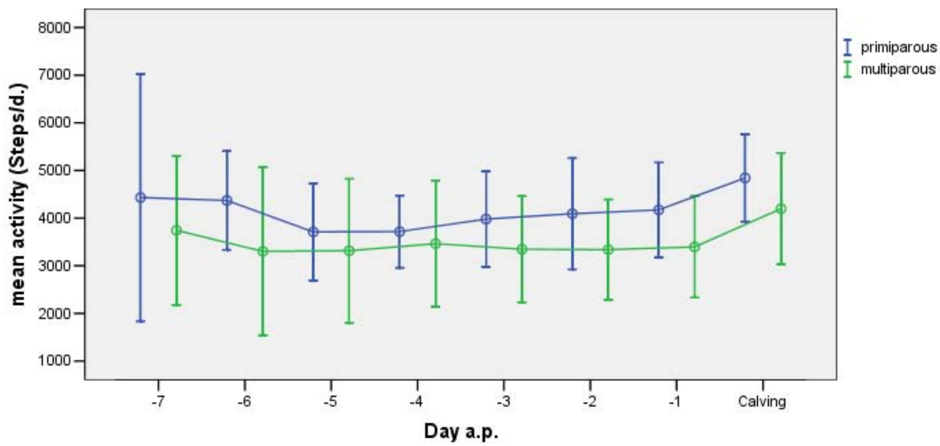

Figure 1. Changes in mean (±SD) daily activity steps during the last week before parturition

The average activity steps (± SD) in the last week before parturition for primiparous and multiparous cows were 4171±1128 steps/d. and 3529±1297 steps/d. respectively. On the day of parturition the mean of activity steps for the primiparous cows was 4844±913 steps/d and for multiparous cows 4197±1170 steps/d. Comparing the activity steps of cows across lactations showed that cows in their first lactation had higher ($P<0.05$) activity steps than cows in later lactations.
Figure 2 shows the change in activity steps of all cows in the last 72 h. before parturition.
The activity of all cows was 178 steps/h in the 72th h. before parturition. Up to the calving the activity steps fluctuated between the minimum value of 128 steps/h.in the 49th h.a.p. and the maximum value of 229 steps/h in the hour of calving. This result stands in agreement with the result of the study of SHAW et al. (1988), in which the activity steps of mares increased by 20%

before birth, and with the study of Bahr 2006, in which the activity steps of cows increased from 5 d. a.p until the parturition.
The high number of activity steps in the day of parturition may be due to the high nervousness before the birth processes. The study by LEHR (1997) showed a high heart frequency in the last 48 h. before parturition. That is a clear sign of high nervousness at the parturition.
This increase of the activity steps is not interconnected with food-search but proves as an accompaniment to the birth-preparations.

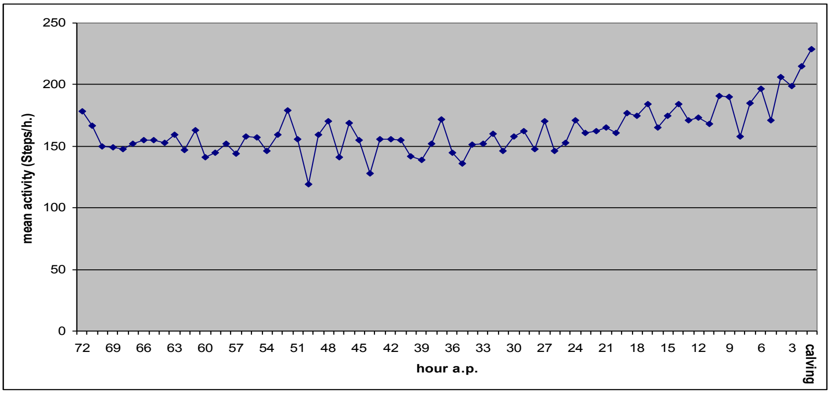

Figure 2. Changes in mean activity steps during the last 72 hours before parturition

The following figure shows the change in CUSUMQ for the activity steps for all cows.

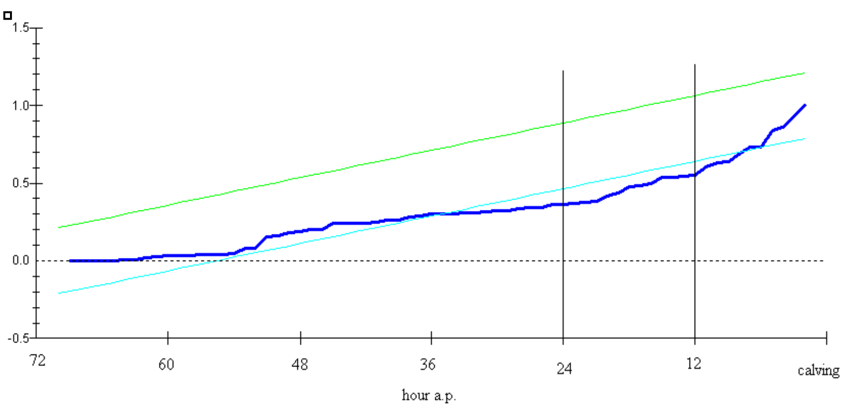

Figure 3. CUSUMQ-test of activity steps in the last 72 hours of parturition

The CUSUMQ curve of the activity steps lies within 5% level of significance from the 72th h. a.p. to 32th h. a.p. and from 8th a.p. to the parturition and outside the 5% level of significance between 32th h and 8th h. a.p. That means a clear break in the curve of activity time.

The following table shows the results of the Chow-Test.

Table 1. Result of the chow-test for the activity steps

hour a.p.	Regression equation	P-Value
72 - Calving	$\hat{Y}_t = 57{,}3821 + 0{,}64879\ Y_{(t-1)}$	
72 – 24	$\hat{Y}_t = 162{,}8774 - 0{,}066748\ Y_{(t-1)}$	
24 - Calving	$\hat{Y}_t = 68{,}6713 + 0{,}63058\ Y_{(t-1)}$	CHSQ =34,0534[0,000] F =17,0267[0,000]
24-12	$\hat{Y}_t = 145{,}4261 + 0{,}15134\ Y_{(t-1)}$	
12 - Calving	$\hat{Y}_t = 103{,}8851 + 0{,}47022\ Y_{(t-1)}$	CHSQ =3,9919[0,136] F =1,9959[0,162]

The Chow test indicates a change point only at the 24th h a. p.

The following Figure shows the course of the coefficient of the regression equations of the Chow-tests for the activity steps from 72 hour until parturition.

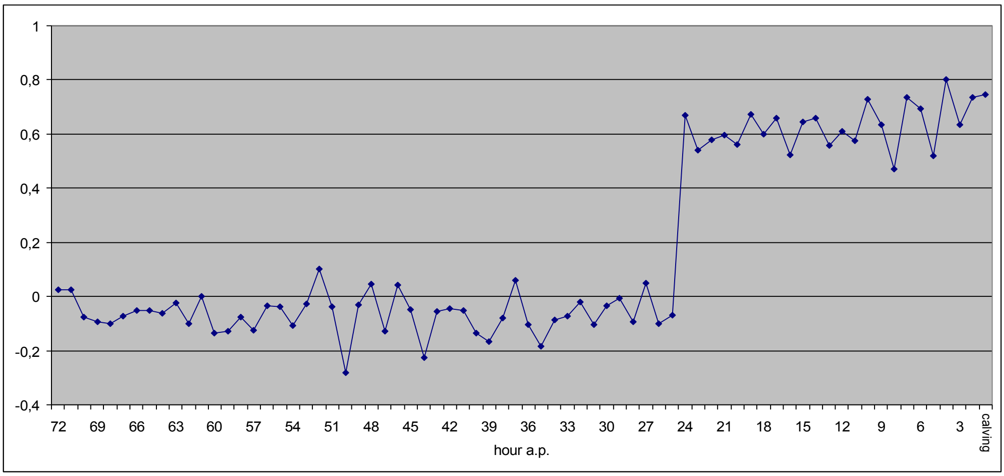

Figure 4. Changes in the coefficients of the regression equation of the chow test for the activity steps

In the time domain between 72th h. and 24th h. the coefficients of the regression equations of the Chow tests vary in the range between -0.3 to +0.1. Between 24 th h. and parturition the coefficients change very clearly, enter the positive range and vary around the value +0.8 up to 3th hour a.p..

Figure 5 shows the mean (± SD) of daily activity time for the last 7 days before parturition for primiparous und multiparous cows.

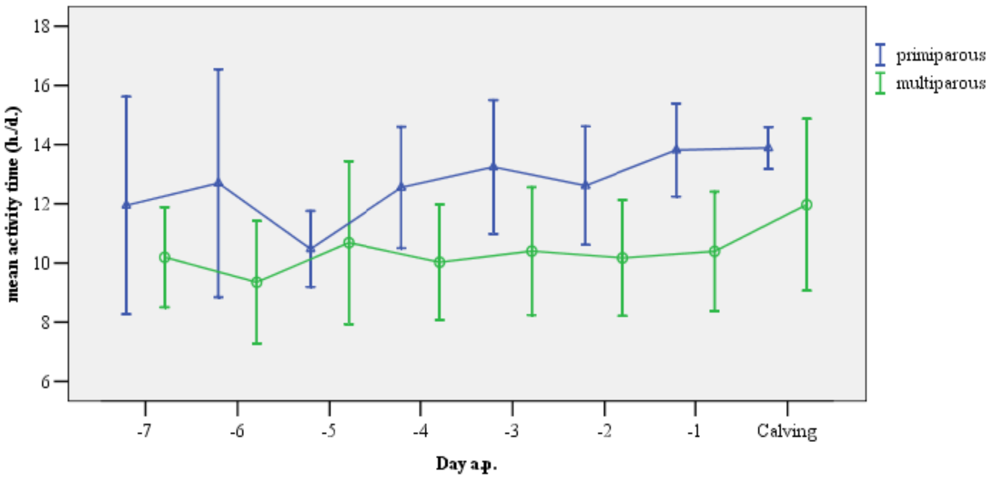

Figure 5. Changes in mean (±SD) daily activity time during the last week before parturition

The average (± SD) of activity time during the last week of parturition was 3635 ± 1269 steps/d. in all cows. The average activity time (± SD) in the last week before parturition for primiparous and multiparous cows was 12.8±2.1 h/d. and 10.5±2.3 h/d. respectively. Thus, primiparous cows are 14% above the herd average and multiparous are 7% below the herd average.

The following Figure shows the change in the activity time for all cows in the last 72 h. before parturition.

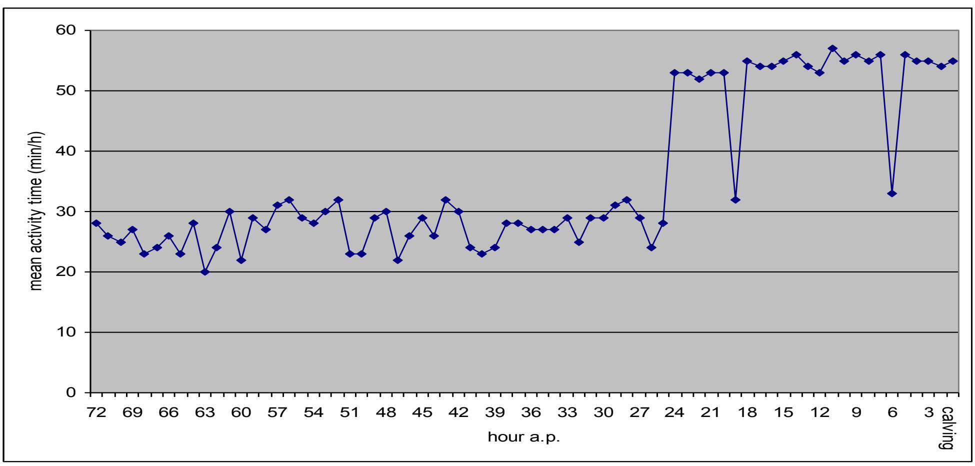

Figure 6. Changes in mean activity time (min/h) during the last 72 hours before parturition

The mean of activity time (activity and standing) for all cows in the 72 h. before parturition was 36 min/h. and between 72th h and 24th h the mean of activity time varied between 25 and 30 min/h and achieved 53 min/h. in the 24 th hour a.p. and about 55 min/h in the last three hours before the calving. The increase in the activity steps and activity time in this study is consistent with the results from SÜSS und ANDREAE (1984) and STRAITON (1991).

The following Figure and Table show the CUSUMQ–curve and the results of the Chow-Test for the activity time of all cows in the last 72 h. ante partum.

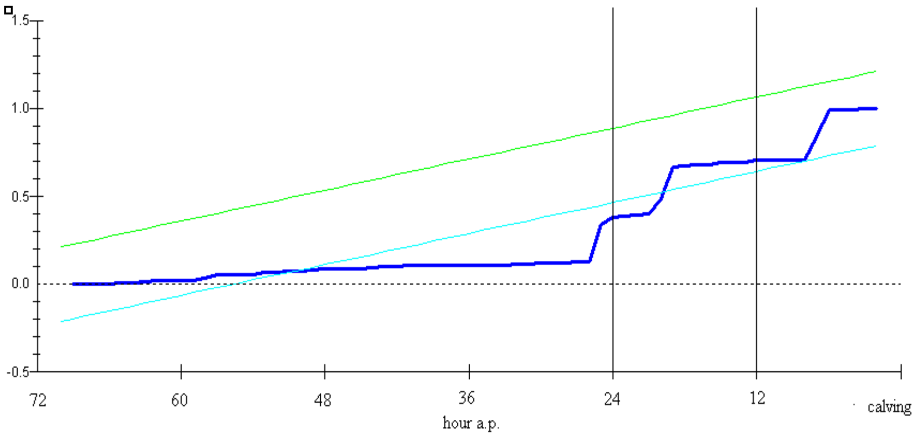

Figure 7. CUSUMQ-test for activity time in the last 72 hours before parturition

Table 2. Result of the chow-test for the activity time

Hour a.p.	Regression equation	P-Value
72 - Calving	$\hat{Y}_t = 5{,}0186 + 0{,}86884\ Y_{(t-1)}$	
72 - 24	$\hat{Y}_t = 22{,}0998 + 0{,}18236\ Y_{(t-1)}$	
24 - Calving	$\hat{Y}_t = 56{,}8777 - 0{,}080923\ Y_{(t-1)}$	CHSQ =93,6117[0,000] F =46,8058[0,000]
24-12	$\hat{Y}_t = 55{,}6938 - 0{,}071226\ Y_{(t-1)}$	
12 - Calving	$\hat{Y}_t = 62{,}1398 - 0{,}16433\ Y_{(t-1)}$	CHSQ =0,37915[0,827] F =0,18957[0,829]

Between the 72th h. a.p. and 46th h. a.p. and in the last 18 hours before the parturition the CUSUMQ-curve of the activity time lies within 5% level of significance and between 46th h and 18th h. a.p. outside the 5% level of significance, showing a clear break in the curve of activity time. The Chow test indicates a change point only at the 24th h a. p.

The following Figure shows the course of the coefficient of the regression equations of the Chow-tests for the activity time from 72th h until parturition.

