Proceedings of the 3rd International Precision Dairy Farming Conference

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Welcome to the 2022 Precision Dairy Conference!

On behalf of our conference planning committee, we welcome you to the third International Precision Dairy Farming Conference.

The last years have shown us how closely animal and human health, and their shared environment are interlinked. In this context Precision Dairy Farming has the potential for prudent use of resources and for early detection of disease so that both intra- and inter-species disease transmission can be reduced. Prevention and early treatment of disorders can contribute to a reduction in the use of pharmaceuticals and minimise antibiotic resistance. Therefore, Precision Dairy Farming technology is a key element to achieve the Sustainable Development Goals (SDGs) and looking to the brighter future.

During the conference, Vienna is the central meeting point for the world's leading scientists, manufacturers, farmers, veterinarians and other stakeholders interested in Precision Dairy Farming technologies. One of the key elements for further development and adoption of new technologies in dairy farming is education of a new generation of students in the interdisciplinary field of Precision Dairy Farming. This topic will also be addressed in scientific sessions.

We are happy to announce the opening of a unique, new master programme on Precision Animal Health offered by Vetmeduni Vienna and its partners. This master programme will support students in acquiring skills to understand and explain the technological basis and principles underlying the application of information driven technologies in the areas of veterinary medicine, animal husbandry and agricultural production.

We would like to thank all authors for their papers and presentations, the reviewers for their important comments and contributions which have helped to ensure the high quality of the papers. We want to thank our organising committees and conference partners. We especially would like to thank our sponsors and supporters, without whom we could not run this conference successfully.

We hope that the third International Precision Dairy Farming Conference will stimulate fruitful discussions and networking, identify common goals and develop new research collaborations. We hope that delegates enjoy their visit to Vienna.

Sincerely,

Maciej Oczak
Michael Iwersen
Karen Wagener

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The conference was organised as a joint event of PDC and ECPLF.

Only contributions from the PDC are presented in the conference proceedings.

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Poster Presentations

iDDEN - A new data exchange system for dairy cattle data

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Background

In the recent years, dairy production has seen a lot of technological advances in different areas. On the farms, technologies for automatisation of work processes are increasingly implemented, particularly automatic milking and feeding systems. Furthermore, livestock sensors for the acquisition of behaviour and health data as well as sensors for environmental parameters (e.g., barn climate) become widely available. These systems are able to deliver large amounts of data from which conclusions on the animal wellbeing and welfare can be drawn.

Digitalisation adds another dimension to the use of new technologies. Networking and integration of different data sources provide the basis for enhanced data science approaches such as Big Data analyses, and image and pattern recognition. The challenge of the current situation is the existence of disconnected data silos, and a heterogeneous landscape of application programming interfaces (Egger-Danner et al., 2019). However, both performance recording organisations and their data processing centres as well as original equipment manufacturers (e. g., for milking equipment or animal sensors) and farm management solution providers rely on the integration of the variety of traditional and new data sources in order to fully leverage the potential of data for functional equipment and services for farmers.

The international Dairy Data Exchange Network (iDDEN) was set up to increase the availability of data by providing the technical platform for a globally standardized data exchange.

Design Principles

For the implementation of the iDDEN Hub, the goal was reuse as much as possible of what is already existing at the potential user organisations. Therefore, iDDEN took over the existing infrastructure of NCDX, a data exchange solution originally built for the purpose of multinational data exchange in Scandinavia (Kyntäjä et al., 2018). The solution is built with up-to-date technical features based on a C#/.NET environment. The iDDEN Hub is also designed to reuse existing authentication and authorization services. Therefore, established systems at the data providers can usually also be used when data is exchanged through the iDDEN hub.

Another design principle was to rely on existing open standards. This is obvious for the web technologies that are used for the data exchange itself. More important is the support of the

ICAR Animal Data Exchange (ICAR ADE) messages, which are implemented to facilitate the globally standardised exchange of core livestock information, such as registration and movements, milking and live weight gain, conformation scores, or health treatments (ICAR, 2021). iDDEN will usually implement the latest version of the ICAR ADE specification (currently 1.2) wherever possible. iDDEN seeks to realise additional messages – if not yet covered by the implemented version of the specification – according to the design principles of the ADE specification.

Scope of iDDEN

The goal of iDDEN is to streamline data exchange between dairy herds, milk recording organizations, farm service providers, dairy equipment manufacturers and on-farm software organizations. iDDEN restricts itself to the technical part of the data transfer and the monitoring of the data flows. As a consequence, partners that are willing to share data need to agree on the business aspects in agreements that are decoupled from the mode of data transfer. Likewise, the data exchange partner organisations are responsible to acquire the mandate for data provision from the farms and to check if the data requesting partner is authorised to access the data.

In summary, iDDEN is a data exchange system based on current technical standards for on farm data and cloud based data repositories. It will be further developed to better serve the needs of farms and organisations by adding further ICAR ADE compliant messages. iDDEN is owned and governed by a consortium of farmer-controlled member organisations from different countries that teams up with strategic partners from the industry. iDDEN uses standardised interfaces and provides a standardised data transfer mechanism. Thus, costs will be significantly reduced for the transformation and processing of data from different sources and costs for developing and maintaining multiple equipment interfaces are avoided. iDDEN provides recommendations and support for organization to become 'iDDEN ready' and to reach the ultimate goal to have one universal point of integration with many data exchange partner organisations.

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Estimating Dairy Cow Rumen Fill: 3D Vision versus Manual Scoring

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The rumen is the largest chamber in a dairy cow's gastrointestinal tract and its condition is directly associated with a cow's health. One of the important indicators of the rumen condition is rumen fill, which describes the amount of liquid and dry matter kept in the rumen. The rumen fill is often used on farms to estimate a dairy cow's feed intake, whereas a low rumen fill could indicate problems in feeding practices and cow metabolism. In practice, the widely accepted expert method to assess rumen fill is to visually estimate the concaveness of the left paralumbar fossa of a dairy cow on a 5-point scale. This manual scoring system offers farmers an estimation of the rumen condition and feed intake of dairy cows. Practically, however, daily assessments on all individual cows of a herd are labour-intensive, hence costly to farmers. The objectives of this study were to design a 3D-vision-based rumen fill assessment and to validate the automated system with manual rumen fill scoring.

Fifteen Holstein dairy cows were randomly selected on a dairy farm equipped with an automatic milking robot. A 3D camera was mounted on the frame of the milking robot to remotely capture the left paralumbar fossa of each cow at 4 frames per second during milking (Figure 1-A), without interfering with the cow. Thereafter, the recorded images were processed to detect the hip bone, the 13th rib, and tips of the transverse processes (Figure 1-B). The depth difference (mm) between the median of the rumen area and the tips of the transverse processes were calculated and averaged for the whole milking as the estimated rumen fill of the cow (Figure 1-C).

The automated rumen fill assessment (i.e., the depth difference of the rumen area and tips of the transverse processes in mm) was validated by the 5-point manual rumen fill scoring given by an expert to each cow (Figure 2). A Spearman correlation (ρ) was calculated between the automated assessments and the manual rumen fill scores of the 15 cows and reached a result of $\rho = 0.121$ ($P > 0.05$). This non-significant correction could be caused by the manual rumen fill scores, which was given quickly after the cow left the milking robot. On the other hand, the automated assessment took the median of the depth differences between the rumen area and bones of a cow over the whole milking process, which could be more stable and reliable even under the influence of the continuous rumen contractions. In the future study, a more reliable referential method is required to validate the automated system. Furthermore, the 3D-vision-based system needs to be tested longitudinally on a large number of cows with great varieties in ages and breeds.

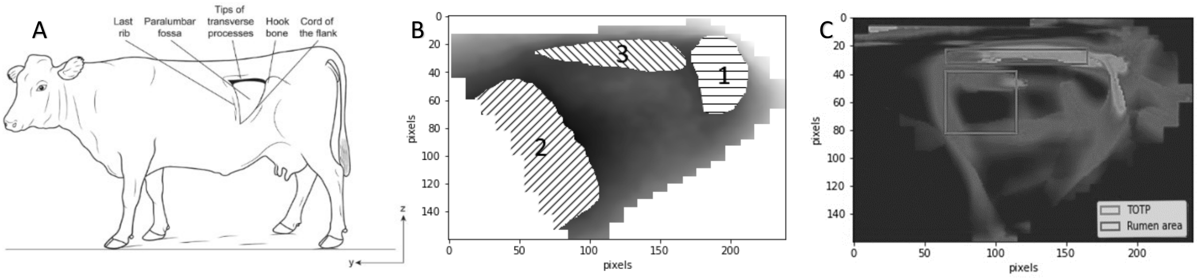

Figure 1. A. The left paralumbar fossa of a dairy cow. B. The automatically detected (1) hip bone, (2) the 13th rib, and (3) the tips of the transverse processes. C. the selected area of the tips of the transverse processes (TOTP) and the focused rumen area on a 3D image.

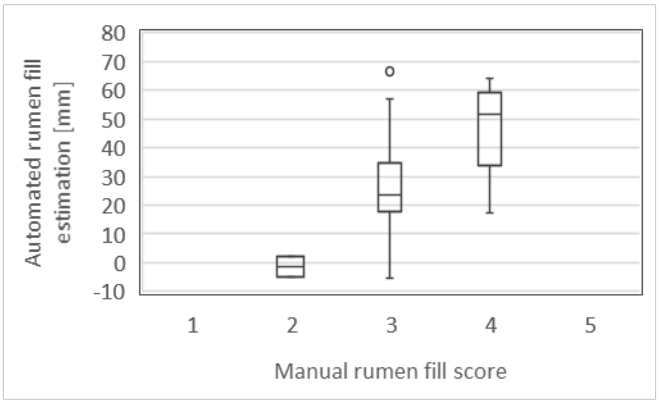

Figure 2. A boxplot of rumen fill estimation by using 3D vision versus the manual rumen fill score of the 15 selected cows. The central mark is the median of all the automated estimations with the same manual rumen fill score. The bottom and top edges of each box are the 25th (Q1) and 75th (Q3) percentiles, respectively. The whiskers extend to the extreme data points that are within the range of [Q1 – 1.5 × (Q3 – Q1), Q3 + 1.5 × (Q3 – Q1)]. The outlier is located outside of the range and plotted individually as a dot.

Early detection of abnormal weight patterns in dairy cows based on AMS weighing data

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Introduction

With increasing herd sizes, more farmers in Danish dairy herds install an automatic milking system (AMS) to ease the milking routines. During the daily management, farmers check the well-being of the cows and observes if some are lame, ill, or in other ways in need of extra attention. It can, however, be difficult to recognize early signs of lameness and diseases like post-calving metabolic disorder or fat cow syndrome timely enough to make preventive interventions. Preventive interventions could reduce both economic and productivity costs as well as the impact on health and welfare. In many AMSs a scale is installed, whereby the cow is weighted multiple times a day as it gets milked. This paper presents the first steps to develop an automatic monitoring system based on weighing data from the AMS to make an early identification of individual cows who need extra managerial focus.

Materials

Data concerning reproduction, medical treatments, breed, parity, days in milk (DIM), status of the cow (dried off or lactating), herd ID and cow ID were obtained from the Danish Central Cattle Database, whereas weight observations were obtained from the AMS. Weight observations were aggregated to a daily mean for each cow. For herds where a cow has access to more than one AMS per day, a correction was made to minimize differences in calibration across scales in different AMSs. In addition, the accumulated weight of the foetus was subtracted from the daily aggregated weight of the cow.

For each herd, the data set was split into training data and test data. The training data sets consisted of all unique cow-parity combinations where the cow had had no registered medical treatment and where weight observations were registered for minimum 250 days in the lactation. The test data sets consisted of all the cow-parity combinations which were not included in the training data set.

Methods

A dynamic linear model (DLM) was developed per herd for each cow-parity combination. The overall aim of a DLM is to predict the next observation of the monitored variable by estimating the parameter vectors, $\boldsymbol{\theta}_1 \dots \boldsymbol{\theta}_t$ from the observations, $Y_1 \dots Y_t$. Every observation is added to the model's prior knowledge of the modeled system, and this dynamic updating enables the model to predict the next observation with increased certainty over time as described by West & Harrison (1999). The expected daily change in weight was estimated by fitting a spline function to all observations from all cows in the herd, and the observation variance, $\boldsymbol{V}$, was assumed to increase linearly over time. Linear functions describing $\boldsymbol{V}_t$ given DIM was made separately for each parity group. A two-sided moving average was applied to the daily weight data of each cow, and the residuals between the observed values and the moving average were aggregated to daily variances. The system variance, $\boldsymbol{W}_t$, was estimated using a discount factor.

Forecast errors, generated by the DLM, were monitored by a two-sided tabular Cusum (Montgomery, 2013). If the summed forecast errors exceeded a threshold, an alarm was generated.

Results and conclusion

30 cows from the test data set from each herd were randomly selected to visually qualify if abnormal weight patterns were identified by the DLM based only on weight observations from the AMS. Thresholds for small alarms (small limit) and for large alarms (large limit) were arbitrarily defined to illustrate how alarms can be of different severity. A sudden change in weight was expected to be the indirect consequence of a disease. An example is shown in Figure 1, where the day of the first treatment is marked, and the diagnosis is shown as well.

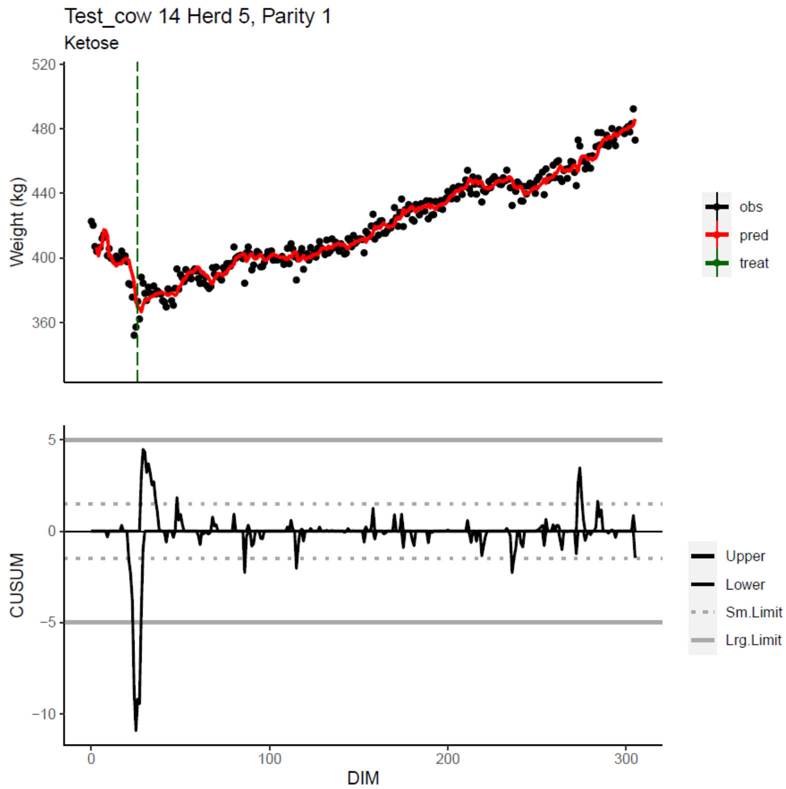

Figure 1: An example of the relationship between Cusum alarms and abnormal changes in weight pattern. The upper plot shows the observed weight (black dots) and the weight curve predicted by the DLM (red line). Day of treatment is shown (dashed green line).

The lower plot shows the two-sided Cusum. The Lower Cusum exceeds the large lower limit around the time of the treatment. Both upper and lower small limits are exceeded multiple times during the lactation, indicating that the cow has an unstable weight curve and should get extra managerial focus

In conclusion it was possible to detect abnormal weight patterns in dairy cows based on AMS weighing data, although adequate thresholds must be defined, and more variables must be included to reduce false alarms.

Acknowledgements

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Automatic Lameness Scoring: Comparing Absolute to Relative Scoring

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Introduction

Lameness is a prevalent health issue on dairy farms, impacting both animal welfare and economic performance. Frequent lameness scoring and subsequent treatment could lead to improved outcomes. Systematic visual lameness scoring is often not performed due to the skill, time, and cost required. Additionally, without adequate training it is a subjective measure and underestimates lameness prevalence (Beggs, 2019). Automatic lameness scoring using sensor data could assess lameness in a frequent, reliable, and objective manner.

Automatic and visual lameness scoring methods typically predict absolute lameness scores per animal. This manuscript investigates the performance of automatic relative pairwise lameness scoring, where the prediction is a relative score indicating which of two animals is more lame.

Materials and Methods

Automatic individual animal gait assessment was achieved with four low-cost Microsoft Xbox Kinect v2 3D sensors placed alongside and over a 3.6m long, 0.8m wide race at the exit of an automatic rotary milking dairy in Cobbitty, NSW. A GoPro Hero 5 Black colour camera was placed 8m perpendicular to the animal flow for conventional visual lameness scoring.

Two DeepLabCut v2.0.3 neural networks using ResNet-50 feature extractors were trained to detect locomotor keypoints in side and overhead images individually. For the side-on images, 765 training images were hand labelled with 25 keypoints. For the overhead images, 482 training images were hand labelled with 20 keypoints. These 45 locomotor keypoints were detected and tracked in new images, resulting in a trajectory in time and space. 118 gait metrics were extracted from the trajectories, including hoof placement, spine arch, head bob, and vertical hip displacement metrics.

300 passings collected between 2017 and 2019, of 197 individual animals, were scored from video by a single trained observer according to the Dairy Australia Healthy Hooves 4-level visual lameness scoring system. A score of 0 indicated no sign of lameness, and a score of 3 indicated severe lameness. For absolute score ground truth, scores were binarized into two groups, passings with score 0 (133 passings), and passings with scores 1, 2, or 3 (167 passings). For relative score ground truth, relative pairs were generated from the 300 absolute scores. 20652 pairs with a difference of 1, 6897 with a difference of 2, and 1064 pairs with a difference of 3 points were generated. For each pair, automatic relative lameness scoring had to predict

which animal was more lame, the first (11931 pairs) or the second (16682 pairs) animal. A random forest classifier was trained with 100 trees for absolute and relative pairwise prediction individually, followed by hold-one-out cross validation for absolute, and 10-fold cross validation for relative prediction. The relative classifier used the difference in gait metrics as input. The data pipeline described in this section is illustrated in Figure 1.

Results and Discussion

Automatic lameness scoring performance metrics can be found in Table 1. It is clear that relative pairwise lameness scoring outperforms binary absolute lameness scoring by a large margin. Raw automatic relative scores are however not directly applicable on farm as absolute scores are; ultimately a decision has to be made whether an animal requires treatment or not. Relative scores could however be used to rank animals from most lame to least lame, and each animal could be compared to a database of gait metrics that have defined conventional absolute visual lameness scores. With the latter approach, the higher accuracy of automatic relative pairwise scoring can be combined with a small database of visual absolute scores, and provide an actionable output for on farm decision making.

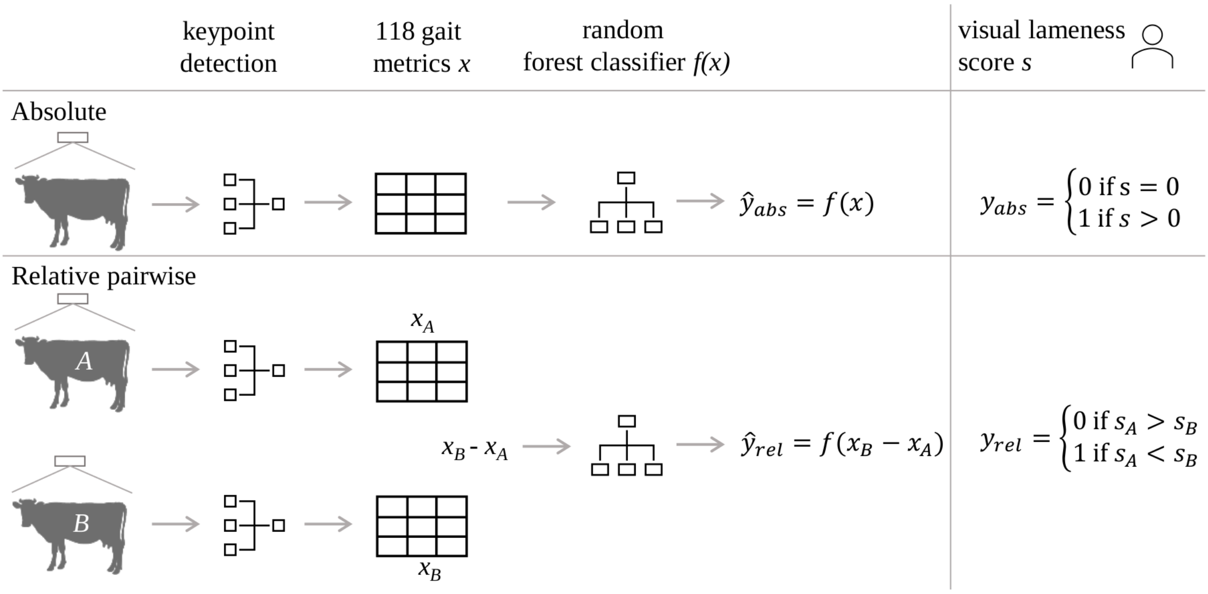

Figure 1: Data pipeline for absolute and relative pairwise automatic lameness scoring.

Table 1: Comparison of absolute vs. relative pairwise automatic lameness scoring.

Lameness Prediction	Sensitivity	Specificity	F1-score	Accuracy
Absolute	0.77	0.61	0.74	0.70
Relative pairwise	0.95	0.90	0.94	0.93

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Automated gait analysis with a deep learning key point detection model

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Abstract

Lameness is a costly and frequent disease impacting all aspects of sustainability including animal welfare, and production. Automation of gait assessment would allow to detect deviating locomotion at an early stage, allowing early intervention and treatment. This study used a neural network to detect key points in cows in side view, from which gait features of the animals can be derived. At the moment of this writing, analysing the gait features for repeatability and individuality has key priority as this lies the basis for an automated lameness monitoring system.

Introduction

Lameness in dairy cows is a costly and frequent disease, impacting welfare and production. Typically, lameness is assessed visually by observing the gait of the animals. This is time consuming, subjective and has a high risk not to detect animals that are in an early stage of lameness. Treatment of lameness in an early stage (e.g., by hoof trimming) could prevent developing more severe cases that require antibiotic treatment, or in the worst case, culling. The resulting higher longevity and better welfare would positively affect the sustainability of the dairy farm, in the social (welfare, antibiotics use) as well as in the economical and environmental dimension (more output with the same inputs, lower need for maintaining many replacement heifers).
Automation of lameness detection has been a vast focus in the past decades. Multiple technologies have been explored, such as the use of pressure mats and analysis of parameters that have been associated with lameness in the past (e.g., activity, lying behaviour). With recent developments in the machine vision area, and the increased accessibility of computational power, the use of deep learning based solutions for animal monitoring boomed. For example, Russello et al. (2022) developed a method (T-LEAP) to estimate 17 cow key points on the legs, head and back of dairy cows in an outdoor situation using a neural network. Their model uses temporal information by including 2 successive frames and explicitly representing this link in the network's architecture. As a result, this method was more robust to occlusions, which are often present in farm environments.
In the current research, we bring the T-LEAP model to an indoor farm environment, and use the key points to subsequently calculate gait features. Application of the model in a farm environment, and linking it with the cow identity will allow to study repeatability and individuality of key point derived gait features, and assess how many steps would be needed to obtain gait times series to automate gait assessment.

Materials and methods

Two cameras (frame rate = 25 fps) were installed at the Dairy Campus research facility of Wageningen University and Research, Leeuwarden, the Netherlands. These cameras collect footage of the cows from the side after they exit the milking parlour. A figure of the footage collected is shown in Figure 1.

Figure 1. Key points of 2 successive frames from which gait features are calculated.

Key points were annotated on approximately 400*2 frames representative for the conditions and animal variability with the free and open-source annotation tool 'CVAT' (https://cvat.org). The frames for annotation were selected such that they cover a representative sample of the footage conditions in the farm and a variety of animals (e.g., in coat patterns). Annotation was always done on paired frames to be able to include the temporal information which is an essential part of the T-LEAP model. For each cow, 17 key points were determined as shown in figure 1, which included 12 key points for the legs, 3 for the back and 2 for the head.
Next, the T-LEAP model was trained on the frames, starting from the weights and 2-frame architecture as described by Russello et al. (2022). T-LEAP is an 11 layered neural network based on the initially proposed model by Pereira et al. (2019), and extended to include temporal information. The model was implemented using the PyTorch deep-learning framework and the output of the model consists of 17 heatmaps containing the predictions for each key point.
When considering the key points over the different frames, several gait features can be calculated to assess locomotion scores. Besides the raw key point time series, these manually crafted features include step size, regularity of left and right foot time series, speed of movement, arching of the back, amplitude of the head movement etc.