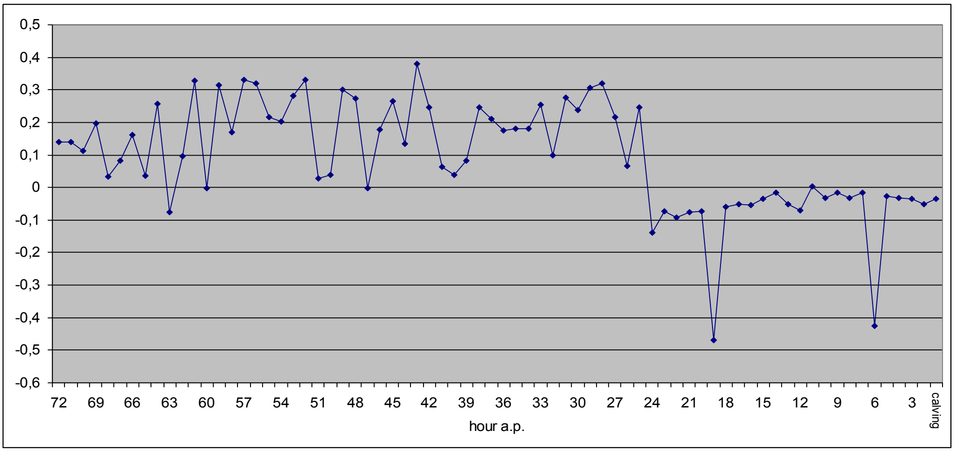

Figure 8. Changes in coefficients of the regression equation of the chow test for the activity time

In the time domain between 72th h. and 24th h. the coefficients of the regression equations of the Chow tests vary in the range between -0.1 and +0.4. Between 24th h and parturition the coefficients change very clearly, become negative and vary around the value -0.1 until 3th hour a.p..

Figure 9 presents the mean (± SD) of daily lying time for the last 7 days before parturition for primiparous und multiparous cows. The average (± SD) of lying time during the last week before parturition was 12.9 ± 2.60 h/d. in all cows. The average lying time (± SD) on the last week before parturition for primiparous and multiparous cows was 11.1±2.2 h/d. and 13.4±2.3 h/d. respectively. On the day of parturition the mean of lying time for the primiparous cows was 10.1±0.71 h/d and for multiparous cows was 12.03±2.90.

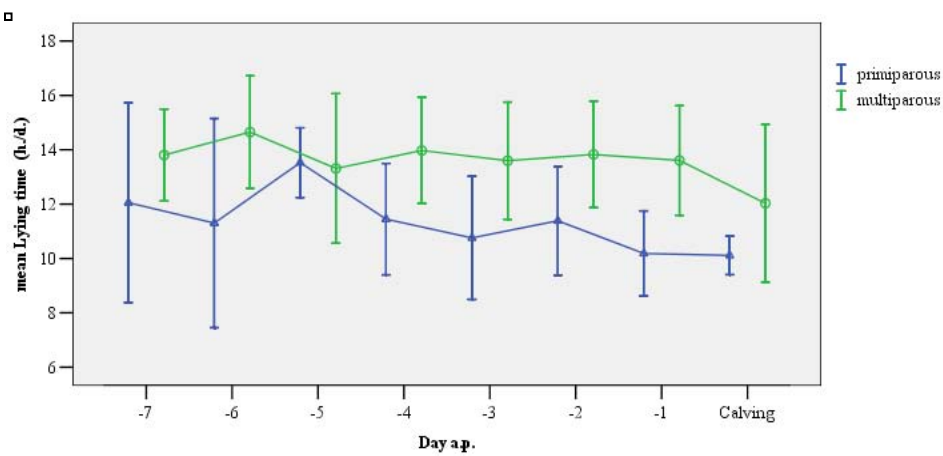

Figure 9. Changes in mean (±SD) daily lying time during the last week of parturition

The information in the literature about the average of daily lying time of dairy cows are strongly inconsistent among each other and vary between 6 and 13 hours per day, significantly influenced by race, age, weight, sex, housing, performance and environmental factors (REITER et. al. 2007).

The following Figure shows the change in lying time of all cows in the last 72 h. before parturition.

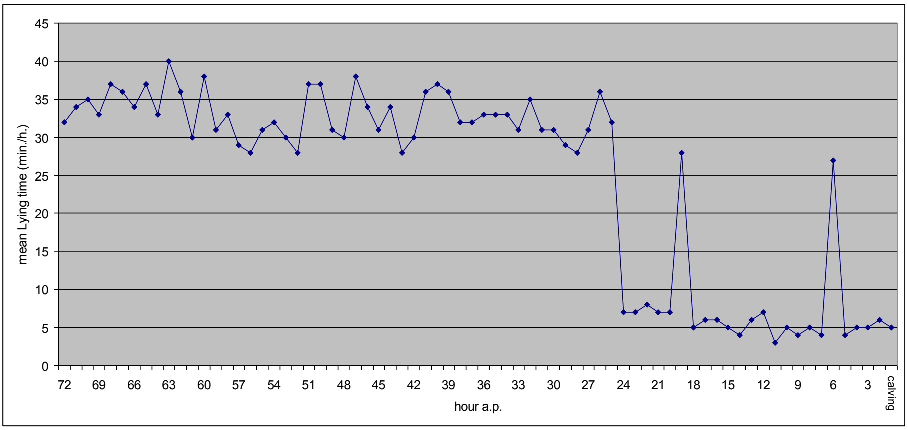

Figure 10. Changes in mean laying time during the last 72 hours before parturition

The average of the lying time in the last 72 hours before calving was 24 min/h. Up to the 24th hours the mean of lying time varied in the range from 20 to 30 min/h. and in the 22-24th the average was 7 min/h and fluctuated in the last 24 hours a.p. and achieved 5 min/h. in the last three hours before calving. The following Figure and Table show the CUSUMQ–curve and the results of the Chow-Test for the laying time of all cows in the last 72 h. a.p.

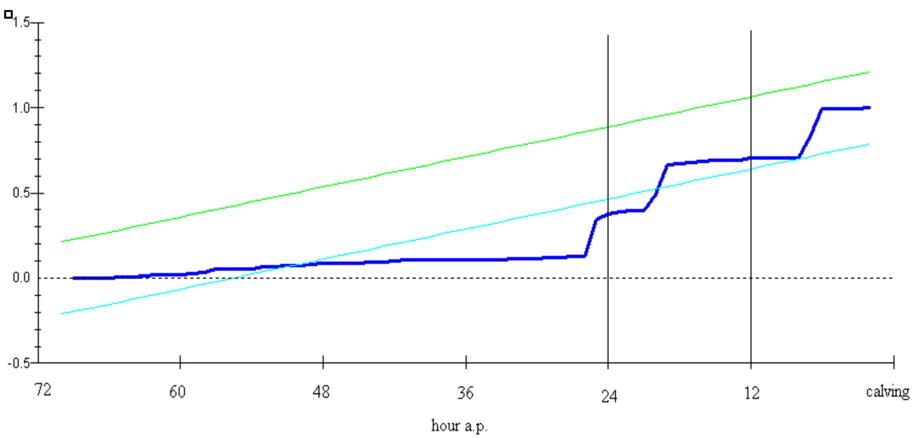

Figure 11. CUSUMQ-test for lying time in the last 72 hours of parturition

Table 3. Result of the chow-test for the lying time

hour a.p.	Regression equation	P-Value
72 – Calving	$\hat{Y}_t = 2{,}8509 + 0{,}86884\, Y_{(t-1)}$	
72 – 24	$\hat{Y}_t = 26{,}9584 + 0{,}18263\, Y_{(t-1)}$	
24 – Calving	$\hat{Y}_t = 7{,}9777 - 0{,}080923\, Y_{(t-1)}$	CHSQ =93,6117 [0,000] F =46,8058 [0,000]
24-12	$\hat{Y}_t = 8{,}5797 - 0{,}071226\, Y_{(t-1)}$	
12 – Calving	$\hat{Y}_t = 7{,}7201 - 0{,}16433\, Y_{(t-1)}$	CHSQ =0,37915 [0,827] F =0,18957 [0,829]

Between the 72th h. a.p. and 46th h. a.p. and in the last 18 hours before parturition the CUSUMQ-curve of the activity time lies within 5% level of significance and between 46th h and 18th h. a.p. outside the 5% level of significance, showing a clear break in the curve of activity time. The Chow test indicates a change point only at the 24th h a. p.

The following Figure shows the course of the coefficient of the regression equations of the Chow-tests for the activity time from 72 hour until parturition.

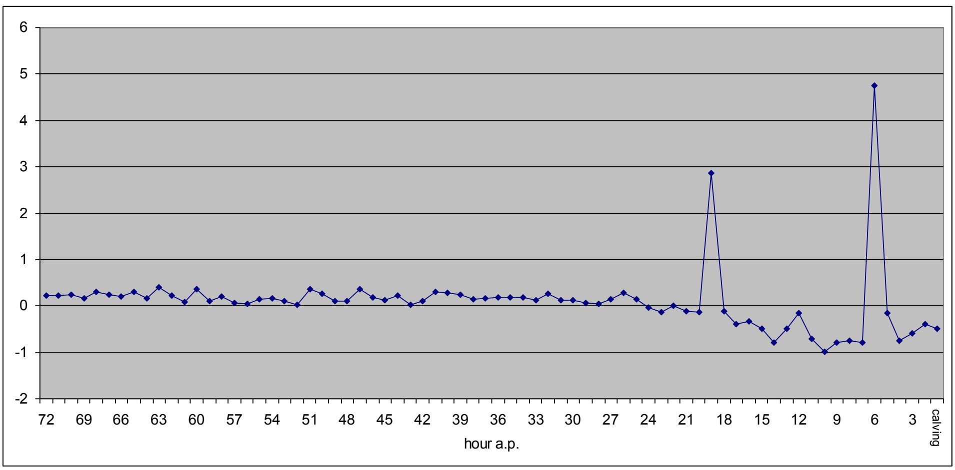

Figure 12. Changes in coefficients of the regression equation of the chow test for the lying time

In the time domain between 72th h and 24th h the coefficients of the regression equations of the Chow tests vary in the range between +0.1 and 0.0. Between 24th h and parturition the coefficients change very clearly, enter the negative range and vary around the value -0.5 until 3th h a.p.

Conclusion

The results of this study is to conclude that behaviour of activity steps, activity time and laying time in continuous measurement in the antepartal time to show physiologically and psychically conditional changes with different selectivity appears.

In the individual, the following observations were made:

- The activity steps and activity time of heifers and cows increase clearly in the last day before parturition
- The laying time of heifers and cows decreases from day to day and is further reduced on the day of calving.
- The activity steps vary from 72^{th} h. a.p. until 12^{th} h a.p., however from 12 hours a.p. the number of activity steps increases and achieves the highest value at parturition.
- The course of activity time changes from 24^{th} hours to the parturition from low values to the highest value, but decreases in the 19^{th} and 6^{th} hours ante partum. The course of laying time changes from 24^{th} hours to the parturition from highest values to the low value. In the 19^{th} and 6^{th} hours a.p. the laying time increases.
- The CUSUMQ-test and chow test of activity steps, activity time and laying time show a significantly (P<0,001) change point at the 24^{th} hours before the calving.

The activity steps, activity time and laying time are suited clearly as an indicator for the prediction of the calving time.

References

Bahr, C. (2006): Sensorbasierte Analyse und Modellierung ausgewählter Verhaltensparameter von Mutterkühen. Dissertrations, HU-Berlin.

Brehme, U.; Stollberg, U.; Holz, R.; Schleusner, T. (2006): ALT Pedometer- a new sensor-aided measurement system for improvement in oestrus detection at dairy cows.

Zemedelska Technik, Prague, Volume 52, Heft 1, 1-10

Hashem, M.; Bahram, P. (1997): Working with Microfit 4.0 Interactive Econometric Analysis.Oxford University.

Lehr, A. (1997): Verhaltensphysiologische Reaktionen bei Mutterkühen und ihren Kälbern im peripartalen Zeitraum. Wissenschaftliche Mitteilungen der Bundesforschungsanstalt für Landwirtschaft Braunschweig-Völkenrode. Sonderheft 177. S. 138-148

Reiter, K.; Tutsch, S.; Plesch, G.; Oppermann, P.,(2007): Verhaltensuntersuchungen bei Gelbvieh und Fleckvieh zur Optimierung der Liegefläche. Bayerisches Staatsministerium für Landwirtschaft und Forsten.

Shaw, E .B.;Houpt, K. A., D.; Holmes, F. (1988): Body temperature and behaviour of mares during the last two weeks of pregnancy Equine Vet. J. 20, 199-202

Stration, E. C. (1991): Rinder-und Kälberkrankheiten und Geburtshilfe. 4 München. BLV Verlagsgesellschaft Gmbh.

Süss, M.;Andeae, U. (1984): Spezielle Ethologie Rind. Hrsg.: Bogner, H.;Grauvogl, A.: Verhalten landwirtschaftlicher Nutztiere. 1 Stuttgart, Eugen Ulmer Gmbh.

BioBusiness project: Research training program on Precision Livestock Farming (PLF)

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Abstract

Global and European animal production are an undergoing major transformation that reveals health and welfare problems related to intensive livestock production. Implementing new technology in combination with understanding biology can contribute to solve health and welfare problems in livestock production. However people educated in biology are not aware of the possibilities of modern technology. The main objective of the 4 years EU BioBusiness project is to train early stage researchers in technology for livestock. 11 well trained people are expected to understand the innovative potential of Precision Livestock Farming (PLF) looking from the animal side. Furthermore they are expected to present innovative product concepts and business models on the field of intensive animal production benefitting the industry and consumers.

Keywords: training, young researchers, automatic monitoring, animal health and welfare

Introduction

Human world population is growing enormously and there is an increasing demand for more food production, mainly on the developing countries. (FAO, 2009; Thornton & Gerber, 2010). Consecutively, consumption of meat and other animal products continues to grow considerably. To be able to satisfy this higher demand for meat products, global animal food production are undergoing major transformations that has revealed industrial livestock-related health and welfare problems (de Passille & Rushen, 2005; Thompson *et al.*, 2007; Fraser, 2008; Botreau *et al.*, 2009; Main *et al.*, 2009; Tuyttens *et al.*, 2009; Webster, 2009; Blokhuis *et al.*, 2010; Sorensen & Fraser, 2010; Swanson, 2010). Being directly related to population health, such issues need to be resolved. Modern livestock production systems have improved essentially by the increasing adoption of new technologies. Precision Livestock Farming (PLF) approaches have offered lot of interesting possibilities in automatic monitoring and control for supporting the management of such complex biological production processes (Berckmans & Guarino, 2008; Wathes *et al.*, 2008; Banhazi & Black 2009; Wathes, 2009).
In this regard, the combination of new technology with biology offers high opportunities for EU in terms of realising and implementing directives in different applications as well as in economic terms. To develop new products for bioprocesses, such as livestock production, the combination of biological knowledge with expertise in technology should be fastened. An obstacle however is that people educated in biology are not aware of the possibilities of

modern technology. At the same time technical people developing technology are not participating to the world of biology. Animal scientists know which are the most important variables to be measured from the animals while engineers can provide the best technology solutions to measure the requested variables.
The main objective of the 4 years EU BioBusiness project (from December 2009 to November 2013) is to train biological educated people (veterinarians, biologists and animal scientists) to collaborate with technology driven people (bio-engineers and computer engineers) and make them familiar with modern technology by means of PLF. This is done by training them in research, product definition and development, marketing and sales for bio-business in EU. The aim of this network is to train 11 early stage researchers in the disciplines of biology and technology to understand the evolutionary origins of measuring, modelling and controlling in relation to bioprocesses in order to foster the development of high-tech products or services for livestock within industry. This can only be gained if the scientific results lead to products which can later undergo product development and marketing strategies.

Material and Methods

The project is conducted by a strong PLF related consortium formed by the 10 partners of research institutions, universities and companies (Table 1).

Table 1. List of partners on BioBusiness project

Partner number	Partner name	Country
1 (coordinator)	Katholieke Universiteit Leuven	Belgium
2	The Royal Veterinary College	United Kingdom
3	Agence Nationale de Sécurité Sanitaire de 'alimentation, de l'environnement et du travail	France
4	Stiftung-Tieraerztliche Hochschule Hannover	Germany
5	Animal Science Group - ASG Wageningen UR	The Netherlands
6	The Agricultural Research Organization of Israel – The Volcani Centre	Israel
7	Universita degli Studi di Milano	Italy
8	DeLaval International AB	Sweden
9	Fancom B.V.	The Netherlands
10	Petersime N.V.	Belgium

A total of 11 early stage researchers are recruited as Marie-Curie fellows to work as a part of a team for development of high-tech products and services in the field of PLF focusing on the complex biological organism and practical implementation of their science.

The transfer of knowledge between academia and industry is the guarantee to evoke, from hands-on experience and state-of-the-art problems, real outcome products which can be used and developed within the small and medium enterprises.

The network focuses as well on research that will enhance animal welfare and health management. The main areas of interest are behaviour monitoring, disease detection and monitoring, process monitoring and management considering the following topics: 1) chicken embryo development; 2) lameness in dairy cows; 3) pig aggression behaviour. Work of the young scientists has been focused on issues related to the above areas, leading to new knowledge in concepts and understanding.

Table 2 shows the summary of the research methodology proposed in the BioBusiness project to achieve the research objectives.

Table 2. Overview of the research methodology

Topic	**Details of the research objectives**
Animal health and welfare indicators	Define health and welfare indicators for an automated system for monitoring livestock
Experimentation	Define technical specifications to measure the variables, perform animal experiments and data collection
Manual Labelling	Define and realize manual labelling as a reference method
Algorithm Development	Develop an algorithm for automatic continuous monitoring
Field Testing	Validation trials and development of prototypes
Dissemination and Exploitation	Define product strategy, product definition and commercialisation strategy

Also, mathematical modelling techniques will be used that allow for the results to be quantified whilst providing insight to the biological process. In addition, the 11 fellows will be introduced to the bio-business path from research to sales by means of complementary trainings on the whole product oriented research chain (Figure 1) focusing on animal applied research, technology, product and process development and market introduction.

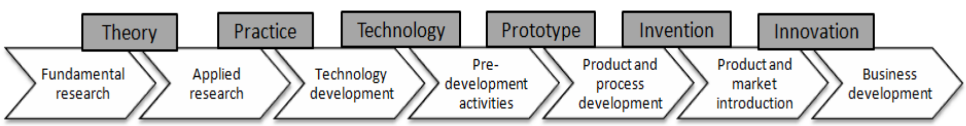

Figure 1. Flow chart of the product oriented research concept on BioBusiness Project

Each young student has a supervisor responsible for the scientific education. Fellows affiliated with academic partners are making their PhD studies in the project.

The progress of the young students is monitored by a group of selected expert researchers under 3 specific conditions: a) individual academic/scientific progress; b) industrial progress considering the product development activities and; c) individual development by the network and synergy on group activities.

Expected Results

The BioBusiness project will allow fellows to experience all the stages that are required for an innovative idea to reach the market. Also, coming closer to the industrial environment (by direct employment or secondment by the industrial partners), they will be introduced to product oriented research in both economic and marketability terms.

A main result of the project will be 11 well trained people who understand the innovative potential of PLF looking from the animal side. Moreover they will show their innovative product concepts and the corresponding business models. They will provide tools to improve the farmer's business and animal welfare and health.

Researchers that will successfully complete the training program will be able to continue their career in different sectors such as industry, civil service, academia, teaching or research institutions. They will be trained to conduct high quality research which is required by the academic environment while, at the same time, they will be able to conduct research supporting product development. They will understand the scientific, time and financial constraints that this imposes and they will be able to work under such conditions either in SMEs, high-tech companies and research institutes. Fellows should have the skills in bringing PLF related solutions to the market, benefiting the industry as well as the consumers.

The most important experimental results, the contents of the trainings and workshops discussion as well as the informative newsletters and scientific publications are being constantly updated on the BioBusiness project website.

References

Banhazi, T. M., and J. L. Black. "Precision Livestock Farming: A Suite of Electronic Systems to Ensure the Application of Best Practice Management on Livestock Farms." Australian Journal of Multi-Disciplinary Engineering 7, no. 1 (2009): 1-14.

Berckmans, D., and M. Guarino. "Smart Sensors in Precision Livestock Farming - Preface." Computers and Electronics in Agriculture 64, no. 1 (2008): 1-1.

Blokhuis, H. J., I. Veissier, M. Miele, and B. Jones. "The Welfare Quality (R) Project and Beyond: Safeguarding Farm Animal Well-Being." Acta Agriculturae Scandinavica Section a-Animal Science 60, no. 3 (2010): 129-40.

Botreau, R., I. Veissier, and P. Perny. "Overall Assessment of Animal Welfare: Strategy Adopted in Welfare Quality (R)." Animal Welfare 18, no. 4 (2009): 363-70.

de Passille, A. M., and J. Rushen. "Food Safety and Environmental Issues in Animal Welfare." Revue Scientifique Et Technique-Office International Des Epizooties 24, no. 2 (2005): 757-66.

Food and Agriculture Organization of the United Nations (FAO). "The state of food and agriculture". Rome, 2009.

Fraser, D. "Toward a Global Perspective on Farm Animal Welfare." Applied Animal Behaviour Science 113, no. 4 (2008): 330-39.

Main, D. C. J., M. C. Appleby, D. B. Wilkins, and E. S. Paul. "Essential Veterinary Education in the Welfare of Food Production Animals." Revue Scientifique Et Technique-Office International Des Epizooties 28, no. 2 (2009): 611-16.

Sorensen, J. T., and D. Fraser. "On-Farm Welfare Assessment for Regulatory Purposes: Issues and Possible Solutions." Livestock Science 131, no. 1 (2010): 1-7.

Swanson, J. C. "How Welfare Is Measured and Why Scientists Do It Differently." Journal of Veterinary Medical Education 37, no. 1 (2010): 89-93.

Thompson, P., C. Harris, D. Holt, and E. A. Pajor. "Livestock Welfare Product Claims: The Emerging Social Context." Journal of Animal Science 85, no. 9 (2007): 2354-60.

Thornton, P. K., and P. J. Gerber. "Climate Change and the Growth of the Livestock Sector in Developing Countries." Mitigation and Adaptation Strategies for Global Change 15, no. 2 (2010): 169-84.

Tuyttens, F. A. M., D. Maes, N. Geverink, P. Koene, and T. B. Rodenburg. "Assessing Animal Welfare at Farm and Group Level: Introduction and Overview." Animal Welfare 18, no. 4 (2009): 323-24.

Wathes, C. M. Precision Livestock Farming for Animal Health, Welfare and Production. Edited by A. Aland and F. Madec, Sustainable Animal Production - the Challenges and Potential Developments for Professional Farming2009.

Wathes, C. M., H. H. Kristensen, J. M. Aerts, and D. Berckmans. "Is Precision Livestock Farming an Engineer's Daydream or Nightmare, an Animal's Friend or Foe, and a Farmer's Panacea or Pitfall?" Computers and Electronics in Agriculture 64, no. 1 (2008): 2-10.

Webster, J. New Trends in Farm Animal Welfare: Science Values and Practice. Edited by A. Aland and F. Madec, Sustainable Animal Production - the Challenges and Potential Developments for Professional Farming. Wageningen: Wageningen Academic Publishers, 2009.

A computer program for monitoring and controlling ultrasonic anemometers for aerodynamic measurements in animal housing

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Abstract

Ultrasonic anemometers are widely implemented in animal housing to measure the air velocity in different measuring points throughout the whole barn, which ultimately leads to determine the velocity fields and the air flow patterns drawing an overview of aerodynamics in practice barn. The problem is the timely inconsistent data transmission from the different anemometers leading to varied data recording, which makes the comparison between the recorded velocities in different points timely inappropriate. One key issue is to monitor and control the ultrasonic anemometers, meanwhile, debug and record the data. Therefore, LabVIEW 8.5 which is a platform and development environment for a visual programming language was used to configure a computer program to monitor and control the ultrasonic anemometers. The principal functions of the system are represented in a main block diagram which consists of 39 sub-diagrams. Five versions of the program were consecutively developed, where each version was validated and further developed to get the next enhanced version, and so on till Version 5.0. The evaluation and data recording are carried out simultaneously, where the data are transferred from the anemometers to the program which detects accidental errors that may have been introduced during data transmission or storage using a checksum algorithm. The developed computer program has been implemented successfully for monitoring and controlling ultrasonic anemometers used for carrying out air velocity measurements in livestock housing.

Keywords: Computer program, animal housing, aerodynamic, air velocity, ultrasonic anemometer.

Introduction

Decision support systems (DSS) are computer programs, which encode algorithms that assist in making management decisions. These algorithms are then embodied in computer programs, expert systems, hybrid systems, databases, or spreadsheets as so-called "decision support". Agricultural decision support systems must be able to make recommendations that can be easily understood, trusted, and applied to particular situation (Greer *et al.*, 1994). A software system is an intelligent computer program that uses knowledge and inference procedures to solve problems. These computer programs manipulate symbolic descriptions of facts and heuristics following predefined reasoning processes. Heuristics are rules of thumb making educated guesses about potential problem approaches and dealing effectively with incomplete or inconsistent data. Software systems try to model these heuristics as exemplified by metaphors, analogies, gestalts, algorithms, logic, and mathematics. The heuristics or patterns of thought are developed and represented in the form of block diagrams (Broner *et* *al*., 1990; Greer *et al*., 1994). According to Giarratano & Riley (2005), a computer program should consist of a database module, a knowledge base, a reasoning machine, a case elicitation tool, an explanation subsystem, and a user interface. The tasks performed by software programs are numerous; the functional categories for software applications are interpretation, prediction, instruction, diagnosis, monitoring, debugging, repairing, controlling, designing, and planning.

Snell *et al*. (2003) estimated the influence of the climatic data on the ventilation rate and the emission by means of a stepwise regression. They added that depending on the building design, 73–84% of the ventilation rate could be explained by the climatic values (wind velocity, wind direction, temperature, and relative air humidity). Where, the wind velocity is of outstanding importance. The wind velocity is of central importance for the ventilation, only becoming less significant in the case of flowing against the gable end. Bartzanas *et al*. (2007) stated that air velocity measurements incarnate the corner stone for airflow analysis in rural buildings. Bjerg & Sørensen (2008) mentioned that the modern demands of airflow in livestock buildings should be fulfilled, which are: air distribution, control, energy efficiency, and air velocity in the animal occupied zone. Several procedures -which requires air velocity measurements- should be implemented, and they are: determining air velocity at animal level, limiting air velocity in the animal occupied zone, homogenizing air velocity distribution in the entire barn, determining whether air velocity distribution inside and close to the inlet are similar, investigating air velocity profiles and turbulences, homogenizing air velocity direction the whole barn, reducing air velocity at floor level at high ventilations rate without increasing the pressure drop over the inlet.

The wind master measures the times taken for an ultrasonic pulse of sound to travel from an upper transducer to the opposite lower transducer, and compares it with the time for a pulse to travel from lower to upper transducer. Likewise times are compared between each of the other upper and lower transducers. The speed of sound in air can be calculated from the times of flight. In other words, the air velocity along the axis between each pair of transducers can be calculated from the times of flight on each axis. This calculation is independent on factors such as temperature. From the three axis velocities, the wind speed is calculated, either as signed U, V, and W, or as Polar and W (Gill Instruments Limited, 2009).

When implementing several ultrasonic anemometers in animal housing to measure the air velocity in different measuring points throughout the whole barn, the data transferred from the different anemometers are timely inconsistent which leads to varied recording of data making the comparison between the recorded velocities in different point timely inapt. Lacroix *et al*. (1998) stated that in order to accelerate analyses and improve decision-making, it is necessary to develop computer tools that have the ability to pre-process the data so as to produce value-added information.

The objective of this study is to develop a tool to monitor and control the ultrasonic anemometers for aerodynamic measurements in animal housing, and then to debug and timely record the measured values.

Materials and methods

General Procedures

The overall computer program architecture consists of user interface, algorithm, display module, and user model; whereas: (a) the user interface has three responsibilities: querying the user for suitable inputs to the algorithm, acquiring knowledge about the individual user to inform the user model, and presenting output to the user, (b) the algorithm carries out an analysis of the user's commands and generates a table of numeric values as output, (c) the display module shows the output of the algorithm and generates displays, taking into account information in the user model, (d) the user model determines general and specific attributes of the user and provides modification rules to the display module, which are used to individualize the display.

The systematic procedures carried out by the program in coordination with the commands given by the user through the user interface, are summarized as following: (a) the data file, where the measured values will be written, and the anemometer(s) that should be used will be called up; (b) the data file and the used anemometer(s) will be called up; (c) the system will attempt to debug all buffers of the implemented anemometer(s); (d) the telegram(s) of the used anemometer(s) will be read continuously, and can be written into the data file if required; (e) all interfaces will be closed; (f) the system will look for errors; and (g) in case of finding errors, they will be displayed.

Knowledge Acquisition

The knowledge used to configure the computer program was acquired from different sources, such as: references, manuals, and experts. The most important manuals were: user manual of ultrasonic anemometer (Gill Instruments Limited, 2009), universal board user's manual (Moxa Inc., 2008), and LabVIEW user guide. Furthermore, contacts were made with experts to acquire knowledge concerning the required abilities of the program, practical application, and the method of carrying out aerodynamic measurements in practice barn. Further experts were inquired about the algorithm developed for calculating the air velocity by means of U and V which represent the air velocity components.

Programming

LabVIEW short for Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW Professional Development System 2007, Version 8.5, National Instruments Corporation, Austin, Texas, USA), which is a platform and development environment for a visual programming language, was used to configure the computer program via the algorithms in order to form the block diagram of the software system, and then to develop the user interface. The algorithms, rules, and functions are included in the detailed block diagrams with descriptive characteristics at each branch code and a decision at each terminal node.

The computer program was prototyped to contain one main block diagram which consists of 39 detailed block sub-diagrams for monitoring and controlling ultrasonic anemometers during aerodynamic measurements in animal barns and then debugging and recording the data, i.e. the measured values, transmitted from the anemometers into a Text Document which represents the data file. Figure 1 shows the overview block diagram of the developed software and the reciprocal interactions between the different main functions. The block diagram is the system's back diagram code which represents the functions by blocks connected by lines showing the relationships between the blocks. Hence, this block diagram is a visual description of the course of actions carried out by the software system.

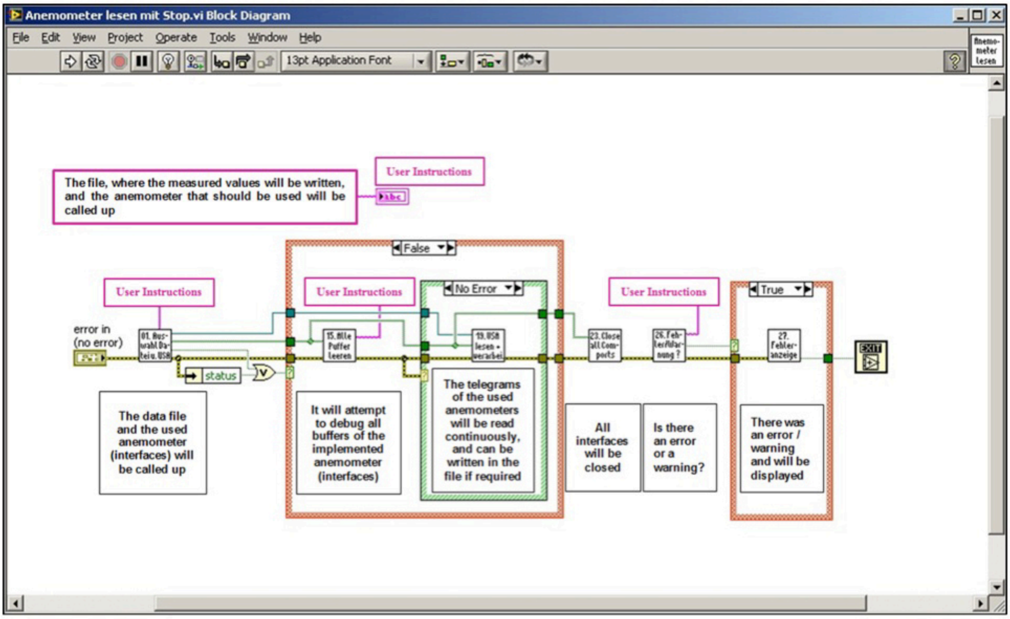


Figure 1. Block diagram of the configured software.