Results & discussion

This study transferred an existing neural network to a new setting to detect key points of cows filmed indoors when walking back to their barns after milking. From the key points, we manually crafted 'gait' features that, from an expert point of view, might relate to locomotion score and lameness. These features include the average arching of the back, amplitudes of the leg points, amplitude of movement of the head, regularity of the gait, etc. This setting allows to evaluate key point based gait scoring for lameness detection. It is expected that coming months the results will be obtained in terms of 1) accuracy of the key point detection in this new setting and 2) gait feature crafting. Results will be presented at the Precision Dairy Farming 2022 conference.

Acknowledgements

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Managing stakeholder participation for the adoption of digital livestock technologies: Expectations, performance, relationships, and support

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Digital Livestock Technologies (DLTs) such as Precision Livestock Farming (PLF) technologies are receiving increasing attention due to their potential to assist livestock farmers in managing their animals by monitoring aspects of productivity and animal health and welfare. Despite this interest and the increasing number of technologies being made available to farmers, their adoption has been relatively slow. Involving users in the early stages of technology development and engaging with them beyond technology installation has been considered key for successful adoption. However, participation can also present a variety of challenges. This study is based on the Theory of Adoption and Use of Technology for Decision Support Tools by Rose et al. (2016) and takes inspiration from studies on user-centered design (e.g., Jakku and Thorburn, 2010; Eastwood et al., 2012) to help refine strategies for successful adoption. It focuses on two case studies during which two different DLTs were tested and implemented. Stakeholders' experiences of being involved during these processes were explored through in-depth, semi-structured interviews (N=29), and the results of a separate survey were used to complement our findings. Findings suggest that while participation can help improve technologies in terms of being better aligned with users' needs and promoting learning and a sense of ownership; the way these processes are managed can also influence users' attitudes towards DLTs. This includes the extent to which stakeholders are involved and how expectations are managed, the support and training available, as well as technology performance. How users are engaged with during these processes must therefore be considered carefully, as challenges such as technology failure or lack of support and insufficient training can impact their perceptions and confidence in the technology and thus prevent its use.

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Dairy farmers' involvement in precision farming research

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Dairy farming has undergone substantial changes in the past few decades. On average the number of farms in a country are dropped, while the number of dairy cattle remained relatively stable. This trend, along with related changes such as the increase use of precision technologies, is expected to continue. At the same time, changing societal values resulted in increased attention on the quality of life of dairy cattle and on the pressure of farms on the environment. When farm management practices fail to resonate with societal values, the social licence to farm may be in jeopardy.

Involving systems experts, like dairy farmers, as consultants is valuable for identifying future challenges and opportunities. It has been argued that involving farmers in a new initiative, e.g. technology development, increases the rate of success. On the other hand, regulations are only effective in changing behaviour when they are enforced. This may be especially true when farmers do not believe that the regulations steer them in the right direction. To improve the effectiveness of efforts to change dairy practices, farmers' values and norms and research to sustain or improve sustainable farming need to be aligned.

The aim of this presentation is to share the experiences of a dairy farmer involved in two different scientific research project to improve the environmental sustainability of dairy farms. The first project is the development of a digital twin (DT) which is a digital equivalent of a real-life object of which it mirrors its behaviour and states over its lifetime in a virtual space. In this project a DT of a dairy farm is developed to manage the nitrogen cycle of the farm in such way that nitrogen losses are minimized and that the use of nitrogen is also minimized. The second project is about large-scale recording of methane emissions of individual cows. These data can be used to monitor the emissions on a farm and to develop the tools to allow for breeding of lower emitting cows. For this project, we collect data on 100 commercial dairy farms. This presentation will show the importance of involving farmers during the research process, and the challenges and opportunities for farmers and researchers.

Cow Identification Network Trained with Similarity Learning

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Abstract

Cow identification is a key phase in automated processing of cow video footage for behavioural analysis. Previous cow identification works have achieved up to 97.01% accuracy on 45 cows and 94.7% on datasets containing up to 200 cows. This paper presents new results from applying similarity learning to a cow identification Convolutional Neural Network on a group of 537 cows. Our method achieves identification accuracy of up to 99.3% and generalizes well to new cows, eliminating the need for retraining every time a new cow is added to the heard.

Introduction

Some work has been done to perform cow identification (Kobayashi, 2018; Yao et al., 2019; Zin et al., 2020) which take various approaches. Of this related work, (Kobayashi, 2018) achieves the highest accuracy of 97.01% identifying cows using a Convolutional Neural Network (CNN) classifier. The drawback of classification CNN approaches is that resulting network representations do not necessarily generalize well to new classes, meaning that if new cows are to be introduced, the entire network will require to be retrained - not just the final classification layer. This work focuses on training cow pattern identification CNNs with similarity learning to overcome these limitations.

Similarity learning is an alternative training approach to the standard classification training, first introduced in Google's Facenet paper (Schroff, Kalenichenko, & Philbin, 2015). Similarity learning trains a network to produce embeddings that are close in terms of Euclidean distance if images are of the same class and further apart if they are of different classes. Classification is done on the embeddings by using a more basic classifier such as a K Nearest Neighbours (KNN).

Dataset

Training data was acquired by positioning an IP camera above the radio frequency identification (RFID) scanner in the rotary milking parlour within the target farm. Each new RFID detected by the scanner trigged the acquisition of three images to capture the cow at different perspectives. The acquired images were passed through a YOLOv3 model (Redmon & Farhadi, 2018) which generated bounding boxes on the cows present in the image. The central localised cow bounding box from each image was then saved in folders corresponding to its RFID value. Human verification was required to ensure all cow images were in the correct folder locations.

All image pixel values were min max normalized between 0 and 1. The images were cropped to remove the RFID antennae and resized to 224x100. Of the 537 cows in the dataset, the first 500 were used for training and the final 37 were reserved "unseen" testing. Each individual cow had 15 images and of the 500 cows selected for training, 10 images from each were used for training, 3 were used for validation and 2 were reserved for testing.

The model used was ResNeXt50_32x4d (Xie, Girshick, Dollár, Tu, & He, 2017) due to its cardinality property which improves performance without additional parameters. The model was trained with an initial learning rate of 0.00001 and the learning rate was reduced by a factor of 0.1 every 200 epochs. A hard triplet selection strategy was employed on batches of 40 with 10 unique cows. The dataset was augmented with random: rotation +/-10 degrees; erasing; gaussian blur; colour jitter; auto contrast; perspective. The model was trained for 349 epochs.

Results

All images from the training set were embedded and used to fit a KNN classifier with K=5. Various combinations of "seen" cows (first 500 cows used to train the embedding model) and "unseen" cows (final 37 cows not used to train the embedding model) were used for testing to examine the performance on trained and untrained classes. Each of the KNN sets utilise the first 10 images from each relevant cow and each of the test sets utilise the final two images from each relevant cow. Results can be seen in Table 1.

Table 1 - Cow Identification Accuracy Results.

KNN set (first 10 images per cow)	**Test set** (final 2 images per cow)	**Accuracy (%)**
Seen cows	Seen cows	99.3
Seen + unseen cows	Seen + unseen cows	99.16
Seen + unseen cows	Unseen cows	97.3

Conclusion

This work has shown that similarity learning can provide cow identification performance above 99% on a data set of 537 cows. Our results show that our model generalises well to new classes, it is therefore possible to add new classes to the KNN classifier without the need to retrain the embedding model. Although not directly comparable to other works, our model boasts significantly higher identification accuracy on a dataset with significantly more classes.

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Computer vision system for 3D localization of cows with deep learning

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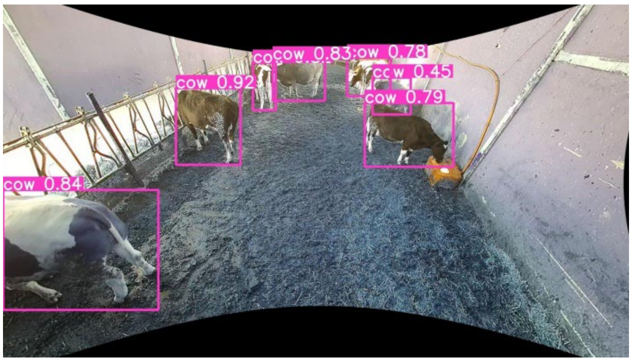
With the rapid development of modern dairy production, loose housing, i.e. free stalls became the most common housing alternative. It has become mandatory to systematically monitor the movements of each individual cow in dairy farms. This study aims to find the actual location of dairy cows in a freestall barn using RGB cameras and computer vision techniques. Our method uses 3 RGB cameras placed on 3 separate walls of the housing stalls to be monitored. In order to test the accuracy of this process, 1 RGB camera is placed on the upper ceiling. To get a cow detection method, a pre-trained YOLOv5 deep neural network model is finetuned over a cow image dataset. The images from 3 cameras are passed through our cow recognition network to detect cows in the barn. The returned bounding boxes from the cow detection network are then combined to find the actual location of each cow. The locations found were compared to the bounding boxes obtained from the camera located on the ceiling. The system was able to accurately find 95% of cows' locations.

1000 frames were taken from each camera. The interval between two frames was 1 second. Each frame taken from 3 cameras was given as input to the YOLOv5 model. Figure 1 on the left picture is an example of the first camera's bounding boxes. The positions of the cows were calculated using the midpoint of the bottom edge of the bounding boxes by using planar homography.



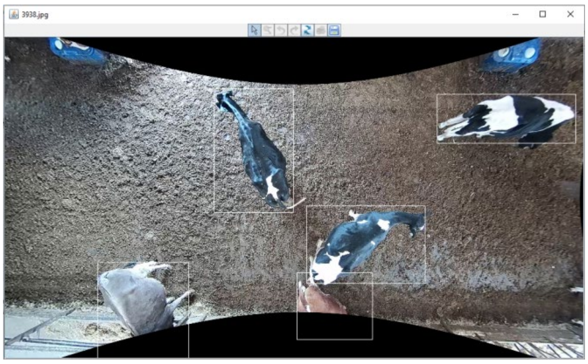


Fig. 1. The bounding boxes of an image of the first camera obtained with the YOLOv5 program (image on the left) and manual drawing of bounding boxes from the camera on the ceiling (image on the right).

While some cows are viewed by 3 cameras, the other cows are viewed by 2 or 1 camera. We clustered the blue, yellow and red dots for each frame using our own clustering algorithm (Figure 2 left image) because it must not be of the same color in the same cluster and there must be no more than 3 dots in the same cluster. For each cluster found, we assigned its midpoint as the actual position of the cow.

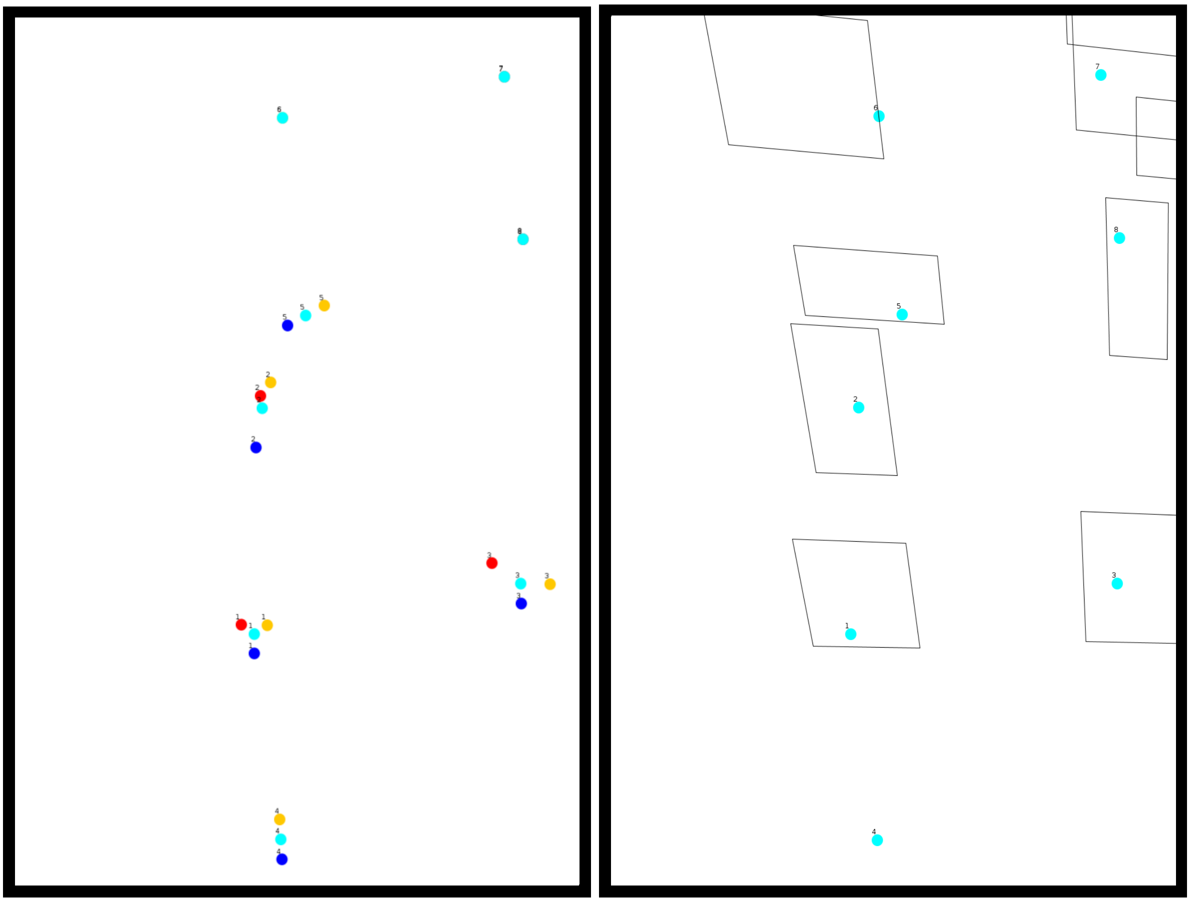


Fig. 2. In the left picture, Blue, yellow and red are points obtained from camera 1, 2 and 3, respectively. The cyan dots are the midpoint of the 3 clustered dots. In the right picture, bounding boxes belong to the 4th camera placed on the ceiling.

Bounding boxes are drawn by hand for 1000 images which are taken from the camera located on the ceiling for testing purposes (Figure 1 right image). The reason why the bounding boxes are crooked in the picture was that the bounding boxes were also normalized by the planar homography method (Figure 2 right image). The bonding boxes were matched with the midpoints of each cluster. Any mismatched cluster midpoints were not considered as a failure if they were outside the view of the top camera. Again, if there is a bounding box (not matched with any point) that cannot be matched, but is less than or equidistant from the two cows side by side, this is also considered a success.

Of the 7530 cluster midpoints, whose success or failure could be calculated in 1000 images, 4938 were successfully matched with bounding boxes. 275 of them could not be paired with a bounding box. The success rate was found to be 95%. After examining the study on un-matched points, it turns out that all the un-matched cases are in these two situations, (I) the cow is in the field of view of only one of three cameras or (II) the upper cannot have clear vision for the whole part of the cow.

In conclusion, based on high degree of accuracy, the proposed system is promising for fully automated continuous monitoring of dairy cows.

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A computer vision approach for the automatic detection of social interactions and space-usage of dairy cows

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In recent years the dairy industry has intensified efforts to improve animal health and well-being due to increasing ethical issues and public concern. Animal welfare is influenced by the social environment and by the opportunity to interact with conspecifics despite the limitations due to bounded space and management practices [1]. Cows are highly social animals that evolved to live in large and structured groups. As in other group-living species, individuals differ in the level of association they have with others, and these associations often result in lasting social bonds. The social interactions not only are important for animal welfare and productivity but also drive major mechanisms by which transmission of infectious diseases within a herd may occur [2]. Moreover, the space-use behavior within a commercial barn may be directly related to disease status (e.g., lameness) and productivity of individual dairy cows [3]. Therefore, a better comprehension of social context and space-usage of dairy cows can improve animal welfare and enhance control of health of the herd, as well as provide useful information to develop the best management strategies. In this context, in the field of Precision Livestock Farming, computer vision represents a suitable, promising, and non-invasive method for automatic cow detection and tracking.

In our study, we developed and tested the reliability level of a computer vision system, based on deep learning techniques, for the automatic recognition of individual cows within images representing their location. The research was carried out in a cubicle free-stall barn of a commercial dairy farm. The barn consisted of two rectangular enclosed areas of 45x30 meters each. Each area hosted 120 dairy cows each (primiparous and multiparous) and contained two automatic milking systems. We placed a total of eight Super Wide Angle Fixed Bullet Network Cameras (Hikvision). Each camera was mounted in a corner of the two areas and was positioned towards the center of the area to provide a clear view of the milking robots (Figure 1A). The combined camera views ensured that there were no blind spots, and each angle overlapped with the others to offer multiple viewing angles and optimize visualization of cows regardless of their position in the barn.

The main goal was to locate the real-world coordinates of the cow via camera feed; our method consisted of three separate components: a camera model, a Convolutional Neural Network (CNN)-based detector and a tracking model. The first steps of the process were the following: (1) calibration of the intrinsic and extrinsic parameters of the cameras, this step consisted in selecting a parametric model which mapped each real-world point to the pixel where it is located within the image. We selected the OpenCV rational model implementation due to its ease of use; (2) rectification of wide-angle images in order to recover the original proportions of the cow; (3) selection of the training sample of images characterized by a variety of contexts (light conditions, time of the day, cow numbers and body position); (4) manual annotation of the cows in the training sample with a bounding box containing entirely the visible surface of the animal (Figure 1B).

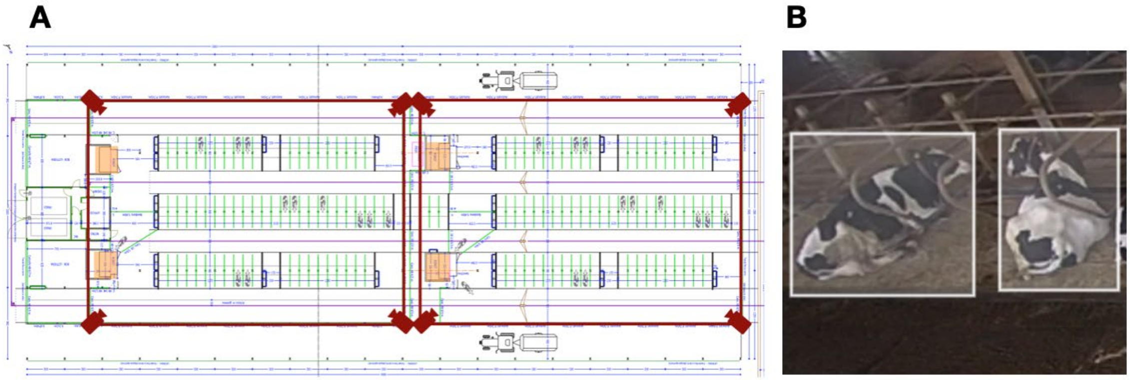

Figure 1. A: map of the barn and positions of the video cameras, orange squares indicate the milking robots; B: example of a (cropped) image annotated with bounding boxes.

Afterwards the annotated images were used to train a CNN-based detector (EfficientDet [4], SSD [5], etc.), this model allowed us to retrieve the location of the cow in the image for any previously unseen frame. The detection model analyzes each frame independently thus, in order to track the identity of an object across time, we tested two tracking methods: one using only estimates of the motion of a bounding box (SORT [6]) and one also including an appearance similarity metric (DeepSORT [7]). When a cow was detected for the first time a temporary unique ID was assigned, and its identity was propagated through time by the tracking module. The temporary unique ID assigned during the tracking was associated with the real unique ID (a constant and unique ID identifying each cow) the first time an unidentified cow (no real ID associated) was registered by the milking robot. Then, we associated to each bounding box a further point representing an estimate of the projection on the floor of the center of the cow, this point was used to revert from the image coordinates to the real-world coordinates. This process allowed us to obtain the exact position of the cows in the barn and the spatial proximity between each dyad of cows, to identify the social interactions and to build the social network of the herd.

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2 years' experience in climate monitoring in dairy farms

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Pessl Instruments GmbH was asked in summer 2017 to participate in an Austria wide big data project collecting a wide range of data from dairy farms. We were allowed to install sensors for temperature and relative humidity inside the barns and sensors for precipitation, temperature and relative humidity in the open field outside the building area. We decided to use LoRa as the basic communication system. The project was accepted by FFG and the installations could be realised starting from October 2019. In summer 2021 we have been approached by LKV-Bavaria to equip 120 Dairy farms with temperature and relative humidity sensors inside the barns. Based on the results from the Austrian project we are realising this project on an improved manner. Installations were started in August 2021 and will be finalised during October 2021. In this 2 projects size and structure of the dairies varies widely. In Austria dairy size varies from 20 to 60 cows whereas in Bavaria dairy size varies from 45 to 400 cows.

In this presentation we like to discuss the experiences and results we could gain in the D4Dairy project and first results from the Bavarian project

- on the use of on Farm LoRa Networks
- the challenges we found in sensing
- differences we could find in between farms and buildings

Preliminary studies to develop a novel, cow-centred index to monitor heat stress in dairy cows.

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Introduction

Heat stress in dairy cows is of growing importance in many dairy producing regions of the world. Global warming is raising average summer temperatures and increasing the risk of extreme events. At the same time rising milk yields are increasing the cow's susceptibility to heat stress. Successful measurement and control of heat stress is important in reaching net-zero as it improves productive efficiency and reduces the use of fossil fuels. Current methods of assessing heat stress risk measure the environment rather than the animal's physiology and so only capture the potential risk and are only suitable for fully-housed systems. There are no suitable indices for assessing heat stress on farms that make full or partial use of grazed grass. Furthermore, none of the existing indices incorporate cow factors such as breed, milk yield, acclimatisation or the effect of genetic traits and risk thresholds are often adjusted *ad hoc* to cope with different climates and production systems. Given these deficiencies, the objective of this work was to develop a novel cow-centred index to monitor heat stress in dairy cows.

Methods

Data were collected from three commercial farms in south England (Table 1) over the summer of 2021. The patterns of calving in all three herds were such that there were high-yielding cows in the milking herd throughout the summer. All herds were fed supplementary feeds to yield in the milking parlour.

Table 1. Details of commercial farms used in trials

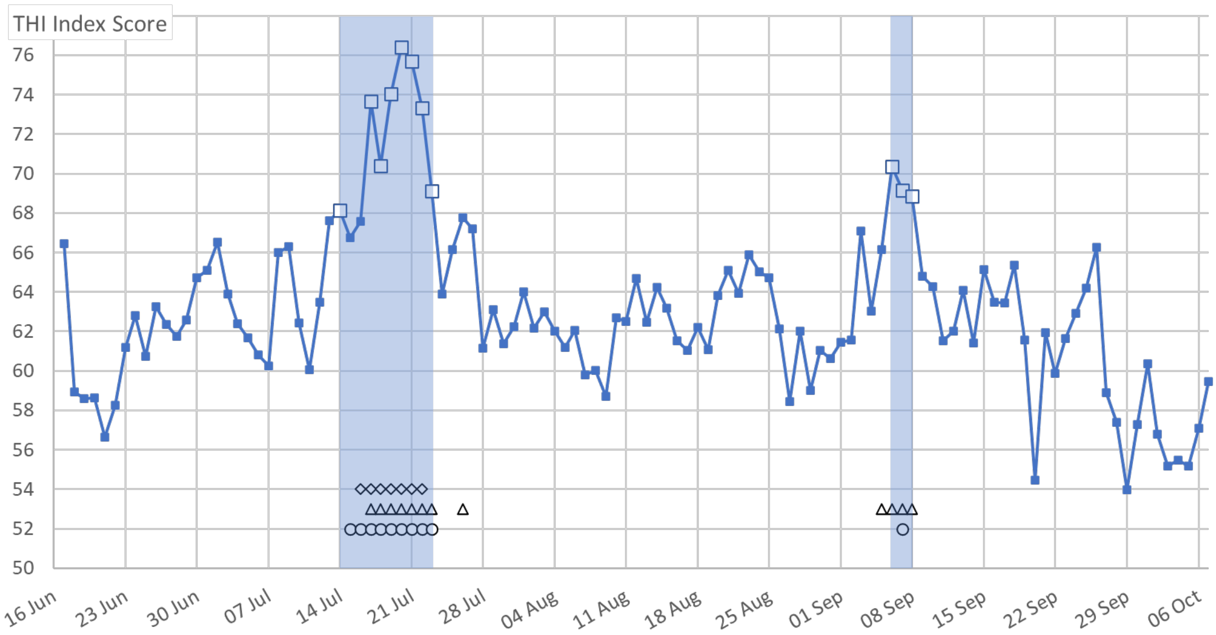
Farm	Herd size cows	Milk yield l/cow/year	Type of parlour	Summer Management
1	460	12,400	54 point rotary	Predominantly housed on TMR.
2	720	9,400	54 point rotary	Some groups housed, some grazed.
3	260	11,200	20:20 herringbone	Predominantly grazed.