<u>Data Transmission</u>

The specified baud rate for data transmission from the different ultrasonic anemometers to the program is 19200 symbols (ASCII Code) per second. The data are transferred from the ultrasonic anemometer to the program according to the following mode or telegram: identification node address (anemometer name), U axis speed and polarity (m s^{-1}), V axis speed and polarity (m s^{-1}), W axis speed and polarity (m s^{-1}), units (metric system), sonic temperature (°C), status or error code, and checksum.

<u>Validation and Evaluation</u>

The validation of a computer program aims to determine if the system is operating correctly or not. Therefore, five versions of the program had been consecutively developed, where each version was validated to uproot system errors, then the amendments and the corrections were executed getting a new version which in turn had been verified and further developed, and so on till the software prototype has been developed as Version 5.0. The first version had been issued year 2009, but was unable to display any wind rose. Afterwards, the program was further developed to issue more developed versions by uprooting system errors, where the last version has been issued year 2010 and is able to show a wind rose for each anemometer.

On the other hand, the evaluation of software system aims to determine the system's accuracy. Accordingly, the system carries out a continuous validation of the timely data recording process using the fixed-size datum method known as checksum or hash sum which is computed from an arbitrary block of digital data in order to detect accidental errors that may have been occurred during data transmission or storage. In order to check the timely data recording, the program achieves an inquiry cycle over the serial ports in 20 ms. Furthermore, the accuracy of the data can be tested at any time by re-computing the checksum and comparing it with the saved one. If the checksums match, the data was not altered. The checksum algorithm, i.e. the function that computes the checksum from the data, will display a different result with high probability when the data is accidentally corrupted. While computer programs are able to use some algorithms from purely mathematical models, computers can combine algorithms with reality of actual events, such as generating input responses, to emulate test subjects who are no longer present. Whereas the missing test subjects are being modeled, the system they use could be the actual equipment, revealing performance limits or defects in long-term use by the users.

Hardware

The developed software should be installed on a special personal computer that allows the data cables of the different ultrasonic anemometers to be plugged-in. Therefore, the personal computer should be amended to enable this process. Consequently, the computer has been equipped with an electronic card with 8 serial ports, i.e. 8 ultrasonic anemometers can be plugged-in. The installed electronic chip is Moxa CP-118U (8×RS232|422|485). The specifications of the used computer are: AMD Athlon Processor 1 GHz, RAM 256 MB, and the VGA card should allow 1152×864 pixel.

Ultrasonic Anemometers

Seven ultrasonic anemometers (WindMaster and WindMaster Pro, ultrasonic anemometer, Gill Instruments Limited, Lymington, Hampshire, UK) are used to carry out air velocity measurements in practice barn. Wind software (Wind (c) 2008 Gill Instruments, Version 2324-106, Gill Instruments Limited, Lymington, Hampshire, UK) has been used for configuring the ultrasonic anemometers. Using the aforementioned software the technical characteristics of the different anemometers can be specified, which are: baud rate (symbols per second), message output format (UV, or Polar), output rate (Hz), measurement unit (m s^{-1}), alignment (North to spar), resolution, temperature display (sonic), and analogue output mode.

Results

The developed computer program has been called Wind-Master Reader (WMR) referring to its main tasks which is reading, debugging, recording, and controlling the data transferred by the wind masters. WMR, which is a stand-alone system (657 kB without the installer) that can be easily installed using a compact disc (CD).

In order to install data transmission connection(s), a determined interface is required. Therefore, a window for installing data transmission connections has been configured (Figure 2). This window allows the user to install connection(s) with determined ultrasonic anemometer(s) for data transmission from the anemometer(s) to the system where the data will be processed and either displayed or written to data file. Furthermore, the simultaneously data displaying and recording is achievable.

Figure 3 shows the main window of the developed program, where the command buttons are also shown. The velocity range should be specified using the “Velocity Range” button as following: 0 – 0.1 m s^{-1}, 0 – 0.4 m s^{-1}, 0 – 1 m s^{-1}, 0 – 4 m s^{-1}, 0 – 10 m s^{-1}, or 0 – 40 m s^{-1}. Writing the measured values by the anemometers into the data file can be achieved through different procedures as either writing the data transmitted from all anemometers or determining which anemometer(s) among all other anemometers whose data will be recorded. The data of each ultrasonic anemometer (USA) are displayed. By clicking the button, the user can select whether data should be written into the data file or not. On the other hand, the wind rose data and diagrams of each anemometer are also displayed (Figure 3). Where the diagram of a determined anemometer shows the direction (degrees) in which the wind blows, and the displayed data show the wind speed (m s^{-1}) in 3 dimensions (U, V, and W) and the air velocity which is computed by an algorithm using the air velocity components. Furthermore, air temperature (°C) will be displayed.

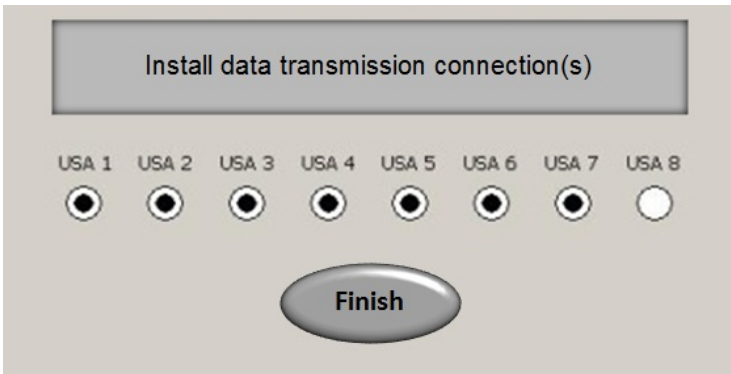


Figure 2. Window for installing data transmission connections.

The data transmitted from the ultrasonic anemometers to the program, are being controlled by the program and then saved into Text Document (Figure 4). The configured computer program has been used successfully for monitoring and controlling ultrasonic anemometers used to carry out air velocity measurements in a naturally ventilated dairy barn located in Dummerstorf, Mecklenburg-Vorpommern, Germany (217 km north-west Berlin, at latitude of 54° 1' 0'' N, longitude of 12° 13' 60'' E, and altitude of 43 m). Figure 4 shows a data sample of the measured and written data into a Text Document as data file. The data can be further transferred from the Text Document to an Excel file for further data processing.
On the other hand, the measured value line (Figure 4) is formulated as follows: number of the computer-connection where a cable data of a determined anemometer is plugged-in, date of the measurement (dd.mm.yyyy), time (hour, minute, second, and centisecond), anemometer name in form of one Latin letter, status or error code (if 00 then true, if 80 then false either as checksum error or as detected measurement/value error by the anemometer), air velocity components (U, V, and W measured in m s^{-1}), and temperature (°C).

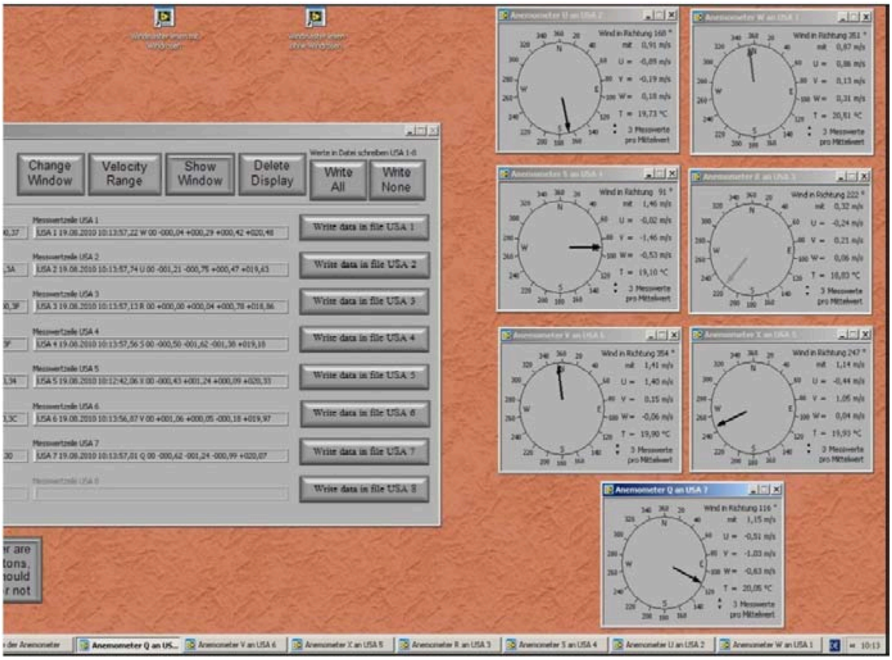
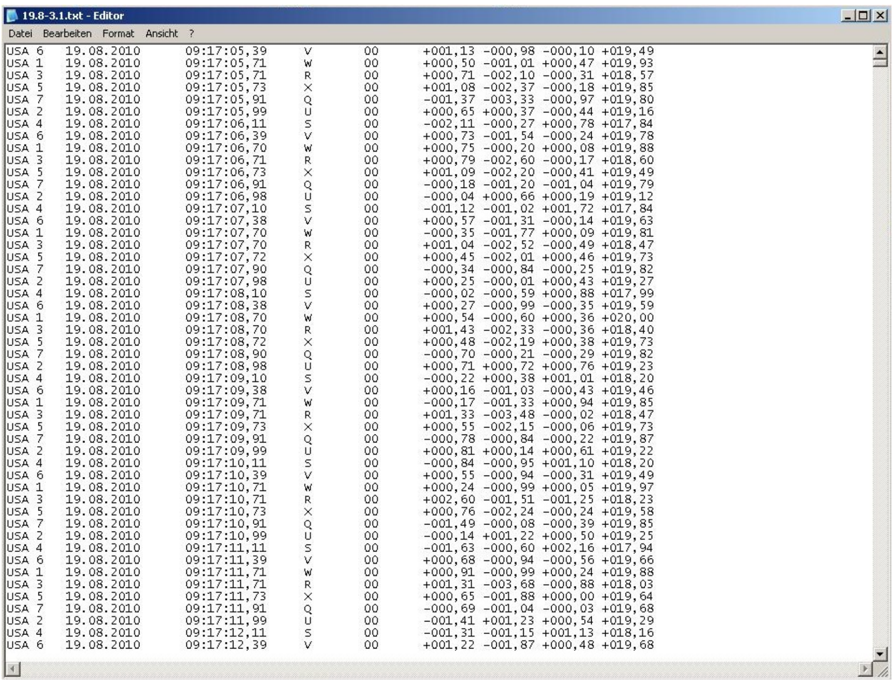


Figure 3. Main window of the developed software.



19.8-3.1.txt - Editor

Datei Bearbeiten Format Ansicht ?

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USA 3   19.08.2010   09:17:05,71   R   00   +000,71 -002,10 -000,31 +018,57
USA 5   19.08.2010   09:17:05,73   X   00   +001,08 -002,37 -000,18 +019,85
USA 7   19.08.2010   09:17:05,91   Q   00   -001,37 -003,33 -000,97 +019,80
USA 2   19.08.2010   09:17:05,99   U   00   +000,65 +000,37 -000,44 +019,16
USA 4   19.08.2010   09:17:06,11   S   00   -002,11 -000,27 +000,78 +017,84
USA 6   19.08.2010   09:17:06,39   V   00   +000,73 -001,54 -000,24 +019,78
USA 1   19.08.2010   09:17:06,70   W   00   +000,75 -000,20 +000,08 +019,88
USA 3   19.08.2010   09:17:06,71   R   00   +000,79 -002,60 -000,17 +018,60
USA 5   19.08.2010   09:17:06,73   X   00   +001,09 -002,20 -000,41 +019,49
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USA 2   19.08.2010   09:17:06,98   U   00   -000,04 +000,66 +000,19 +019,12
USA 4   19.08.2010   09:17:07,10   S   00   -001,12 -001,02 +001,72 +017,84
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USA 4   19.08.2010   09:17:12,11   S   00   -001,31 -001,15 +001,13 +018,16
USA 6   19.08.2010   09:17:12,39   V   00   +001,22 -001,87 +000,48 +019,68
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Figure 4. Data file where the data transferred from one anemometer are recorded.

Discussion

Structured Induction

Knowledge acquisition has been identified as the 'bottleneck' in the software system development process. Structured induction offers a method for acquiring and formalizing knowledge. Induction is the opposite of deduction, a more familiar process whereby general knowledge is applied to a specific problem to predict an outcome. Induction takes specific examples, and develops general knowledge which is consistent with those examples. From such a set of examples, rules representing underlying knowledge can be derived, and structured into a block diagram which can be developed into a functional knowledge base for a computer program. Structured induction takes a sample set of scenarios and applies an algorithm to them. The output is a block diagram, optimized according to predetermined criteria, with descriptive characteristics at each branch node and a decision at each terminal node. A block diagram expresses the knowledge contained in the example set in an ordered and efficient structure. Since many block diagrams are possible for a given set of examples, optimization must be employed to get the most efficient diagram possible. Knowledge acquisition and formalization using structured induction in which an induction algorithm was used to derive rules. This perception is contingent to that stated by Broner *et al.* (1990). Sensitive parameters, dependent variables, and constant values of the developed algorithm were structured to be used as input/output data of the relevant diagram and later to configure its interface.

Induction structures the declarative data to minimize some measure of uncertainty in the diagram structure. Induction is a very powerful tool for computer program development. It should however be regarded as one of many strategies for knowledge acquisition. Personal dialogue between domain experts and the knowledge engineer is a critical part of the process, whether or not induction is used. When applied with a little common sense on the part of the knowledge engineer, induction can provide structured knowledge representing true expertise. Therefore, experts were deployed in order to emulate their expertise thought and using it in developing the algorithm and the structured induction of the software, which agrees with the concept generalized by Spangler *et al.* (1989).

Programming Concepts

The computer program had been configured using two programming concepts. The first is the block diagraming of individual sub-diagrams and integrating them into the overview block diagram, i.e. using the structured systems analysis and design method which addresses technological aspects of system development by breaking down system development into smaller parts (sub-diagrams), each part consists of a sequence of stages, each stage consists of a number of steps, and each step consists of a number of tasks. The second programming concept is the use of LabVIEW 8.5 visual programming language to buffer the software system from the details to individual processes. The implemented programing concepts agree with those developed by Batchelor *et al.* (1992), Giarratano & Riley (2005), Samer (2008), and Samer (2010).

Computer Program

Computer programs are special software applications that are capable of carrying out reasoning and analysis functions in narrowly defined subject areas at high proficiency levels.

The advantage of computer programs is that once developed they can raise the performance of the average scientist/technician to the highest possible level. The use of software systems is appropriate and necessary to solve pieces of a larger problem. Often, pieces of the problem might be solved best using an algorithmic approach. Typically, this concept had been adopted while developing the WMR. The configured computer program for monitoring and controlling ultrasonic anemometers for aerodynamic measurements is a software system with a set of algorithms, rules, and functions that debug and record data transmitted by the anemometers, and recommends one or more courses of user action, this conception agrees with Giarratano & Riley (2005), Doluschitz & Schmisseur (1988), Doluschitz (1990), Yoo (1989), and Engel *et al.* (1990).