From June to October 2021 temperature and humidity were recorded every twenty minutes in a stocked cattle shed on each farm and the Temperature Humidity Index (THI) was calculated (NRC, 1971). Temperature readings were collected in the milking parlour every six minutes during milking and temperatures excesses calculated. The temperature excesses were used to determine heat-stress risk days and, where the excess was positive, it was numerically compared to the cow-shed THI values during heat stress episodes.

Results

The THI values over the summer averaged over the three herds are shown in Figure 1. There was a major heat-stress episode (THI > 68) in mid-July and a smaller one in early September. Heat stress risk days are shown along with the temperature excess days that our index identified on each farm.

Figure 1. Daily THI index score over summer, 2021. Heat stress days (THI>68) shown as open squares and heat stress periods by shading. Heat stress risk days as identified by temperature excesses shown as diamonds (Farm 1), triangles (Farm 2) and circles (Farm 3).



The numerical values for the temperature excesses were correlated with the THI values at the time of collection (Table 2)

Table 2. Correlation between temperature excesses on heat stress days and THI value.

Farm	Correlation	95% CI		n
1	0.952	0.909	0.975	38
2	0.962	0.934	0.978	51
3	0.649	0.416	0.802	38

Discussion and Conclusions

The temperature excess index developed herein closely identified days when the THI was over 68 and, numerically, it was highly correlated with the THI values. However, THI 68 may not have been the correct threshold for each farm. The correlation was lowest for the grazing herd where THI was probably not the appropriate reference index. This study shows that our novel temperature excess index can be used to assess heat stress risks across different farm types. As the index tracks the cow's response, rather than the environment, it is able to accommodate the animal's acclimatisation and genetic variation and work across different climates. Furthermore, tracking the animal's response will allow optimisation of mitigation actions with associated cost and environmental optimisation. Future work will look to collect the data in real time using Internet-of-Things (IOT) technologies to enable farmers to track and quantify heat stress risks in real time that are specific to their local environment, farm structure and cows.

Acknowledgements

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How smart technologies can change farming

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Abstract

The main question that precision livestock farming (PLF) companies need to ask is which technology they need to develop. However, the answer lies in determining which areas farmers are seeking help from technology. Those areas of need should provide the framework for improving the economic, environmental, and social sustainability of farming. In our view, there are three areas of need where technology can have a direct impact on farming: improving farmers' quality of life, improving productivity of the farm, and fulfilling regulatory compliance. Using this definition, Datamars SA has developed Internet of Things (IoT) applications to provide insights into 4 different aspects of animal farming: reproduction, nutrition, production performance, and welfare. These aspects were defined by looking at the value proposition of the technology and the farmers' needs. The technology acceptance model (TAM) was applied to choose which developed IoT application provided the best value to customers. Here, we present examples of this approach and propose that this methodology can help us define smart farming applications that will be easily accepted and used by farmers worldwide.

Framework for IoT development

Technology implementation in livestock farming will provide a framework for improving economic, environmental, and social sustainability. In recent decades, several techniques and applications have been developed to fulfil that promise. However, not every type of technology has been successful; for instance, accelerometers have received mainstream attention, whereas boluses to monitor rumen fermentation remain of limited use (Borchers and Bewley, 2015). In principle, ruminal pH cannot detect acidosis or monitor fermentation (Laporte-Uribe, 2016), whereas heat monitoring with accelerometers mimics visual observation, hence their dissimilar fates (Crowe et al., 2018).

There is a broader explanation for technology adoption success related to the factual or perceived value assigned to a specific issue (Borchers and Bewley, 2015). Farmer needs can be separated into three categories: improving farmers' quality of life (QoL), improving productivity of the farm, and fulfilling regulatory compliance. Farmers' **QoL** involves their workload and workplace relationships, which influence their psychological burden and perceived happiness (Herrera-Sabillón, 2021). The **productivity** measures the return on investment, labour, and cost on all aspects of farming. Regulatory **compliance** relates to the fulfilment of standards set forth by the law, policy, or industry. Naturally, there is a trade-off between the different areas (Figure 1), but in this stage of smart technology development, QoL is the main driver for technology uptake. For instance, the adoption of automatic milking systems is based on a reduction in labour cost and workload (QoL), not their economic profitability (Salfer et al., 2017). Similarly, heat detection by accelerometers replaces visual observation, another labour-intensive activity (Crowe et al., 2017).

There are four different aspects of farming that concentrate most of the value that farmers assign to their needs: **reproduction**, **nutrition**, **production** performance, and **welfare** (Figure 2). Datamars SA has created IoT applications based on proprietary technology and key performance indicators (KPIs) that give an overview of those farming aspects. The main implementation issue (adoption) is to select the most appropriate KPI and visualisation so farmers can quickly adapt the findings to make changes in their farm management practices, i.e., workflow improvement. However, adoption has been difficult to frame and evaluate due to the multiple socioeconomic factors associated with the selection of technologies.

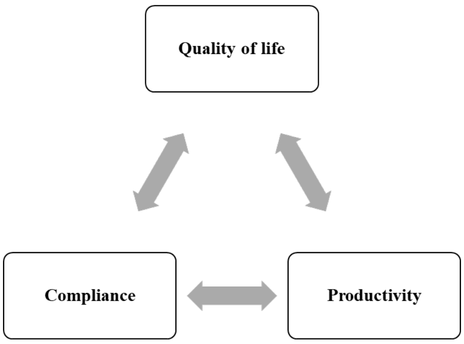

Figure 1. Categorisation of farmers' needs on which smart technologies can have a fundamental impact.

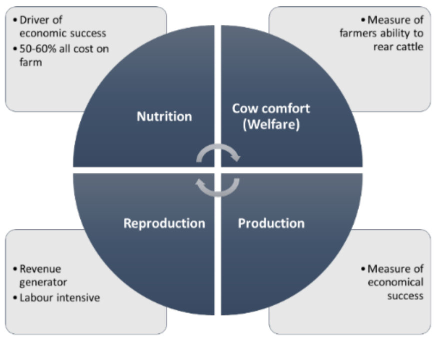

Figure 2. Aspects of farming that concentrate most of the value associated with farmers' needs.

Evaluating the adoption of IoT solutions

In our opinion, the technology acceptance model (TAM) provides a simple framework to evaluate the adoption of technologies; moreover, the TAM might be the right tool to select the most appropriate displays and metrics for each farming aspect (Venkatest et al., 2003). Therefore, a farmers' adapted version of TAM can be used to create questionnaires that could be applied to our customers, and their results can be used to select the best IoT solutions based on the usefulness and degree of easy implementation of each metric as perceived by farmers.

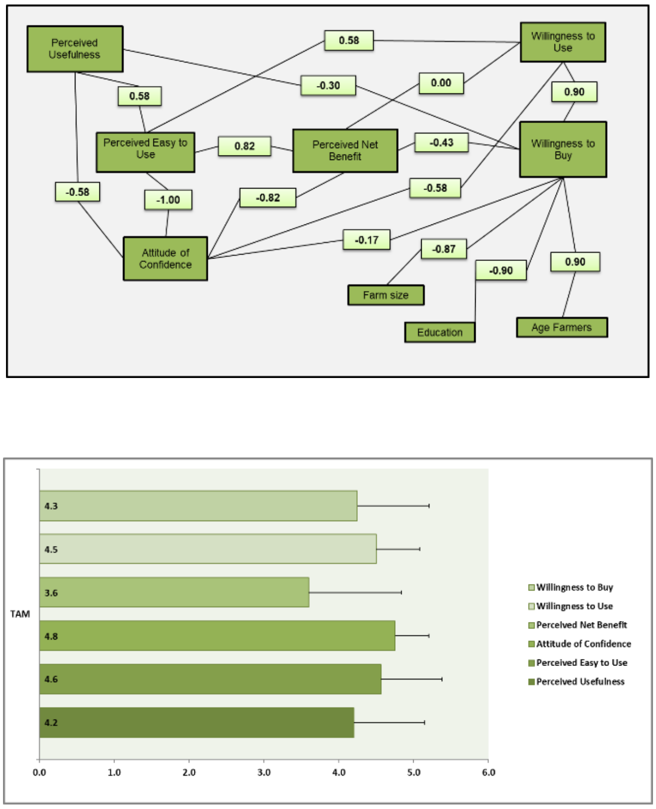

Figure 3. Output of the adapted version of the technology acceptance model (TAM). On the right, the Pearson correlation between factors shows the positive and negative associations between the predicted variables of the model. On the left, category scoring allows us to identify the strength and weaknesses of each IoT application with regard to the core TAM factors.

Results and discussion

The adapted TAM questionnaire was applied to different IoT solutions across different countries and production systems. This approach allowed the development of KPIs that were perceived to be useful and easy to use by our end customers. Moreover, the TAM allowed us to optimise new features on the overall customer experience of our products. For instance, Figure 3 shows an example of the outcome of the TAM model for one feature. The Pearson correlation, left, describes the positive or negative relationships between variables and their effect on the acceptance of the IoT solution. The willingness to buy is strongly affected by socioeconomical aspects, whereas the adeptness to use technology (attitude of confidence) will influence costumers' perception of usefulness and their willingness to use the IoT solution (Venkatest et al., 2003; Borchers and Bewley, 2015). The bar chart on the right showcases the willingness to use and buy the application, a key aspect of any commercial IoT solution. Additionally, it gives an overview of the perceived net value and confidence in the product experience. Therefore, the modified TAM allowed us to reduce the uncertainty surrounding the sociocultural and economic aspects that might influence farmers' adoption of each IoT application (Venkatest et al., 2003). In this way, the final KPIs and displays chosen for our products using the TAM approach should ensure adoption of the IoT solution by having a broader acceptance across different production systems and countries, and reaching customers with different levels of adeptness.

Conclusions

A framework for the successful adoption of smart technologies is described by cataloguing farmers' needs according to simple criteria. Different IoT technologies provide answers to the aspects of farming that fulfil those needs. Finally, the selection of the most appropriate metrics and displays is based on the farmers' perception of usefulness and fast adoption (easy to use) of those solutions into their daily routine according to TAM. We believe that this framework will help us design IoT applications that will improve the economic success, environmental impact, and social sustainability of farming worldwide.

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Digital Twin Technologies in Dairy Farming: the Digital Farm of the Future

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Nitrogen (N) inputs have played a large role in the intensification of grassland-based dairy farming, but increased N inputs also contributed to increases in N losses to the environment. With respect to circular farming, it is essential for farmers to balance the different N streams. This is even becoming more important now environmental legislations are in place to restrict the use of N inputs and minimise N losses at farm level.

Managing N on the farm has no simple and standard recipes, because each region, field, crop and year have a different yield potential, N demand and N use potential. Adoption of new precision dairy farming (PDF) systems linked with the internet of things affects the way in which N decisions can be made on the farm. In situ sensors can routinely and reliably provide farmers with real-time information of available soil N status, plant N status, as well as soil moisture and pasture growth rates that will enable them to precisely determine when to apply N fertiliser and how much of it. If we combine this data with projected data (forecasts) from weather services it has the potential to predict the response of the farm in the short to mid-term.

In reaction to the nitrogen problems and developments of PDF systems, the Digital Future Farm project of Wageningen University and Research, is developing a Digital Twin (DT) of a dairy farm. A DT is a digital equivalent of a real-life object (in this case, a dairy farm) of which it mirrors its behaviour and states over its lifetime in a virtual space. Various technological developments are integrated, such as Internet of Things, Artificial Intelligence, machine leaning and software analytics to develop a digital representation of a real-world living or non-living physical identity.

The aim of this specific DT is to manage the nitrogen cycle of the farm in such way that nitrogen losses are minimized while crop yield stays at the same level or even improves. The DT provide knowledge that is to inform decision making of farmers and allows the exploration of interventions, which could not be done without such a digital representation.

Body weight change during early lactation is associated with milk production in automatic milking system herds

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Introduction

The early lactation represents a challenging period for dairy cows, as they are faced with calving and the sudden onset of a new lactation. The rapid increase of nutrient requirements for milk production is rarely met by the feed intake of cows in the early postpartum, resulting in a negative energy balance. As a response mechanism to this increased unmet energy demand, adipose and muscle tissues are mobilized leading to losses in body condition and weight. However, this tissue mobilization has been shown to vary in magnitude among cows. The objective of this observational study was to investigate the association between early lactation body weight (BW) change and milk production of dairy cows in automatic milking system (AMS) herds in Minnesota and Wisconsin, USA.

Materials and Methods

Retrospective daily cow body weight and milk yield data were collected from the AMS software (T4C, Lely Industries, Maassluis, the Netherlands) on 33 farms. Cows were categorized by parity into first lactation (P1), second lactation (P2), or third and greater lactation (P3+). Body weight (BW) change was calculated over 7 and 21 days in milk (DIM) as a percentage related to DIM 1.

The 90-day milk yield was the outcome variable in the model with each BW change variable (7 or 21 DIM), parity, and their interaction as explanatory variables. Due to prior knowledge of a possible quadratic relationship between BW change and milk yield, fixed effects included both the linear and quadratic term of 7-day or 21-day BW change (continuous), parity (3 categories), and the respective BW change × parity interaction, along with a random effect of cow nested within farm (n = 3,936). The quadratic term fitted the data better, so only the interaction between the quadratic term and parity was included. Model fit was assessed by visual observation of residual plots. The denominator degrees of freedom were estimated using Satterthwaite's method. Graphical visualizations of data were created using tools of the ggplot2 package. Significance was declared at $P \leq 0.05$. The Tukey *P*-value adjustment was used for pairwise comparisons.

Results

On average, cows in all 3 parity groups lost BW during the first 21 DIM. As shown in Figure 1, the 7-day BW change was not associated with 90-day milk yield for P1; however, the association was negatively quadratic for P2 and P3+. Cows in P2 and P3+ that maintained BW over 7 DIM had greater 90-day milk yield. The 21-day BW change had a negative quadratic relationship with 90-day milk yield for all parity groups; P1 cows with a 21-day BW change of −8.2% and P2 and P3+ cows with 21-day BW change of about −4% were more productive over 90 DIM.

The curve turning point (i.e., greatest 90-day milk yield) decreased along with parity number, where P1 cows who lost an average of 8.18% of their DIM 1 BW produced an estimated (LSM ± SE) 3,100 ± 53.2 kg over the first 90 DIM; P2 cows achieved the greatest average production at 4,265 ± 53.8 kg when 21-d BW change averaged at −4.18%. Lastly, the turning point for cows in P3+ (4,567 ± 53.5 kg) was achieved when 21-d BW change averaged at −3.58% of their DIM 1 BW.

Conclusions

In summary, cows that maintained (over 7 DIM) or lost up to ~8% of BW (over 21 DIM) were more productive during the first 90 DIM. The findings of this study may help improve existing algorithms for the identification of animals at risk for health disorders and for the prediction of future milk production of dairy cows in herds using AMS.

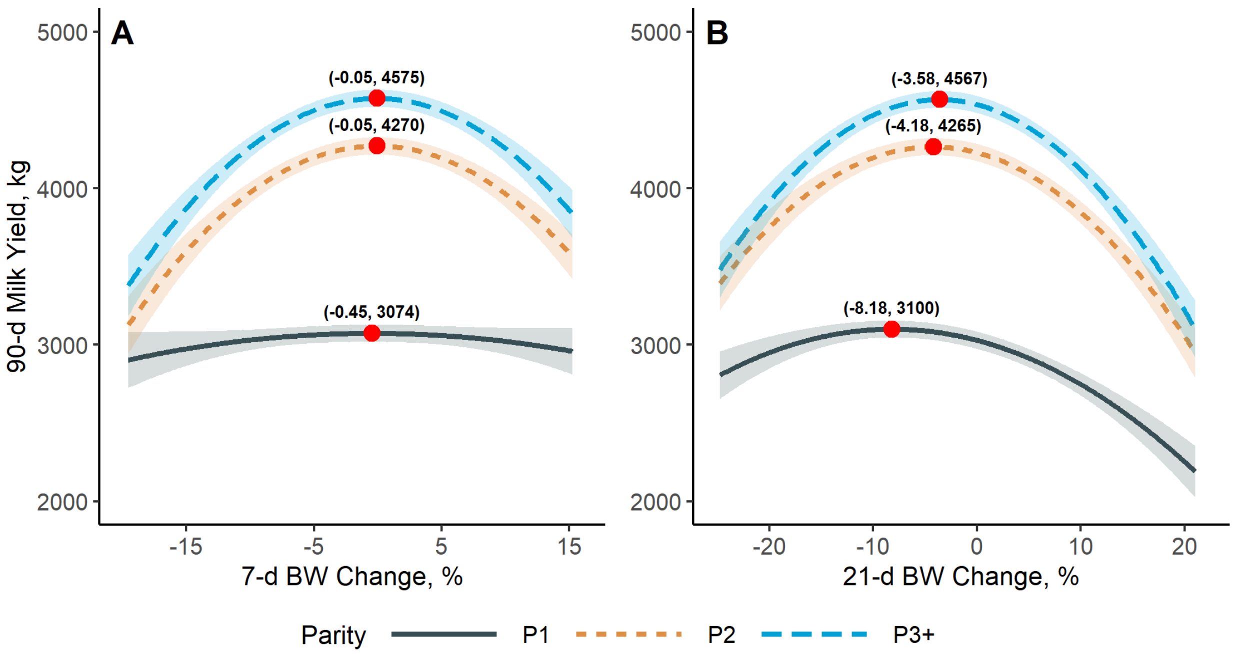

Figure 1. Association between body weight change in early lactation (7 days in milk, A; 21 days in milk, B) as a percentage related to day in milk 1 and 90-day milk yield for dairy cows in automatic milking system farms in Minnesota and Wisconsin, USA.

Monthly daily milk yield prediction for individual cow using test-day and genomic evaluation data

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Introduction

Predictions of the shape of the lactation curve and corresponding daily milk yield (MY) for individual cows are paramount for herd management and decision-making. Historically, test-day (TD) models have been developed to describe the general shape of the lactation curve for fixed subsets of cows grouped by age at calving, season of calving, breed composition, or herd (Wood, 1967; Wilmink, 1987; Olori et al., 1999). However, there are no cow-level models using multisource and multilayer integrated data that predict the next test-day or the remaining of the lactation. Therefore, the aim of this study was to develop and illustrate an integrated blended modelling technique combining both herd level and individual level models for predicting lactation curves of individual cows using TD data corresponding to MY, health, reproduction, and genomic evaluations.

Materials and Methods

The analysis used filtered test-day (TD) milk yield (MY) and genomic evaluations records from 4800 cows from three Wisconsin dairy herds collected over a 3-year period (2019-2021). Each lactation record contained a cow identification number, county code, herd number, date of birth, calving date, age at calving, lactation number, TD number, MY, and DIM on TD. Genomic PTA value of MILK trait in genomic evaluations records were also selected as a model input feature. The herd level model was set up to receive monthly updated training input data and indicate the seasonality (monthly trend) in the milk yield of the group of animals (herd level). Then, the difference between the actual and predicted milk yield was measured and utilized as an additional training input data along with the monthly updated training data for a specific cow in the corresponding herd. Also, the difference between the actual and predicted milk yield for each individual cow in a herd were measured as an aggregated input for the training input of herd level model in the following month (Figure 1). Therefore, this blended methodological framework allows for the predicted accuracy be improved over time according to the amount and quality of data flowing through the system.

Results and Discussion

Proposed herd and individual level blended prediction approach, consistently, outperformed the herd regression model in predicting TD MY of cows in different parity groups (parity 1, 2 and 3, respectively; Table 1). Across all 3 parity groups, the mean and median of mean absolute error (MAE) of proposed blended approach predictions indicated superior predictive ability than the herd regression predictions (Table 1). On average, the mean MAE of TD MY of our blended approach was 27.3% (1.2 kg/d), 22.4% (1.1 kg/d) and 11.3% (0.6 kg/d) lower than the mean MAE of TD MY of the herd regression. Different than a recent study that predicted only first TD MY (Dallago et al., 2019), our blended approach is able to predict TD MY for the entire lactation.

Conclusions

The proposed integrated blended modelling approach can predict herd and cow expected month-ahead test-day milk yield and entire lactation curves with better accuracy than the herd regression model.

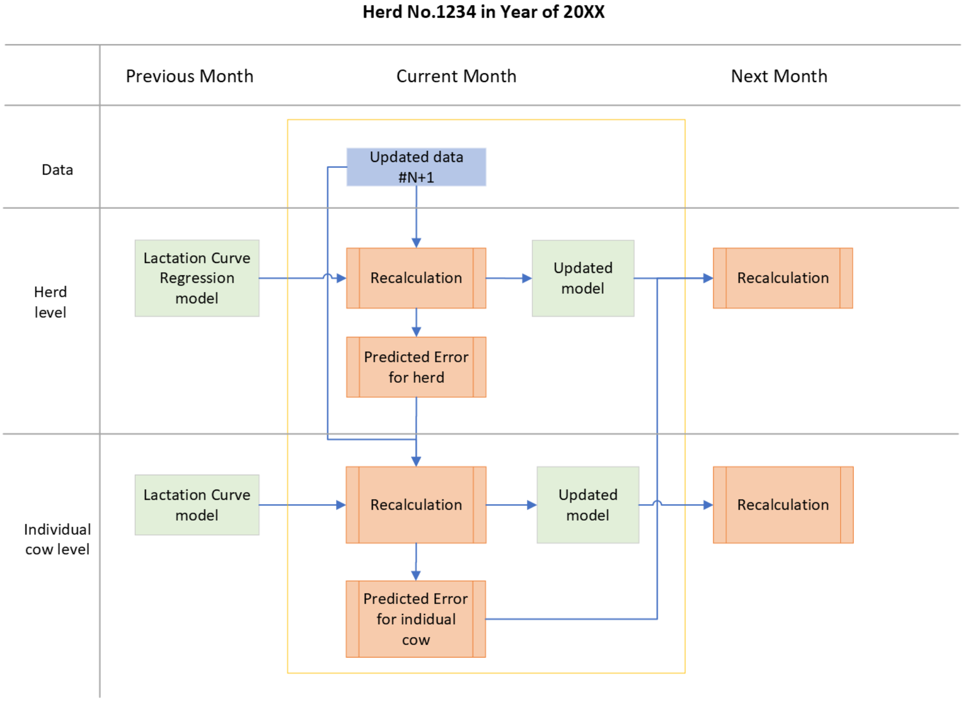

Figure 1. Illustration of the proposed blended prediction modelling approach.

Table 1. Average Mean Absolute Error (MAE) of milk yield prediction of 10 test days (kg/animal) for a selected number of cows in different parity groups.

Parity (No. of cows)	#1 (n=100)		#2 (n=50)		#3 (n=50)	
Model	Herd regression	Blended prediction	Herd regression	Blended prediction	Herd regression	Blended prediction
Mean	4.4	3.2	4.9	3.8	5.3	4.7
SD	2.6	1.6	2.4	1.8	3.0	2.7
Median	3.5	2.9	4.5	3.5	4.3	3.9

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Validation of a software module for gradually reducing milk yield before dry-off in high yielding dairy cows

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Introduction

With current high-yielding dairy cows, dry-off is a challenge as milk yields at dry-off may easily reach over 15 kg per day. The increased udder pressure related with high milk yields at the abrupt cessation of milking at dry-off increases the risk of mastitis in the early phase of the dry period. To reduce milk yield in the final days of the lactation, a software module to enable automatic cluster removal at a targeted milk was developed. This study aimed to validate the effect of the automatic cluster removal in the last 10 days before dry-off, on milk production, udder health and next lactation performance.

Materials and Method

During this study 61 dairy cows, producing more than 18 kg of milk per day, were selected and milked either with the automatic cluster removal (ACR) or with a conventional procedure (CON). The cows were followed from 14 days before dry-off until 28 days in milk into the next lactation. Milk yield was gradually reduced starting 10 days before dry-off in ACR. Each individual animal was handled based on its individual daily milk production. At the last milking, in both treatments the cows were milked conventionally and were dried off with a non-antibiotic teat sealant. Aspects that were compared are: milk yield, milk flow, milking duration, teat conditions, somatic cell count, bacteriology of milk and animal health.

Results

Using automatic cluster removal was an effective strategy to decrease milk yield before dry-off in high yielding dairy cows. Automatic cluster removal led to a significant reduction in milk yield during the last 10 days of lactation before dry-off, but did not lead to significant changes in milk composition. There was a tendency for a reduced somatic cell count for ACR cows before dry-off. Using automatic cluster removal 10 days before dry-off did not lead to a significant change in conductivity. During the dry period no mastitis cases or other udder health issues were reported for both treatment groups. No significant treatment effects were found for using automatic cluster removal before dry-off on performance parameters in the first four weeks during the next lactation.