WMR Characteristics

Developing computer programs that achieve high level of performance in a specialized problem domain is considered to be difficult and requiring specialized knowledge and skill. According to the validation and evaluation process, the WMR showed high level of performance when carrying out aerodynamic measurements by ultrasonic anemometers. Additionally, the WMR has the following characteristics:

- heuristic: it employ judgmental as well as formal reasoning;
- transparent: it has the ability to justify its line of reasoning;
- flexible: domain-specific knowledge is generally separate from domain-independent inference procedures, thus evolving the WMR has been accomplished considerably easier than in conventional programming.

This context agrees with the software characteristics mentioned by Samer (2008).

Ubiquity and Verification

The ubiquity of software systems, in all aspects of public and private institutions, means that the environments that have been created need to be critically examined as they have been developed and deployed. Therefore, thorough system validation and verification had been performed in order to reveal and uproot system errors and to verify system accuracy. This procedure is contingent to that stated by Watson *et al.* (1988), Thomson & Schmoldt (2001), Samer (2008), and Samer (2010).

End User

A potential drawback exists when providing access to sophisticated software. Such technology may increase considerably the power of users to make or influence decisions that were formerly beyond the limits of their knowledge and experience. Very powerful software packages allow users to perform all manner of inappropriate statistical tests on data without full knowledge of what they are doing. While current statistical software manuals contain a great deal of information regarding model specification and assumptions, they cannot replace a well-founded understanding of basic statistics by the experimenter (Thomson & Schmoldt, 2001). Therefore, this computer program is addressed to scientists and technicians as end users with high academic training which enable them to manage the aerodynamic measurements.

How Does the WMR Affect the Society?

The WMR has two main effects on the society, which are: scientific and educational effects. This wide scope of its effects on the society illustrates the importance of developing such computer tools for agricultural applications. The scientific effect acts as the WMR is implemented for aerodynamic measurements in practice barns, where the software gives an overview on the anemometers and their transferred data through the whole aerodynamic experiment showing the measured values which are air velocity (speed and direction) and temperature. Furthermore, the WMR gives the potential of deciding whether the data should be written into data file or not. This concept agrees with Samer (2008).

The educational effect appears when the developed computer program, i.e. the WMR, is used as a computer-based training (CBT), which is a type of education in which the student learns by executing special training programs on a computer. Consequently, the WMR can be integrated with the applications of aerodynamics so that students can practice using the application as they learn. Increasing users' decision-making power beyond their former knowledge and experience can also have positive impacts. In particular, when systems are largely based on existing publications typically involve knowledge delivery. The developed computer program illustrates this effect. This context agrees with Samer (2008).

Conclusion

LabVIEW 8.5 which is a platform and development environment for a visual programming language was used to configure a computer program for monitoring and controlling ultrasonic anemometers which are implemented to carry out air velocity measurements in practice barns. The principal parts of the program are epitomized in a main block diagram which consists of 39 sub-diagrams. The evaluation and data recording are carried out instantaneously, where the data are transferred from the anemometers to the program which detects unintentional errors that may have been introduced during data transmission or storage using a checksum algorithm. The configured computer program has been implemented successfully for monitoring and controlling ultrasonic anemometers used for air velocity measurements in a naturally ventilated dairy barn.

References

Bartzanas, T., Kittas, C., Sapounas, A. A., Nikita-Martzopoulou, Ch. 2007. Analysis of airflow through experimental rural buildings: Sensitivity to turbulence models. Biosystems Engineering, Vol. 97: 229 – 239

Batchelor, W. D., McClendon, R. W., Wetzstein, M. E. 1992. Knowledge engineering approaches in developing expert simulation systems. Computers and Electronics in Agriculture, Vol. 7: 97-107

Bjerg, B., Sørensen, L. C. 2008. Numerical simulation of airflow in livestock buildings with radial inlet. Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 06 015. Vol. X. May, 2008

Broner, I., King, J. P., Nevo, A. 1990. Structured induction for agricultural expert systems knowledge acquisition. Computers and Electronics in Agriculture, Vol. 5: 87-99

Doluschitz, R. 1990. Expert systems for management in dairy operations. Computers and Electronics in Agriculture, Vol. 5: 17-30

Doluschitz, R., Schmisseur, W. E. 1988. Expert systems: applications to agriculture and farm management. Computers and Electronics in Agriculture, Vol. 2: 173-182

Engel, B. A., Beasley, D. B., Barrett, J. R. 1990. Integrating expert systems with conventional problem-solving techniques using blackboards. Computers and Electronics in Agriculture, Vol. 4: 287-301

Giarratano, J. C., Riley, G. 2005. Expert Systems, Principles and Programming. 4th ed. Boston, Australia: Thomson Course Technology

Gill Instruments Limited. 2009. Ultrasonic Anemometer. User Manual: Doc No. 1561-PS-0001, Issue 05. Lymington, Hampshire, UK

Greer, J. E., Falk, S., Greer, K. J., Bentham, M. J. 1994. Explaining and justifying recommendations in an agriculture decision support system. Computers and Electronics in Agriculture, Vol. 11: 195-214

Lacroix, R., Huijbers, J., Tiemessen, R., Lefebvre, D., Marchand, D., Wade, K. M. 1998. Fuzzy set-based analytical tools for dairy herd improvement. Applied Engineering in Agriculture, Vol. 14 (1): 79-85

Moxa Inc. 2008. Universal PCI Board User's Manual. Fourth Edition. Brea, California, USA

Samer, M. 2008. An expert system for planning and designing dairy farms in hot climates. Dissertation. VDI-MEG, ISSN 0931-6264, Schrift 472

Samer, M. 2010. A software program for planning and designing biogas plants. Transactions of the ASABE, Vol. 53(4): 1277-1285

Snell, H. G. J., Seipelt, F., Van den Weghe, H. F. A. 2003. Ventilation rates and gaseous emissions from naturally ventilated dairy houses. Biosystems Engineering, Vol. 86 (1): 67–73

Spangler, A. M., Ray, C. D., Hamaker, K. 1989. Knowledge acquisition for expert system development. Computers and Electronics in Agriculture, Vol. 4: 23-32

Thomson, A. J., Schmoldt, D. L. 2001. Ethics in computer software design and development. Computers and Electronics in Agriculture, Vol. 30: 85-102

Watson, D. G., Andrews, M. P., Brook, R. C. 1988. Evaluating a computer program with a structured expert review process. Applied Engineering in Agriculture, Vol. 4(4): 350-355

Yoo, K. H. 1989. Application of dynamic programming in agricultural engineering problems. Applied Engineering in Agriculture, Vol. 5(2): 180-184

Long-term measurement of greenhouse gas and ammonia emissions from a cross ventilated dairy house

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Abstract

Regarding the sustainability of milk production gaseous emissions from ruminants has become an issue for dairy farmers. The study shall provide information about how to mitigate emissions on farm level regarding animal diet and manure management within the barn. The first measurement period was carried out for 21 days during winter time in a newly built cross ventilated dairy barn in Germany. As a result the division of the barn by foil partition is delivering reasonable results for the comparison between the sections and the different floor types. The mean indoor concentration of CH4 and NH3 of the section with solid floor is significantly lower than those of the sections with slatted floor.

Keywords: Greenhouse gas, ammonia, emission, dairy cattle

Introduction

Greenhouse gas emissions from dairy houses are currently subject of a controversial public and political discussion. The emission of contaminant gases from livestock buildings is a major source of pollution within agriculture. Some emission data, based on experimental measurements and calculated data can be found in published literature (Demmers et al., 2001, Amon et al., 2001, Vranken et al. 2004). Furthermore there is already some data relating to the comparison of different floor types (Zhang et al, 2005, Monteney et al. 2006). However, there is a need for emission data of naturally ventilated barns, especially cross ventilation since this type of barn becomes more and more standard in milk production.

Regarding the sustainability of milk production gaseous emissions from ruminants have become an issue for dairy farmers. Many scientists agree that methane emissions from indoor housing dairy production are originated from two major sections; methane emissions from ruminal fermentation and methane release from liquid manure stocks within the sheds. The study shall provide information about how to mitigate emissions on farm level regarding animal diet and manure management within the barn.

Therefore the concentration of ammonia (NH_3), nitrous oxide (N_2O), carbon dioxid (CO_2), and methane (CH_4) in the exhaust air of dairy houses is investigated quasi-continuously by a photo-acoustic spectroscopy using a multi-gas-sensor (LumaSense Technologies e.g. type 1412-5 equipped with optical filters).

Material and Methods

The measurements were performed from December 2010 to January 2011 for 21 days covering the wintertime with an average temperature of 1.3 °C.

Building

Measurements were carried out in a newly built dairy barn of the Chamber of Agriculture North-Rhine Westphalia on the Center of Agriculture House Riswick in Germany. The loose housing barn for 144 dairy cows is divided by foil partitions into three equal sized segments leading to three separate air spaces each of which is designed for two groups of 24 dairy cows (see Figure 1). The barn is cross ventilated whereas the ridge can be opened for additional ventilation. The building is 68 m long and 34 m wide. Measured from floor level the eave height is 5.15 m and the height to ridge is 13 m. There is no outside wall at the long sides of the building, however there is a facility to close the western eave side of the building with curtains.

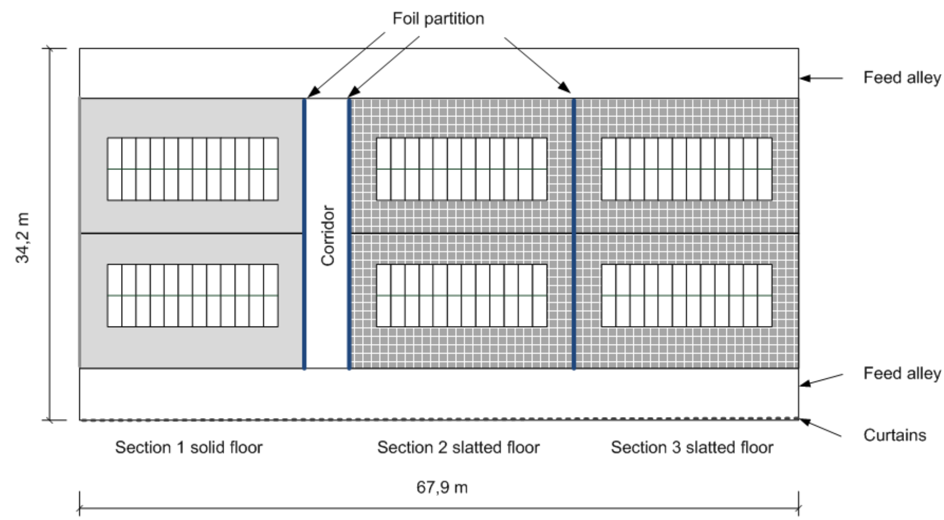

Figure 1. Layout of the dairy barn and the division into subsections

Section 1 has a solid floor with scrapers, section 2 and 3 have slatted floor with a robot system for fully automated cleaning of the slatted floor.

Instrumental setup

In this first part of the study the influence of floor types should be investigated. During wintertime measurements were carried out for 21 days, recording indoor concentrations of ammonia (NH_3), nitrous oxide (N_2O), carbon dioxid (CO_2) and methane (CH_4) for each section. The gas concentrations were measured using a photoacoustic multi-gas analyser 1412 and a multiplexer 1303 /Lumasense Technologies SA, Ballerup, Denmark). Each section was equipped with 8 sampling points put together to one aggregate sample for each section. Therefore in each section the air was sampled by a vacuum pump through 8mm (inner diameter) polytetrafluoroethylene (PTFE) tubes into a sample bottle. By this, the overpressure ensured flushing of the sample bottle through an exhaust air hose. One further outlet of each sample bottle was connected to a multiplexer which forwarded the air samples to the gas analyser. The suction power of the vacuum pump was 33 l min^{-1}, the tube volume was 40 l, so it is assumed that the air exchange of the sample bottle was performed every 72 s. Using a sample interval of 300 s for each section an actual and representative air sample was ensured.

Results

Regarding the gas concentrations in the course of one day, it was possible to record considerable fluctuations, each of which corresponding to specific activities in the operation procedure of the farm (milking, homogenizing of liquid manure; see Figure 2). By this, the instrumental set up, which was designed for a long-term application and thus resulted in long tube-distances of about 100 m, could be validated. In particular CH_4 and CO_2 concentrations, which are mainly dependent from the animals themselves, decrease while the cows are outside the barn for milking.

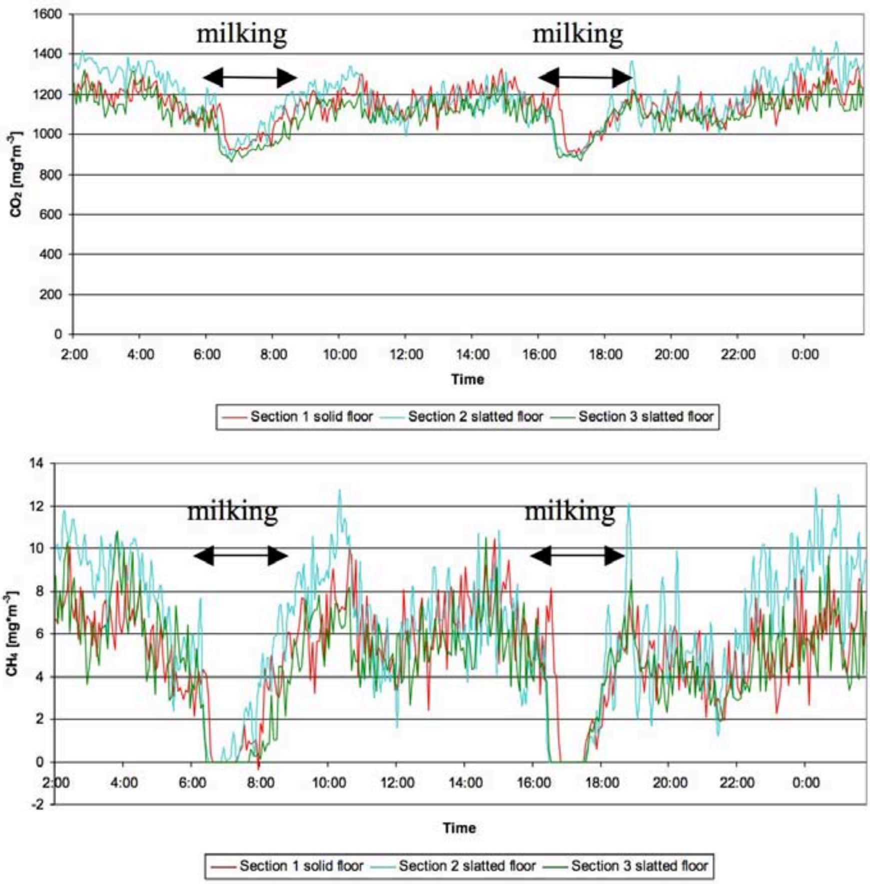

Figure 2. CH_4 and CO_2 indoor concentrations of the sections in the course of the day

The mean indoor concentration of CH_4 of section 1 with solid floor is 7.77 mg m^{-3} and thus is significantly lower than those of the sections 2 and 3 with slatted floor where values of 9.88 und 10.65 mg m^{-3} were measured (see Figure 3). Results for NH_3 also showed a lower indoor concentration in section 1 with solid floor of 1.07 mg m^{-3} compared to section 2 and 3 with slatted floor giving values of 1.46 and 1.51 mg m^{-3}. However, there were no significant differences in the concentrations of N_2O, where in section 1 0.743 mg m^{-3} and in section 2 and 3 0.739 and 0.741 mg m^{-3} were measured.