Detection of mastitis in Holstein dairy cows using an automated infra-red thermography system

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Mastitis is one of the most common and costly diseases faced by the dairy cattle industry and results in substantial economic losses every year. Early detection of mastitis can help minimise these losses, as well as prevent further negative impacts on udder health (Kim *et al.* 2019; Xudong *et al.* 2020). Recent studies have suggested that the monitoring of udder skin temperature via infra-red thermography (IRT) systems could allow for improved detection of both clinical and sub-clinical mastitis (Machado, *et al.*, 202; Sathiyabarathi *et al*., 2016; Polat *et al.*, 2010; Colak *et al.,* 2008). However, while the results of such studies appear promising, information regarding udder skin temperature is typically obtained using expensive hand-held thermography cameras that require precise, manual positioning relatively close to the udder. For IRT to become a commercially viable tool in the dairy industry, the collection of IRT images, as well as the subsequent detection of mastitis, would need to be fully automated (Xudong *et al.* 2020). In an ongoing experiment we are assessing the validity of using a stationary, automatic IRT system in the detection of clinical and sub-clinical mastitis. Once a day for 14 days (during morning milking), ~180 Holstein dairy cows will be manually examined for five indicators of udder health (redness, swelling, firmness, tenderness, and milk constitution) by a trained researcher. Milk samples will also be collected and analysed to determine daily somatic cell counts (SCC). Individuals showing signs of clinical mastitis, an increase in SCC of ≥10% from the day prior, or a daily SCC count of ≥200,000 cells/ml will have milk from all four udder quarters aseptically sampled during the evening milking. These samples will be processed in a microbiology laboratory so that significant mastitis causing pathogens can be identified if present. After each milking, cows will be passed between two stationary IRT cameras (left and right) before being returned to their resting areas. Once temperature data has been collected from these images, maximum udder skin temperature for each side of the udder will be compared to the five manually scored indicators of udder health, SCC, and bacterial growth using general linear mixed effects models. We predict that maximum udder skin temperature, as determined by this automated system, will be strongly related to manually detected indicators of udder health, SCC, and bacterial growth, providing support for the use of automated thermography system on commercial dairy farms.

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Use of an accelerometer as a tool to predict pregnancy status of lactating dairy cows before ultrasonography diagnosis

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Introduction

Accelerometers have been largely used in dairy farms as a tool for detecting estrus and subclinical or acute illnesses with good accuracy. In order to make a better profit of it, new studies have been developed to identify behavioural patterns that could help on partum prediction, or to predict even earlier some important diseases, such as displacement of abomasum or metritis (Gusterer et al. 2020). One aspect that has been less studied is how accelerometers could help on pregnancy diagnosis before the "gold standard" ultrasonography diagnosis, usually performed 32 to 40 days after artificial insemination (AI). Since the reproduction performance in lactating cows is one of the most important challenges in dairy farms, having the possibility of individuating animals that could be possibly negative a few days or weeks after AI would be really helpful to farmers in herd management decisions. Thus the aim of this study is to evaluate the use of an accelerometer in high-producing dairy cows as a tool for individuating behavioural variations from the day of AI until the pregnancy diagnosis' day, performed by ultrasonography at the 32nd day, in animals submitted to a estrus synchronization protocol.

Materials and Methods

Data were collected from a commercial dairy farm housing approximately 150 lactating Holsteins on Teramo province, Italy, from January 2020 to September 2021. Animals were kept in freestall barns with pens dividing animals by lactation number (primiparous vs. pluriparous) and a third group for tail-end lactating cows; each pen was equipped with full concrete floors and bed cubicles with straw, as well as fans and sprinkles automatically activated when the THI got over 70. Activity and rumination data were recorded using an ear-tag based 3D-accelerometer system (SB, Smartbow GmbH, Weibern, Austria). All animal related events (e.g. estrus, AI, clinical diseases, treatments) were entered into the herd management software Si@lleva by farm staff. Daily production data was recorded automatically through lactometers Metatron 21. Cows were milked three times a day. The voluntary waiting period was set at 70 days in milk (DIM). All the animals in the trial were submitted to a standard estrus synchronization protocol. Pregnancy diagnosis was accomplished 32 days after AI by ultrasound, and based in this result, animals' data were retrospectively grouped in "positive" or "negative" pregnancy. A negative animal could come back as a new experimental unit in a later synchronization protocol. The animals not submitted to an estrus synchronization protocol were excluded from the database, as well as herd management's days (e.g. hoof treatment), animals that had any disease 30 days before or during the trial and animals which recorded daily data were abnormal or incomplete. The database eligible for analysis was composed by 442 experimental units. All data were analysed using the software JMP pro v 16 (SAS, NY). The normal distribution of data was verified through Shapiro-Wilk test. The statistical analysis is based on the use of mixed models.

All results are considered tendencies when p ≤ 0.10, significant when p ≤ 0.05 and highly significant when p ≤ 0.01.

Results and Conclusions

No differences between negative and positive animals were found regarding the whole period – from day 0 to 32 days after AI – related to rumination, lying, inactive and active time. Nonetheless, when looking to specific intervals, there was a highly significant difference in lying time (Figure 1), where negative animals spent less time lying than the positive ones, on days 21 and 22, and a tendency on the 23rd day post AI (728±8.46 vs. 776±8.55 min., 721±8.49 vs. 771±8.29 min. and 738±8.49 vs. 773±8.40 min., respectively). It can be explained due to estrus return of negative animals during these days.

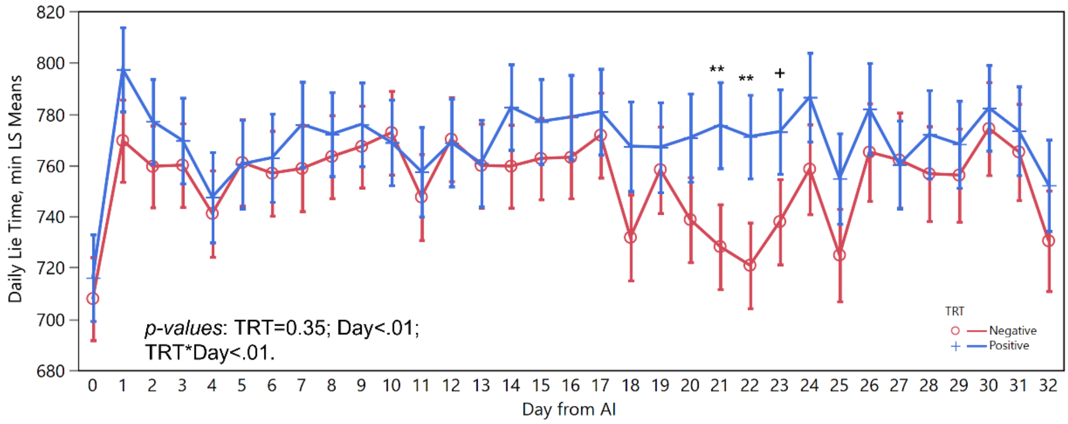

Figure 1. Daily average lie time (min.day^{-1}) of negative (red) and positive (blue) lactating dairy cows, from day 0 (artificial insemination, AI) to day 32 after AI.

There was a difference (p<0.01) regarding the milk production between negative and positive animals during the whole period (48.53±0.73 vs. 46.01±0.76 kg, respectively). In other words, the animals with the highest milk production were more likely to not be pregnant, and it probably occurs as a cause of a higher nutrient allocation to the mammary gland, which leads to a more severe negative energy balance and therefore lower conception rates (Beam and Butler 1999; Pryce et al. 2004). Further investigation is needed in order to develop an alert of probably negative animals, based on activity parameters from days following AI. In conclusion, the accelerometer used was able to identify differences in daily lying time between pregnant and non-pregnant animals on the days of estrus return, which can be useful to the development of a system alert for individuating "probable pregnant" and "probable non-pregnant animals".

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E-learning courses are a popular tool to implement SOPs in calf care

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Introduction

There are still too many calf losses on German dairy farms. Untrained personnel or the lack of accepted routines are important reasons. Standard operating procedures (SOPs) may increase process consistency (Amare, 2012) and thereby contribute to improved animal health and welfare. Unfortunately, SOPs are rarely used on dairy farms (Hesse et al., 2017, Falkenberg et al., 2019). The objective of this study was to evaluate SOP based e-learning and to determine underlying types of users.

Material and Methods

We created eight online courses on calf care and provided them to dairy farmers and their employees for free. Each course included the sections: “what do I need?”, “how to do it?” and “why is it important to do it this way?”, as well as a quiz. The “how”-part explained the given task using an intuitive picture or a short video and a brief description for each step. Study time for each course was just a few minutes. Mobile access was possible. We promoted the e-learning course series at multiple workshops, via social and print media, farming magazines as well as direct mailings in the second part of 2019. Interested persons signed up for the successively published courses on a website (www.kaelberschule.de) and studied at their own discretion over a period of three months while receiving multiple reminder mails. A total of five surveys were conducted before, during and after the release of the courses covering demographics, prior online learning experience, experience with a given task and appreciation of the SOPs. User behavior such as activities in the courses and course section completion was also tracked.

Results

A total of 301 participants (median age = 36 years) was included in the analyses. Only 32% had done an online course before participating in the “Kaelberschule”. Afterwards 85% stated that e-learning could be a nice opportunity for their individual training. The number of course launches decreased over the time.

Interestingly, a considerable percentage of participants did not feel confident when conducting certain tasks (tube feeding: 38%; disbudding 38%; testing colostrum quality 29%).

Even though 69% of the participants were often involved in providing neonatal calf care, 49% stated they had learned a lot in this topic. Qualitative content analysis revealed that participants perceived “colostrum”, “hygiene” and “weighing calves” as the most useful aspects in this course, indicating that learning materials should start with basic concepts.

Before training, only 13% of the participants had access to calf care SOPs; afterwards 69% said they wanted such SOPs. Sixty-six percent stated that the ready made SOPs would work well on their own farm. Sixteen percent stated that they would appreciate SOPs in Polish, and 9% in Romanian. After taking the courses, 64% of participants expressed interest in developing SOPs for their own farm.

Results of latent class analysis identifying different types of users and associations with the satisfaction and usage behavior will be presented.

Conclusion

Our findings indicate that e-learning courses are a useful and well perceived tool to improve knowledge and implement SOPs leading towards an improved calf health and welfare.

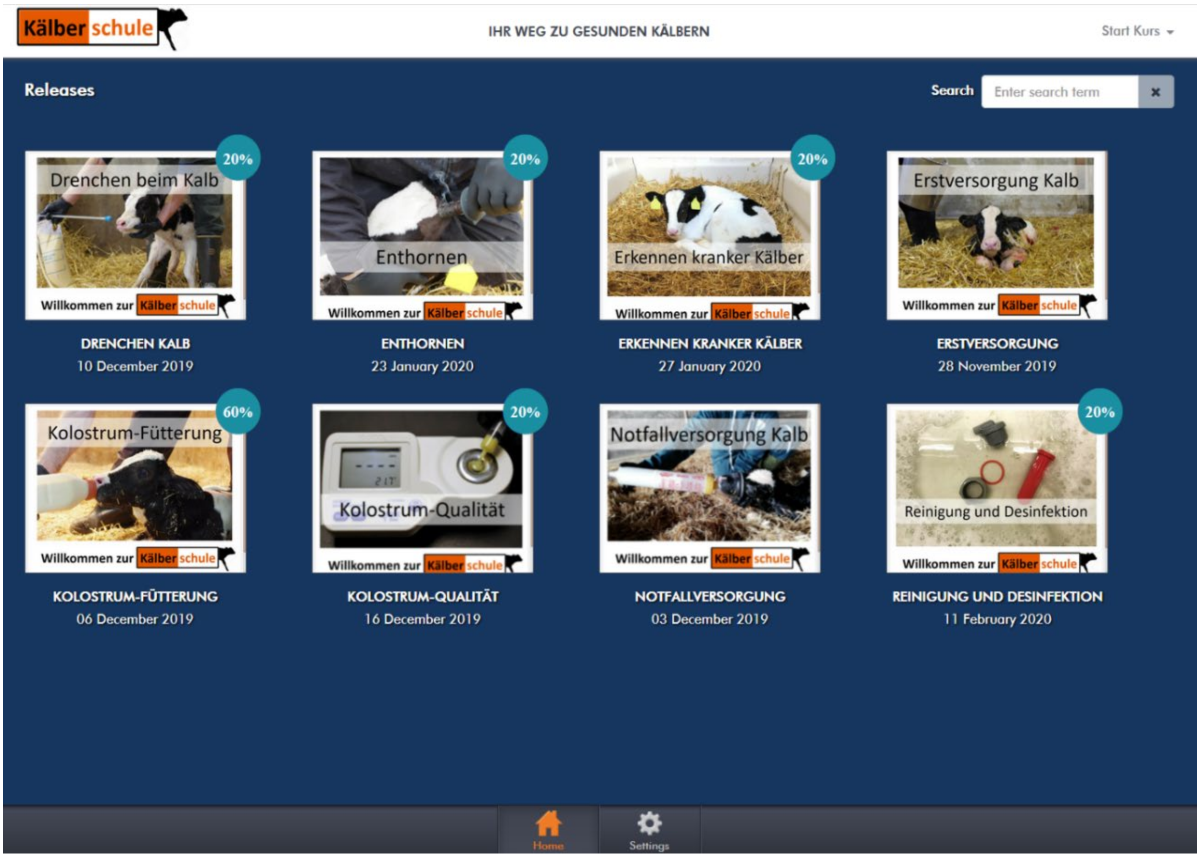

Figure 1. Online course platform („Kaelberschule“), accessible only for registered users.