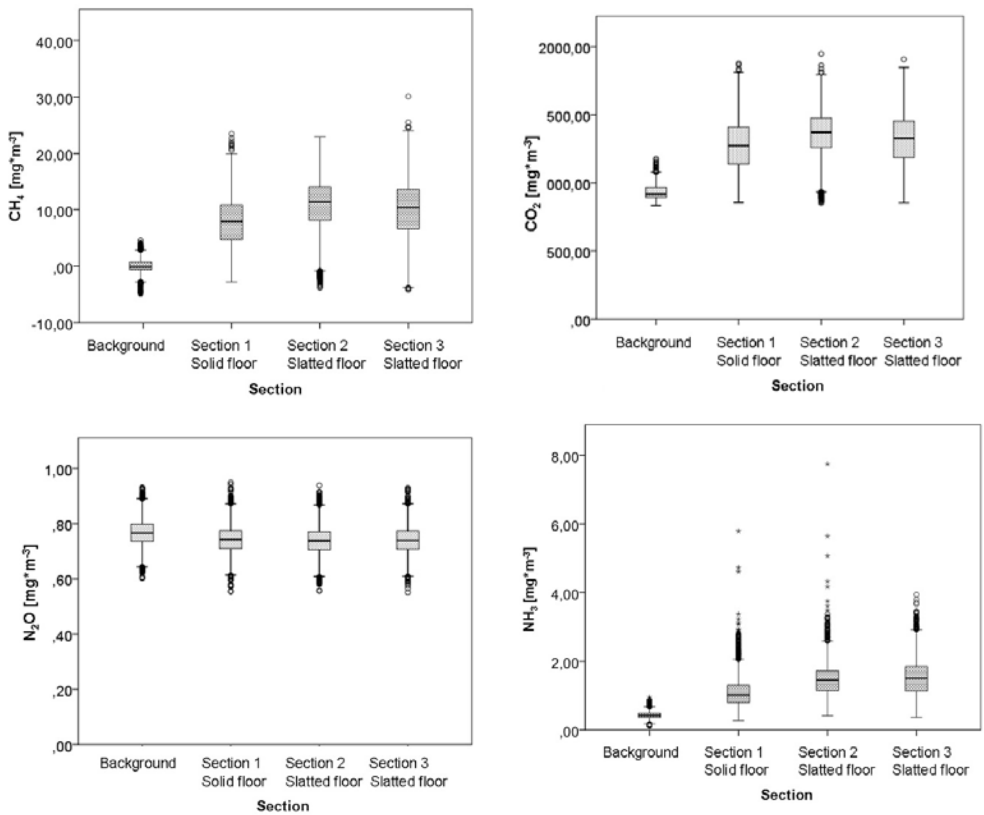

Figure 3. The mean concentrations of CH_4 and NH_3 at different sampling locations

Discussion

Considerably higher indoor concentrations of CH_4 (49-51 mg m-3), NH_3 (4.5 mg m^{-3}) and especially CO_2 (2423-2616 mg m^{-3}) were measured by Ngwabie 2009 during wintertime. The lower values of the own investigation might be the result of a higher ventilation rate due to the large open surfaces of the barn, which will be validated in further investigations. The own indoor concentrations of N_2O are between the values of 0.62 -0,66 mg m^{-3} which were measured in a free ventilated barn with partially slatted floor in winter (Ngwabie et al. 2009) and concentrations of 1,01 mg m^{-3} which were measured in a building with slatted floor

(Jungbluth et al. 2001). It is interesting to note that Ngwabie et al. have also found higher values for N_2O outside the building than inside the building.
As a result the investigation validates the experimental setup, which was especially designed for long-term application. The division of the stable by foil partition is delivering reasonable results for the comparison between the sections. Furthermore the setup for the measurement of gas concentrations has worked precisely, which is verified by the traceable fluctuations of gas concentrations in the course of the day.

Conclusions

This first part of the study has validated the instrumental setup, which was especially designed for long-term measurements. Both the division of the barn into three sections and the experimental setup for the measurement of gas concentrations offer favourable conditions for future investigations. There is still a need for further data regarding gaseous emissions of naturally ventilated animal buildings. Furthermore there is lack of information about long-term effects of feeding, manure handling and specific mitigation measures. For that reason the next part of the study shall investigate the influence of animal diet and manure handling on the emission of the sections and determine how mitigation measures will effect on emissions on long term.

Acknowledgements

We are grateful for the cooperation of the Chamber of Agriculture of North-Rhine Westphalia, where the measurements were conducted. This investigation was funded by the Landwirtschaftliche Rentenbank and the Federal Ministry of Food Agriculture and Consumer Protection, Germany.

References

Amon B.; Amon T.; Boxberger J.; Alt C (2001). Emissions of NH_3, N_2O and CH_4 from dairy cows housed in a farmyard manure tying stall (housing, manure storage, manure spreading). Nutrient Cycling in Agroecosystems, 60 (1–3), 103–113.

Berges M. G. M.; Crutzen P. J. (1996). Estimates of global N_2O emissions from cattle, pig and chicken manure, including a discussion of CH_4 emissions. Journal of Atmospheric Chemistry, 24 (3), 241–269.

Jungbluth T.; Hartung E.; Brose G. (2001). Greenhouse gas emissions from animal houses and manure stores. Nutrient Cycling in Agroecosystems, 60 (1–3), 133–145.

Ngwabie N. M.; Jeppsson K.- H.; Nimmermark S.; Swensson C. ; Gustafsson G. (2009). Multi-location measurements of greenhouse gases and emission rates of methane and ammonia from a naturally-ventilated barn for dairy cows, Biosystems Engineering 103, 68-77.

Vranken E.; Claes S.; Hendriks J.; Darius P.; Berckmans D. (2004). Intermittent measurements to determine ammonia emissions from livestock buildings, Biosystems Engineering 88, 351–358.

Zhang G.; Strom J. S.; Li B.; Rom H. B.; Morsing S.; Dahl P.; Wang C. (2005). Emission of ammonia and other contaminant gases from naturally ventilated dairy cattle buildings. Biosystems Engineering, 92 (3), 355–364.

Selecting the best norms for broiler rearing welfare legislation

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Abstract

Protecting farm animals from adverse conditions during their lives is nowadays a goal of most societies. Meat producing countries are seeking the development of norms and directives to assist standardizing broiler farm conditions, which facilitate auditing. Such norms and directives are often laid down in manuals of good practices. This research aimed to compare the welfare aspects of demands in poultry rearing manuals of good practices adopted internationally (GlobalGap/Europe and RSPCA/Europe), in the USA (EHS-USA and NCC-USA) and in Brazil (MBPB). The comparison used the Likert type scale with scores varying from 1-5 (*very bad, it does not present all necessary items related to welfare rules*, and *very good, it presents all necessary items related to welfare rules*). Multicriterial analysis (Analytic Hierarchic Process - AHP) was used for selecting the best manual which represents the best set of rules. Results indicated that a manual from GlobalGap defines the best of standards for broiler husbandry. Using the AHP analysis the best norm was found. The criteria used in the analysis the GlobalGap had the highest ranking (21.7) followed by the RSPCA/Europe (21.4%), the NCC/USA (19.5%), the MBPB/Brazil, 18.9%, and the EHS/USA (18.4%). The manual which presented the most appropriate items was the GlobalGap. Within this manual the criteria "safety" and "easy assessment" presented the highest weight (15.4% and 14.6, respectively).

Keywords: analytic hierarchic process, broiler production, well being, laws.

Introduction

The primary role of farm animals is for human food production and the level of inputs such as feed, housing, disease control and environment management has reached a high degree of technology driven success The production process has been pushed to their biological limits and there is an increasing challenge to meet high standards of animal well-being, or human-perceived welfare (Dawkins, 2003; McInerney, 2004). Handling procedures, stocking density, free access to feed and water, adequate housing and air quality are well documented in literature, and have been regulated by several countries (Boivin *et al.*, 1992; Wathes *et al.*, 2002). Comprehensive knowledge of farm animals' behavioral activities is important for the improvement of animal husbandry and related information has been used for establishing appropriate directives and legislations for animal welfare worldwide (Puma *et al.*, 2001). This research had the objective of comparing the content of international norms (GlobalGap/Europe, EHS/USA, RSPCA/Europe, NCC/USA, and MBPB/Brazil) and to apply the Analytic Hierarchic Process (AHP) process for selecting the most suitable set of rules.

Material and methods

Welfare of animals is not a single state and it needs to be analyzed as a wide range of identified outcomes and it depends on human perception and judgment. Although the extremes are easily predictable ("very bad" = low welfare standard; and "very good" = high welfare standard), intermediate levels may fall into a subjective analysis, and the specific judgment usually varies from one person to the other. This research was carried out in two steps: (1) the comparison of adopted welfare standards to the considered the most complete set of rules (GlobalGap), and (2) the application of the Analytical Hierarchic Process (AHP) for selecting the best set of rules.

The norms compared were: GlobalGap (2009) which was considered the international standard, EHS (2007), RSPCA (2008), NCC (2008), and Brazilian Good Practice Manual – MBPB (Embrapa, 2007). Adequate information on the following items was considered in the comparison: environment, management production and traceability; rearing ambient data (temperature, relative humidity, ventilation, ammonia concentration and dust); drinking water quality; management (housing disinfection, adequate flock density); and transportation. Scores were given to each specific item (rearing conditions, health, hygiene, feeding, litter, handling, etc) in relation to GlobalGap/Europe, in range varying from 1 to 5 (Likert type scale), such as: 1=very bad (does not present any norms regarding that subject when compared to the international standard), 2=bad (there are few norms and few or none compliance), 3=average (there are norms for at least half of the international standard), 4=good (there is a great deal of norms and regulations regarding several events during production and a good degree of compliance), 5=very good (codes and regulations agree totally with the international norms and there is a high degree of compliance). Tables were built and the average of the scores was calculated both for the specific type of demand and for each evaluated manual (RSPCA in Europe, NCC and EHS in the USA, and MBPB in Brazil), in order to verify and quantify how much they depart from or agree with the international trade code (GlobalGap) on the selected subjects. Comparative analysis of the mean score values was used for evaluating the performance of manual in terms of addressing welfare legislation for broiler. Student t test was applied to the mean values at a confidence interval of 95% using the software MINITAB® 15.1.

The AHP is an appropriate tool to evaluate critically and logically relevant criteria and to assist in making sound decisions. It also helps to organize thoughts and knowledge in terms of goals, criteria and sub-criteria by structuring the problem in a hierarchical fashion and assessing them systematically in order to select the best course of action. AHP was used to compare the overall ranking of norms (Saaty, 1991). This present study was made following the mathematic procedure: let a_{ij} denote the comparison of element i to element j in pair-wise comparison matrix A, and suppose there are n alternatives. In the first approach, the group of decision-maker is required to reach a consensus on each entry a_{ij} in A. Let a_{ij} k denote the comparison of element i to element j for decision-maker k (k=1,2,...,n) in pair-wise comparison matrix A. The individual judgments of the n decision-makers are combined using the geometric mean to produce the entry (Eq. 1, Bolloju, 2001):

$$a_{ij}=[a_{ij}^{1}\times a_{ij}^{2}\times\cdots\times a_{ij}^{n}]^{1/n} \quad (1)$$

If weight w_k is assigned to the decision-maker k, then the weighted arithmetic mean has also been used to combine the judgments of decision-maker (Eq. 2).

$$a_{ij}=w^1a_{ij}^1+w^2a_{ij}^2+\cdots+w^na_{ij}^n \qquad (2)$$

Criteria pair-wise were compared according to their possibilities of reaching the proposed goal (Saaty, 1980).Criteria hierarchy levels were chosen based on qualitative and quantitative characteristics. The goal was to select the most appropriate set of rules. The second hierarchy level had the following items: ease assessment; understandable by user; in accordance to international rules; adequate rearing standard; high possibility of being used; safety and adapt to overall condition (Figure 1). The third level was addressed for meeting specific items and users. Calculations were done using the software Expert Choice®.

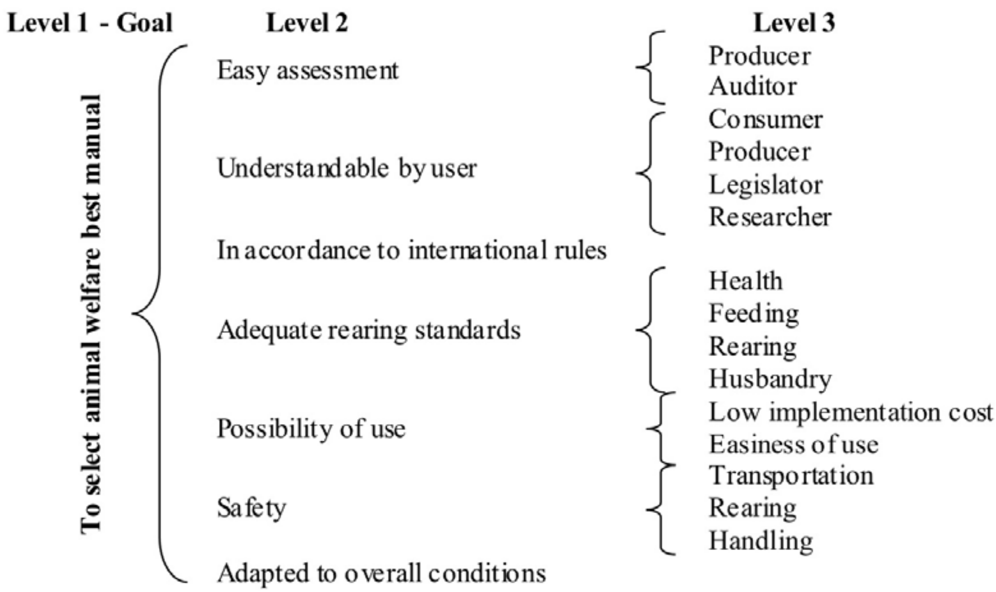

Figure 1. Scheme of the goal and criteria used in the AHP analysis.

Results and Discussion

<u>Comparing the norms</u>

Many legislations do not specifically address animal welfare issues and producers involved in the international meat export market may rely on standards and information found in codes of good practices published by extension and research institutions (Silva, 2008). Table 1 and 2 shows the comparison between studied norms related to production management. High scores are related to the clear and broad presentation of specific items mentioned in the text. GlobalGap received smaller score just in the points where the text is not specific and the focus remains on bureaucratic registrations. EHS presented adequately the items related to

environmental and traceability issues. Brazilian manual did not use appropriate text about traceability and this indicates that traceability may be considered as a critical point to be revised at this manual.
Regarding the building and environment, ventilation and temperature conditions the texts contains in concise form all necessary information to be followed. Regarding flock density although there is material in current literature (Boivin *et al*., 1992; Dawkins, 2003), Brazilian and EU norms (Globalgap and RSPCA) present items with specific measurements and indications, while others do not even mention the subject. There is also important information available in literature related to heat stress and ammonia control (Wathes *et al*., 2002; Aradas & Nääs, 2005) and all the manuals present written information's about these items. Regarding health questions all countries follow the OIE rules, but the item of hygiene is not found specifically in the USA material. Harvesting and transportation are discussed in the analyzed material from Brazil and EU; however, in the American manuals they are not properly mentioned. Welfare related issues are well addressed in the RSPCA manuals, the GlobalGap, and in Brazilian manuals this matter is adequately discussed.

Table 1. Comparative analysis of the mean score values was used for evaluating the performance of each country or economic block in terms of addressing welfare legislation for both broiler, regarding the chosen types of demand.

Item	MBPB	GLOBALGAP	EHS	RSPCA	NCC	Ave
Management of production	4.0	3.5	3.5	4.5	2.0	3.5
Environmental management	3.5	3.5	4.0	2.5	3.5	3.5
Traceability	1.5	3.5	4.0	3.0	3.0	3.0
Ave	3.0	3.5	3.6	3.3	2.8	3.3

The subjects related to management of production are found in the RSPCA and the Brazilian manual, while than the GlogalGap and the EHS/USA lack in this information. The NCC/USA does not mention sufficient information about this item. Regarding light exposition the MBPB/Brazil only mentions housing design related to natural lighting, lacking in artificial lighting data. The GlobalGap is highly descriptive in the aspects of light measurements allowing the reader to easily follow and meet requirements. The NCC/USA does not present specific chapter on this matter but it addresses the issue to the DEFRA norms (Defra, 2008). Bedding use and management are mentioned in details in MBPB/Brazil and EU manuals, but in the NCC/USA only the cleaning of bedding is addressed. Feeding and water quality and availability are well described, and all critical points mentioned in manuals from the EU. Brazilian norms follow the rules dictated by the country's agriculture authority, which are somehow vague; while the USA follows the rules dictated by FAO (1998).

Table 2. Comparative analysis of the mean score values was used for evaluating the performance of each country or economic block in terms of addressing welfare legislation for both broiler, regarding the chosen types of demand.

Rearing, management and welfare	MBPB	GLOBALGAP	EHS	RSPCA	NCC	Ave
Building and environment	4.0	4.0	4.5	3.0	3.0	3.7
Flock density	4.5	4.0	0.0	4.5	3.5	3.3
Ventilation and temp. control	4.0	4.5	4.0	4.5	3.5	4.1
Lighting	4.0	4.0	4.0	4.5	3.5	4.0
Bed	4.5	4.0	4.0	4.5	3.5	4.1
Feeding and water	4.0	4.0	4.5	4.5	4.0	4.2
Health	4.5	4.5	4.0	4.5	4.0	4.3
Harvesting and transportation	4.5	4.5	2.0	4.5	4.0	3.9
Welfare of poultry	2.5	2.5	3.0	4.2	3.0	3.0
Ave	4.0	4.0	3.1	4.3	3.5	3.8

<u>Applying the multicriterial analysis</u>

Using the AHP analysis the best norm was found (Figure 2). Considering the criteria used in the analysis the GlobalGap had the highest ranking (21.7) followed by the RSPCA/Europe (21.4%), the NCC/USA (19.5%), the MBPB/Brazil, 18.9%, and the EHS/USA (18.4%). The manual which presented the most appropriate items was the GlobalGap. Within this manual the criteria "safety" and "easy assessment" presented the highest weight (15.4% and 14.6, respectively).

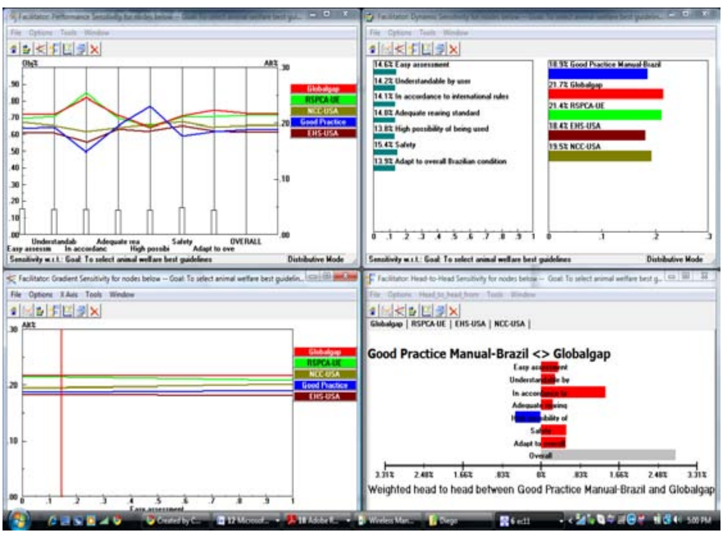

Figure 2. Presentation of AHP final results of the evaluation criteria used in the study.

Conclusions

It was found an important difference in the way of each region or country present their norms related broiler production with respect to rearing, housing and welfare. Higher degree of common norms' characteristics is greatly desired in order to help international trade.

Acknowledgements

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References:

Aradas, M.E.C.; Nääs, I.de A.; Salgado, D. 2005. Comparing the thermal environmental in broiler housing using two bird´s densities under tropical conditions. Agricultural Engineering International CIGR E-Journal **7**:1-10.

Boivin, X., Le Neindre P., Chupin, J.M. 1992. Establishment of cattle : human relationships. Applied Animal Behaviour Science **32**: 325 -335.

Bolloju N. 2001. Aggregation of analytic hierarchy process models based on similarities in decision makers' preferences. European Journal of Operational Research **128** (3): 499-508.

Dawkins, M.S. 2003 What makes free-range broiler chickens range? In situ measurement of habitat preference. Animal Behaviour **66**: 1-10.

Department for Environment, Food and Rural Affairs – Defra. (2006) Welfare Act. Inglaterra, UK: Defra. Available at: http://www.defra.gov.uk/animalh/welfare/act/index.htm. Accessed on: 22/09/2010.

EMBRAPA. 2007. Good practice of poultry production. Concórdia.SC: EMBRAPA- CNPSA. Circular Técnica n. 51. p.12.

Food and Agriculture Organization of the United Nations –FAO (1998) Training manual on food hygiene and the hazard analysis and critical control point (HACCP) system. Food and Standards Service, Food and Nutrition Division. Rome: Management Group – FAO – Information Division, 220p.

GlobalGap. 2009. The global partnership for good agricultural practice. Available at: http://www.globalgap.org/Languages/English/. Accessed on: 16/05/09.

International Finance Corporation – IFC. 2007. Environmental, health and safety guidelines for poultry production. (EHS),Washington, DC, IFC 30, April. p.970.

McInerney, J. (2004) Animal welfare, economics and policy: report on a study undertaken for the farm & animal health economics. Defra. England UK. p. 68.

National Chicken Council Political Action Commitee. (2008) Political action committee campaign contribution details. p.24p

Puma, M.C. , Xin, H., Gates, R.S.; and Burnham, D.J. 2001. An instrumentation system for studying feeding and drinking behaviour of individual poultry. Applied Engineering in Agriculture **17**: 365-374.

Royal Society for the Prevention of Cruelty to Animals –RSPCA. 2008. Good chicken guide: welfare standards for chickens, England, UK. RSPCA, p.60.

Saaty, T. L. 1991. Método de análise hierárquica (AHP). Rio de Janeiro: McGraw-Hill do Brasil/Makron Books.

Silva, R.B.T.R. 2008. Norms of animals' production subjected to intensive system: scenario of national legislation about animal welfare. p.132. Dissertação (MS in Agr. Eng.) – UNICAMP (Abstract in English.

Wathes, C.M., Jones, J.B., Kristensen, H. H., Jones, E. K. M. and Webster, A. J. F. 2002. Aversion of pigs and domestic fowl to atmospheric ammonia. Transactions of the ASAE, American Society of Agricultural Engineers **45**: 1605-1610.

Effect of the milk tube position on the teat-end vacuum condition in the Multilactor® milking system

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Abstract

The current study was conducted to find out, if a change in the milk tube position has an effect on the vacuum conditions at the teat end in a quarter individual milking system. The teat-end vacuum was measured in a factorial-design that involved three types of milk tube positions, between a pneumatic holder called milk magazine and the teat cup of a Multilactor® milking system (Siliconform GmbH, Türkheim, Germany). The three set-ups of tube positioning are called "High level", "Low Level" and "Wavy". The tests were achieved at nine different flow rates. It was found that at a flow rate of 4.8 l/min, the mean vacuum reduction during b-phase has been 3.52 kPa in Low Level, 4.13 kPa in High Level and 4.37 kPa in the Wavy position. Moreover, the mean vacuum reduction during d-phase also showed only marginal differences. The found data has been 25.23 kPa in Low Level, 25.78 kPa in High Level and 26.23 kPa in the Wavy set-up. Thus, the conclusion of this study is that the change of tube position does not disturb a gentle milking process and desirable vacuum conditions at the teat end.

Keywords: milking system; vacuum; wet-test-method; tube position

Introduction

The number of the world-wide installed quarter individual milking systems (QIS) shows an increasing trend. Most QIS on farms are automatic milking system (AMS). But since more than a year some other QIS were presented to the public, which are implementable into milking parlours. For example the IQ milking cluster produced by the GEA group (Bönen, Germany) or the AMR™ robotic carrousel of DeLaval group (Glinde, Germany). Another QIS which has been used in this study is called Multilactor® (MUL). These three mentioned milking systems have been described in their function by Ströbel *et al.* (2010) and by Anonymus (2010) (AMR™). MUL is commercially available and can be introduced to milking parlours. In comparison to the IQ milking cluster it has longer single guided milk tubes. This is an advantage for introducing additional technical equipment to perform a more gentle milking process on quarter level. The quarter individual milking technology and especially automatic milking systems (AMSs) introduce some additional advantages but also some important disadvantages to the milking process. High vacuum reductions and fluctuations were a big problem in the introduction phase of AMSs in the 1990s. In a former study Thiel and Mein (1979) found out that vacuum fluctuations can delay the milking process. Further, vacuum fluctuations can have a negative impact on teat tissue (Hoefelmayr and Maier, 1979a). The main requirement expected from any kind of milking system is to gain the highest milk yield at the shortest time and less labour and this must be achieved without damaging the udder (Rose-Meierhöfer *et al.*, 2010). Thus, the udder health is one of the most important

factors for successful and sustainable dairy farming. Thiel and Mein (1979) further showed that an increase of nominal vacuum leads to higher milk flow levels but also amount of re-milk was higher.
So the adjustment of the teat-end vacuum is very important for the whole milking process. Some researchers have the opinion that too high vacuum at the teat end, especially in d-phase, leads to damage of the teat tissue. The higher the vacuum under the teat is, the more folds the teat cup liner together in c- and d-phase and the tissue get squeezed too much (Hoefelmayr and Maier, 1979a and Sagkob *et al.*, 2010). According to Hömberg (2008) the teat-end vacuum in d-phase should be under 20 kPa, which is very low, but leads how he found out, to lower affecting the udder tissue. Rasmussen and Madsen (2000) reported that milking at low vacuum 26 to 30 kPa in average at the teat end compared to high vacuum of 33 to 39 kPa increased machine-on time and frequency of liner slip. Milking at high vacuum, in contrast has been shown to decrease machine-on time slightly (Reinemann *et al.*, 2001), increase the number of teat ends open after milking and the amount of time for teat ends to close after milking and increase teat-end hyperkeratosis (Mein *et al.*, 2003). On the other hand the fine adjustments, the main settings in milking machines were studied and known for many years. As a result of these studies conducted, the ISO/DIN 6690 (2007), the ISO/DIN 20966 (2007) and the ISO/DIN 3918 (2007) guidelines, which are regularly updated according to the latest scientific knowledge were prepared. These guidelines are obligatory for quarter individual milking systems (QIS) as well as for conventional milking systems.

The objective of the current investigation was to find out, if a change in the milk tube position has an effect on the teat-end vacuum level. A further question is if this potential effect could be a danger to the conformity of the teat-end vacuum data of the system, with the requirements of the ISO/DIN 6690 (2007) guidelines.

Material und methods

Test-setup

Vacuum measurements using the wet-test-method (ISO/DIN 6690, 2007) were conducted in each of the three tested tube positioning set-ups. The constructive style and the geometry of all three tube positioning set-ups are given in Figure 1. To understand this study, it is decisive to know, that for each tube positioning set-up only MUL and its typical tube guidance was used but the way of one milk tube between teat cup and milk magazine was put and fixed on a board in three different ways (high and low level and wavy set-up).

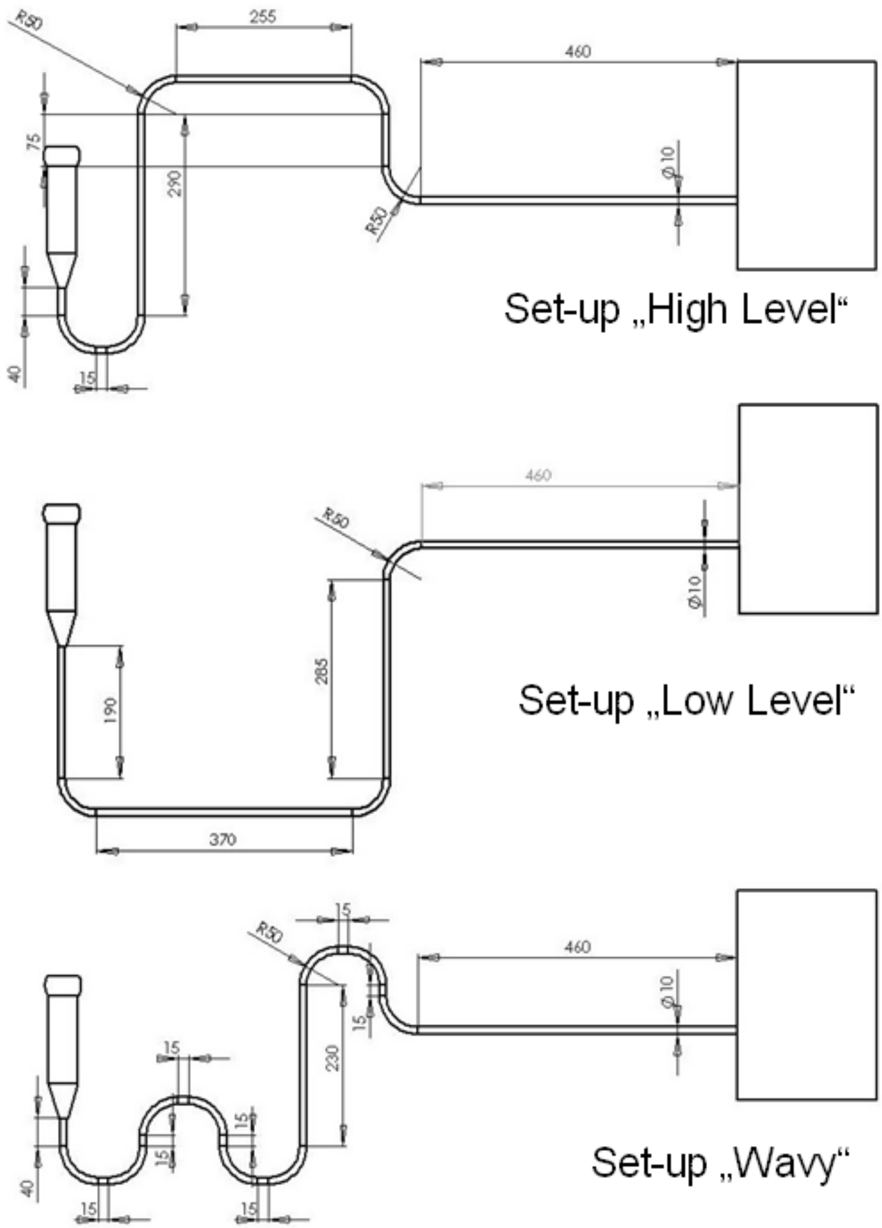

Figure 1. Schematic representation of the three different tube positioning set-ups (tube length in mm), build with one of MUL's four milk tubes.

The milking system Multilactor® (MUL) was developed and has been produced and sold from Siliconform GmbH. The settings of MUL like rate, ratio and nominal vacuum have been set to a level which is given from the producer (Table 1). The settings in MUL were constant during all the experiments. The most important technical innovations in MUL are: Quarter individual tube positioning, teat cup in-between cleaning and disinfection inside and outside of each teat cup with an automatic washing unit, sequential pulsation and four vacuum cut-off valves for each udder quarter one. As the name implies, this valve is automatically able to turn off the vacuum supply, when one or more teat cups are kicked-off by the cow. This function however was deactivated for all the experiments. The sequential pulsation on the contrary enables an even milk transportation and reduces vacuum reductions in b-phase of pulsation in comparison to simultaneous pulsation, when vacuum data for both pulsation variants were measured in MUL (Ströbel *et al*., 2009). Further MUL is equipped with a pneumatic arm called Actuator. This arm moves the four milk tubes regularly, whereby the muscular system of the udder is meant to be stimulated and relaxed additionally and was described by Ströbel *et al.* (2010). Another characteristic of MUL is the integration of the Biomilker® technology (Hoefelmayr and Maier, 1979b), which has not been used in a quarter individual milking system before. The Biomilker® technology with controlled air-inlet in the d-phase of pulsation produces a low level vacuum in d-phase but leads as well to low vacuum fluctuations in the b-phase of pulsation. The MUL's mode of operation is different in comparison to working with conventional milking clusters. For attaching the teat cups a pneumatic holder for the teat cups called milk magazine pivots under the udder. Afterwards the teat cups can be attached manually in pairs. The removal of the teat cups occurs automatically, however not quarter individually so far.

Table 1. Technical details of the milking system Multilactor® (MUL).

Data	Value
Year of production	2008
Nominal vacuum	35 kPa
Pulsation ratio	65/35
Pulsation rate	60/min
Type of pulsation	sequential
Construction of milking unit	quarter individual
Milk tube/pipe length from teat cup to the claw	3.095 mm
Inner diameter of the milk tube at the connection to the teat cup	10 mm
Style of air-inlet	periodic (Biomilker®)

Experiments with milk flow rates as follows have bee performed: 0.0; 0.8; 2.0; 2.8; 4.0; 4.8; 5.6; 6.0 and 7.0 l/min. For each quarter the flow was exact 25% of the total flow rate, however the flow rate of each quarter had the same level in each experiment. Each tested tube positioning set-up is shown in Figure 1. During the wet-tests, ISO/DIN artificial teats were used (ISO/DIN 6690, 2007). Water at room temperature was used to simulate the effects of the milk flow. As a flow simulator, four flow meters (Parker Hannifin Corporation, Cleveland, USA) installed on a board were used. Each flow meter allowed measuring the flow rate ranging between 0.0 and 2.0 l/min with a measuring accuracy of ± 2%. MUL was operated in laboratory and the vacuum was measured using a MilkoTest MT52 measuring system (System Happel, Friesenried, Germany) with an accuracy of ± 0.1 kPa, while a measuring accuracy of ± 0.6 kPa is required as defined in ISO/DIN 6690 (2007). The maximum sampling rate is 1.0 kHz. The vacuum was recorded for five pulsation cycles for each measurement at the end of the artificial teat, in the pulsation chamber and in the main vacuum line, simultaneously. The sensors were connected direct with the artificial teat (ISO/DIN 6690, 2007), with T-pieces to the pulse tube and with direct connection to the main vacuum line. The T-pieces can be used instead of the injection needle for connecting the pressure sensor with the tube inside. From the data recorded, the mean vacuum in the b-phase, the mean vacuum in the d-phase, and the vacuum reductions for the two phases were calculated for each of the five pulsation cycles. Measurements for each flow level at each tube position were repeated nine times.

Results

Vacuum reductions in b-phase

The results of the wet-test for the three different set-ups of tube positioning at flow rates ranging between 0.0 and 7.0 l/min as mean of b-phase vacuum are shown in Figure 2.

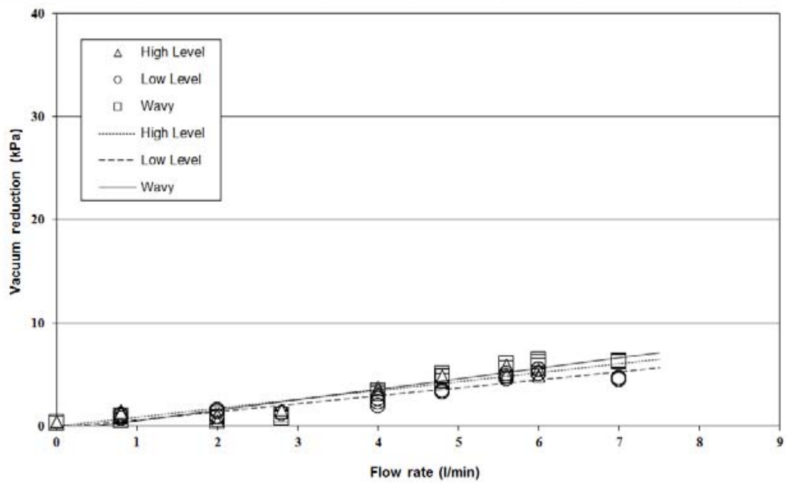

Figure 2. Vacuum reduction at the teat end in b-phase in all three tube positioning set-ups at different flow rates. Both, vacuum data and regression lines are given for each set-up.

For all three positioning set-ups the teat-end vacuum decreased as the flow increases. The highest vacuum reduction was found at a flow rate of 7.0 l/min of about 7.5 kPa for all three positioning set-ups. For each flow level there have been only slightly differences in the vacuum reduction effect. There is only a marginal effect of the geometric tube position on the vacuum reductions measurable. However, the difference under the set-ups is at maximum 2.9 kPa. Nevertheless, by comparing the calculated regression lines, the following order was found: Wavy tube positioning produces higher reductions than high level and low level positioning, while both have more similar geometrics. The position in low level set-up is most similar to that position which the four tubes have under farm conditions. But as shown in Figure 1 the differences also to the wavy set-up are only marginal.

Statistical analysis

In Table 2 the calculation results for the adapted curves for the vacuum reduction data for each tube positioning set-up and for each flow rate are tabulated. The results for the variables are also given within Table 2.

Table 2. Different regression curves and variables for all the data given in Figure 2 and 3.

Phase	Formula for the regression function	Set-up of tube position	Value of variable A	Value of variable B	Value of variable C	Value of variable D	Value of variable E	Value of variable F
b-phase	y=Ex+F*	High level	-	-	-	-	+0.8624	-0.014
		Low level	-	-	-	-	+0.7688	-0.1675
		Wavy	-	-	-	-	+1.014	-0.4954
d-phase	$y=Ax^5+Bx^4+Cx^3+Dx^2$	**High level**	+0.0074	-0.1328	+0.8771	-3.3176	+11.650	+0.9354
	+Ex+F*	**Low level**	-0.0025	+0.036	-0.0976	-1.1216	+10.121	+0.5464
		Wavy	+0.0023	-0.0503	+0.4482	-2.5852	+11.686	+1.0649

**where y = vacuum reduction in kPa and x = flow rate in l/min.*

Vacuum reductions in d-phase

Figure 3 shows the vacuum reduction for all three tube positioning set-ups in d-phase. As seen from the figure, there are also only marginal differences between the set-ups of tube positioning. If comparing the marginal differences the same order than in Figure 2 was found. Wavy tube positioning produces higher reductions than high level positioning. Further, low level positioning leads also in d-phase to the lowest vacuum reduction. In comparison to Figure 2 the curves which can be adapted to the data with least squares method are quadratic equations of fourth-degree. They are given in statistical analysis in Table 2, too. However, also here the difference under the set-ups of positioning is at maximum 3.2 kPa. The range between the data is low.

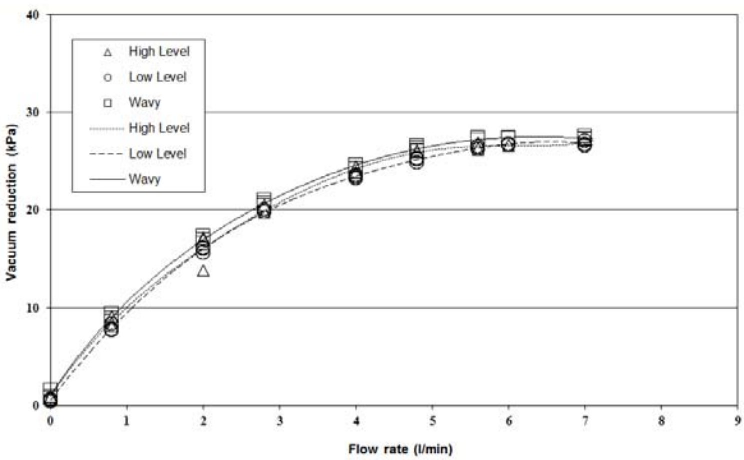

Figure 3. Vacuum reduction at the teat end in d-phase in all three tube positioning set-ups at different flow rates. Both, vacuum data and regression curves are given for each set-up.

Discussion

A first result was that the tested set-ups of tube positioning systems have only a marginal effect on the vacuum reduction in b- and in d-phase. Thus, it is possible to compare the total value of the reductions with data of tested milking systems in former studies. Rose-Meierhöfer *et al.* (2010) found mean vacuum reductions at a flow rate of 4.0 l/min of approximately 10.2 kPa in b-phase for MUL installed in a farm and approximately 9.9 kPa for a conventional milking cluster, which was installed in the same farm in milking-time tests defined by International Dairy Federation (IDF, 1999). In the current study all values for all set-ups of tube positioning lays lower than 5.0 kPa in b-phase. Thus, the tests in laboratory showed lower reductions in b-phase.

The reason could be that MUL in the laboratory was equipped with a better fitting milk meter which is since more than a year the only one advised from the producer to be used in connection to MUL. So far, unpublished observation cover this assumption. In d-phase Rose-Meierhöfer *et al.* (2010) found reduction values of approximately 11.0 kPa for the conventional system and of approximately 23.5 kPa for MUL in the already mentioned study for a flow rate of 4.0 l/min. Therfore, the data of MUL in d-phase in the current study are with approximately 25.0 kPa similar to the data, which were found in the former study. In both studies the reductions are much higher for MUL in the d-phase than for the conventional milking system, because MUL is equipped with a Biomilker® valve for each quarter. As shown in various publications before the Biomilker® technique helps to avoid high forces caused by vacuum on the teat tissue, because it lowers the vacuum in d-phase but produces in b-phase a good adjustable vacuum with low vacuum reductions. Higher vacuum reductions in d-phase are required for a good teat condition. Hamann *et al.* (2001) showed that a positive pressure system caused significantly smaller teat-end diameters and lower thickness values as compared to conventional milking systems. It was further found that the vacuum reduction in d-phase is only very high at flow rates of more than 4.0 l/min. This effect protects the udder against too high vacuum in this phase but the reduction should also be high at low level flow rates to protect the udder from over-milking. It was found additionally, that the effect of the tube position do not influence the teat-end vacuum in b-phase in a way, that the requirements of ISO/DIN 6690 (2007) guidelines would be breached. Further research is needed to find out, if there is a dynamic effect of MUL's Actuator arm on the vacuum reduction, which cannot be evaluated with this study.

Conclusions

The present study leads to the following conclusions:

- The analysis of the vacuum curve of each set-up of tube positioning showed that there are only marginal differences, between the vacuum reduction curves of the three set-ups: High level, low level and wavy tube position.
- Both Figures 2 and 3 show the characteristic vacuum behaviour of the milking system Multilactor® (MUL), which supports the cow with low vacuum in d-phase and with a low vacuum reduction in the b-phase of the pulsation cycle.

- Further research is needed to provide an answer to the question if there is a dynamic effect of the pneumatic Actuator arm on the vacuum conditions in the milk tubes.
- The effect of the tube position do not influence the teat-end vacuum in b-phase in a way, that the requirements of ISO/DIN 6690 (2007) guidelines would be breached.

References

Anonymus. 2010. Edelmetall für 21 Exponate. Neue Landwirtschaft **10** 35.

Hamann, J., Bronzo, V., Moroni, P., Casula, A. and Zecconi, A. 2001. Conventional and positive pressure pulsation effects on bovine teats and on immunological components of different milk fractions. Milchwissenschaft **56** 423-427.

Hoefelmayr, T. and Maier, J. 1979a. Vom klassischen Zweiraumbecher und seinen Funktionsmängeln. Milchpraxis **17** 62-64.

Hoefelmayr, T. and Maier, J. 1979b. So arbeitet der Bio-Milker. Milchpraxis **17** 65.

Hömberg, D. 2008. Wenn Vakuumverluste Kühe krank machen. DLZ Agrarmagazin **11** 119-121.

IDF (1999). Instruments for mechanical tests of milking machines. Bulletin/ International Dairy Federation **338**.

ISO/DIN 3918. 2007. Milking machine installations - constructions and performance. International Organization for Standardization.

ISO/DIN 6690. 2007. Milking machine installations - mechanical tests. International Organization for Standardization.

ISO/DIN 20966. 2007. Automatic milking installations - requirements and testing. International Organization for Standardization.

Mein, G. A., Williams, D. M. and Reinemann, D. J. 2003. Effects of milking on teat-end hyperkeratosis: 1. mechanical forces applied by the teatcup liner and responses of the teat. Proceedings, 42nd annual meeting of the national mastitis council, 26-29.01.2003, Fort Worth, USA.

Rasmussen, M. D. and Madsen, N. P. 2000. Effects of Milkline Vacuum, Pulsator Airline Vacuum, and Cluster Weight on Milk Yield, Teat Condition, and Udder Health. Journal of Dairy Science **83** 77-84.

Reinemann, D. J., Davis, M. A., Costa, D. and Rodriguez, A. C. 2001. Effects of Milking Vacuum on Milking Performance and Teat Condition. Proceedings, AABP- National Mastitis Council. International Symposium on Mastitis and Milk Quality, 13-15.09.2001, Vancouver, Canada.

Rose-Meierhöfer, S., Hoffmann, G., Öz, H., Ströbel, U. and Ammon, C. 2010. Milking-time tests in conventional and quarter-individual milking systems. Landbauforschung - vTI Agri-culture and Forestry Research **60** 11-15.

Sagkob, S., Rudovsky, H-J., Pache, S., Herrmann, H-J. and Bernhardt, H. 2010. Auswirkungen verschiedener Melkzeuge auf Zitzenkondition und Milchabgabeparameter. Landtechnik **65** 27-30.

Ströbel, U., Rose-Meierhöfer, S., Ammon, C. and Brunsch, R. 2009. Quarter individual milking with Multilactor® in milking parlours. Landtechnik **64** 106-108.

Ströbel, U., Rose-Meierhöfer, S., Müller, A. B. and Brunsch, R. 2010. Online-Sensoren auf dem Vormarsch. Neue Landwirtschaft **10** 58-63.

Thiel, C. C. and Mein, G. A. 1979. Action of the cluster during milking. Hrsg.: Thiel, C. C. and Dodd, F. H., Machine Milking. National Institute for Research in Dairying (NIRD), Reading, Großbritannien, pages 116-155.

Keyword Index

Author Index

Precision Livestock Farming '11

Today PLF-technology has developed to a point that the combination with monitoring and control of complex dynamic biological processes has become realistic. This technology offers the possibility to achieve economically, environmentally and socially sustainable farming through continuous automatic observation, real time data interpretation and active control of the smallest possible group of animals.

Also in this world of livestock production the added value will move to knowledge, to intelligent use and combination of information at different levels. Therefore we need to combine the expertise and the collaboration of several disciplines and experiences. Animal scientists, veterinarians, ethologists … and engineers have to collaborate to develop the PLF technology to a strong integrated tool. A totally new service industry around the farmer will show up since the related industries will have to develop totally new business models as is happening in other sectors.

Another trend is that many highly educated young people want their piece of the cake. Globalization and new technology makes that they can be part of the world economy in a very short time. There will be high tech SME's that will bring totally new and creative ideas realised by this modern technology. A key element in the whole PLF development is that we have to analyse how we can create a win-win situation by linking these small new SME' to the established big market players in the world.

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