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Identifying early life indicators of high performance in dairy calves based on precision technology measured variables: early evidence

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Use of precision dairy technology devices **(PDT)** in a calf barn could automate characterization of individual calf behaviors such as feeding behavior and activity patterns in early life. There is the potential to use these early life behavioral patterns to make informed management decisions. However, it is unknown if calf behaviors recorded by PDT in early life are associated with calf performance. The objective of this study was to evaluate if feeding behavior and activity patterns recorded by PDT during the first 30 days of life in dairy calves were associated with indicators of successful performance (average daily gain, **ADG** and total starter intake from birth to 14 days post-weaning). Calves (n=42) never treated with antibiotics and wearing a leg accelerometer (IceRobotics, Scotland) were trained and fed from an automated feeder (Forster-Technik, Germany) at 3 ± 2 days of age. Calves were weighed at birth and twice weekly on a scale. Calves had an allowance of milk replacer at 10 L/d until day 50 and *ad libitum* access to starter from another feeder. Calves were step-down weaned from milk starting on day 50 (50% reduction until day 64, additional 20% reduction until complete weaning at day 70). Calves were followed for 14 days post-weaning. Total starter intake and ADG were summarized over the experimental period (day 3 to 87 ± 2 days of age). The daily feeding behavior variables recorded by the automated feeder were as follows: starter intake, milk intake, rewarded and unrewarded visits, and drinking speed. The daily activity variables recorded by the accelerometer were: lying time, lying bouts, total step count, and an activity index based on acceleration rate and steps. All feeding behavior and activity variables from the day the calf was enrolled on the automated feeder to day 30 were input variables in a Principal Component Analysis; 3 factors explained 70% of the variance. The results of these findings are presented in Table 1. Briefly, in a linear regression, Factor 3 (**"Feed motivated":** calves with high drinking speed and high starter intake) was associated with greater ADG ($P < 0.01$) and a greater total starter intake over the period ($P = 0.02$). Factor 2 **("Milk driven":** calves with high rewarded and high unrewarded visits to the milk feeder) was associated with lower total starter intake ($P = 0.03$), but there was not association with ADG ($P = 0.45$). Factor 1 ("**Active":** calves with high steps, high lying bouts and a high activity index with lower lying time) was not associated with ADG or total starter intake ($P > 0.20$). Feed motivated calves with high drinking speeds and consumption of starter intake in early life may be high performers up to 14 days post-weaning. We suggest that PDT such as an automated feeder has potential to generate an index which records feeding behavior patterns in early life and could be used as a proxy for calf's performance in the first 90 days of life.

Keywords: growth, automated feeder, activity

Table 1. Three factors explained 70% of the variance in feeding and activity behaviors recorded by the technologies in the first 30 days of life. These factors could explain some of the variation in average daily gain and total calf starter intake among healthy calves (n=42) in the rearing period (from 3 to 87 d of age in this study).

Factors	Technology variables First 30 feeder days	Relationship with calf starter intake	Relationship with average daily gain
"Feed motivated"	High drinking speed High calf starter intake	Higher ($P = 0.02$)	Higher ($P < 0.01$)
"Milk driven"	High rewarded visits High unrewarded visits	Lower ($P = 0.03$)	No association ($P = 0.45$)
"Activeness"	High step counts High lying bouts Low lying times	No association ($P = 0.34$)	No association ($P = 0.20$)

Validation of accelerometer data to measure rear leg movement during milking

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A growing trend towards automation of the milking process of dairy cows has progressed in tandem with a focus on monitoring any changes in cow health and welfare resulting from altered milking machine settings. Prominent among such concerns include damage to teat tissue where vacuum on the teat end increases in the absence of adequate milk flow which could impact overall udder health. Marrying increased milking efficiency and cow welfare is strategized in the three pillars of successful milking, i.e. milking gently, quickly and completely. Cow comfort is an important facet in such considerations but has been difficult to quantify.

The present study attached 3 dimensional accelerometers to the rear left legs of thirty cows. During at least one morning and one evening milking, video footage was captured from behind these cows to determine rear leg movement during the period of milking. The output of this observational data was compared to the accelerometer data over the same synchronised time period.

The step count parameter which is designed to record leg movements while standing or walking is the variable of most interest in a milking parlour environment. Lin's Concordance Correlation Coefficient (r_c) was used to assess agreement between the observed values and accelerometer measured step count values. This returned a value of r_c =0.82 indicating good agreement between both methods of measurement. This correlation coefficient does not necessarily account for systemic bias for which a Bland-Altman plot was used to check. A paired t-test produced a significant result for bias ($t_{(106)}$=5.33, p<0.0001) with lower values recorded by the accelerometer. The correlation between the bias and the magnitude (the mean of both methods) was in the low to moderate range, but statistically significant (r_p=0.48, p<0.0001). Over the milking period the accelerometer recorded 76% of the quantity of leg movements observed from the leg to which it was attached and 40% of the observed leg movements from both rear legs.

Accelerometers attached to a rear leg of a cow provide a good indication of leg movement during milking as validated by visual observations. This could be further improved by attaching an accelerometer to both rear legs to be utilised as an indicator of cow comfort.

Evaluation of a climate sensor for the on-farm use in cattle barns

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Introduction

The evaluation of barn climate becomes increasingly important in cattle housing, especially with regard to heat stress. For research in the field and for on-farm use, a cheap, reliable, simple to use method with an easy access to data is required. One commercially available logger which appears suitable for fulfilling this criteria is the Kestrel D2 Drop (Kestrel Instruments, US; **KE**). Environmental data (temperature (T), relative humidity (RH), heat point, dew point, and temperature humidity indices (THI)) are presented in real time, charted, recorded, and can be displayed via bluetooth on a smart device. To the authors' best knowledge, no scientific studies evaluating this logger in cattle barns have been published, yet. Consequently, the aim of our study was to evaluate if this logger marketed for the on-farm use in cattle barns provides reliable environmental data.

Materials and Methods

Because no generally accepted gold standard for climate measurements in barns exists, data were compared to other T and RH recording systems. Devices and settings were:

- Setting 1: KE, **TT** (Tinytag Plus 2 - TGP-4500, Gemini Dataloggers Ltd, UK) and **PP** (Papago Meteo ETH and TH3, Papouch s.r.o, CZ) in an open foamed polystyrene box in a well-tempered room,
- Setting 2: KE, TT, and PP in a confined dairy cow barn,
- Setting 3: KE and TT in an open calf barn,
- Setting 4: KE and **HO** (Hobo RX 3000 and HOBOnet Wireless Temp/RH Sensor, Onset Computer Corporation, US) in an open dairy cow barn.

In setting 1, two KE were used to validate the reproducibility (agreement) of the loggers.
Measurements were recorded either every minute or every 10 Minutes.
We statistically analysed data of T, RH, and THI (calculated by the formula of Kendall and Webster, 2009). Data recorded by the different devices were compared by Pearson correlation coefficient. Furthermore, area under the curve-receiver operating characteristics (AUC-ROC) analysis for THI with a cut-off at ≥ 72 for heat stress (Ravagnolo et al., 2000) was performed for KE with either TT and PP (settings 1-3), or HO (setting 4) as comparison method.

Results

The variance of T, RH, and THI in this study was 2.7 to 31.0°C, 36 to 100%, and 27.8 to 79.9. Overall, correlation coefficients were evaluated based on 248,939 data points. No data losses were observed for the evaluated KE system. The correlations between the different loggers in the different settings are presented in Table 1.

For setting 1 and 4, the AUC-ROC revealed 1.000 (when using TT, PP, or H, respectively as reference method). In settings 2 and 3, the AUC-ROC varied between 0.983 and 0.998, depending on the setting and the reference method.

Table 1 Pearson correlation coefficient for measurements between the Kestrel logger (KE) and either Tinytag (TT), Papago (PP), or HOBO (HO) logger.

Setting	Logger	T[1]	RH[2]	THI[3]
Setting 1	KE *vs.* KE	0.999	0.998	0.999
	KE *vs.* TT	0.999	0.996	0.999
	KE *vs.* PP	0.999	0.999	0.999
	TT *vs.* PP	0.999	0.996	0.999
Setting 2	KE *vs.* TT	0.989	0.940	0.998
	KE *vs.* PP	0.971	0.910	0.996
	TT *vs.* PP	0.992	0.974	0.999
Setting 3	KE *vs.* TT	0.992	0.980	0.993
Setting 4	KE *vs.* HO	0.998	0.968	0.998

[1]T = temperature, [2]RH = relative humidity, [3]THI = temperature humidity index (Kendall and Webster, 2009)

Discussion

In the 'controlled' setting 1, all devices showed a ‘perfect agreement’ (Taylor, 1990). In the other on-farm evaluations, slight differences between loggers and settings were observed. Nevertheless, overall, the agreement was very high. As expected, variance was larger regarding RH compared with T. The THI, however, revealed very good agreement.
The number of possible recorded data, like in many systems, depends on the measurement interval, which has to be kept in mind, because this could lead to data losses.
Our results show that the evaluated logger KE can be used easily on farm under field conditions with receiving reliable data. The advantage, compared to the other systems, is that data can be easily assessed with minimal technical effort and in real-time. Data and information derived from the KE can be used for management decisions on farm to improve barn climate and to avoid heat stress by, e.g., switching on fans or opening curtains.

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Evaluation of a rising plate meter tool to measure herbage mass on Austrian pastures

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Introduction

Access to pasture has been pointed out as a welfare benefit for dairy cows and is increasingly demanded by consumers. However, meeting the nutritional requirements of cattle kept on pasture might be a challenge. On the other hand, grazing, if correctly implemented, can reduce feed costs. Accurate estimation of feed availability in pastures is of great interest for grazing management as these estimations represent economic benefits for dairy farmers. Herbage mass (HM) is a measure farmers typically use to estimate the amount of forage and dry matter (DM) content in pastures and is often reported as kg of DM/ha. These estimations help farmers to make decisions in grazing strategies depending on the forage availability and quality. However, is not always easy to accurately estimate HM. There are multiple methods to perform these estimations. Traditional methods to estimate HM, are often based on visual assessment, this can be subjective and vary from person to person. Manual cutting of grass samples followed by laboratory analysis can be more accurate but requires a lot of time and labor. Other methods use tools for semi-automatic measurement of HM, such as rising plate meters (RPM). An RPM is a device that can measure the compressed sward height (CSH) and transform this variable through a calibration equation into HM. In practice, RPM tools are commonly used in intensive grassland management for accurate estimations of HM, and several studies have evaluated these instruments. However, these tools need to be calibrated for each season, different pastures, and geographical location, since for example; the composition of grasses may vary. Therefore, standardization of calibration methods and evaluation of these tools in different regions are needed.

The objective of this study was to evaluate the accuracy of an RPM tool to estimate HM under Austrian conditions against laboratory methods.

Materials and Methods

The study was conducted at the teaching and research farm (VetFarm) of the University of Veterinary Medicine Vienna, Austria. Measurements were taken between May and October 2021 in five pastures with corresponding plots (10*20 m) within each pasture. Plots were used as a control to avoid the grass composition variance that may exist within pastures.
The Grasshopper® RPM tool (Grasshopper; True North Technologies, Ireland) was used to measure CSH. In pastures, a minimum of 75 RPM measurements per hectare in a zigzag pattern were taken. For the plots, 36 RPM measurements with an approximate distance of 2 m were performed. Measurements were taken approximately every 2 weeks in every pasture.

Three grass samples were taken at random positions every 75 RPM measurements (i.e., 3 samples per ha) for the pastures.

Furthermore, three grass samples at random positions were taken in the plots on every sampling date. Grass samples were collected by using a 50 cm * 50 cm square in the exact place where an RPM measurement was performed. Samples were cut 40 mm above the ground using an electric grass trimmer. Collected grass was weighed and analyzed. Samples were then dried at 100°c for 24 hours to extract the DM and calculate the HM. The following formula was used to calculate HM (collected grass weight * DM % * 40,000).

Results

Preliminary results of HM estimations based on 205 paired measurements from the five pastures between the two methods achieved a correlation of $r_p = 0.83$ and linear regression of $R^2 = 0.70$.

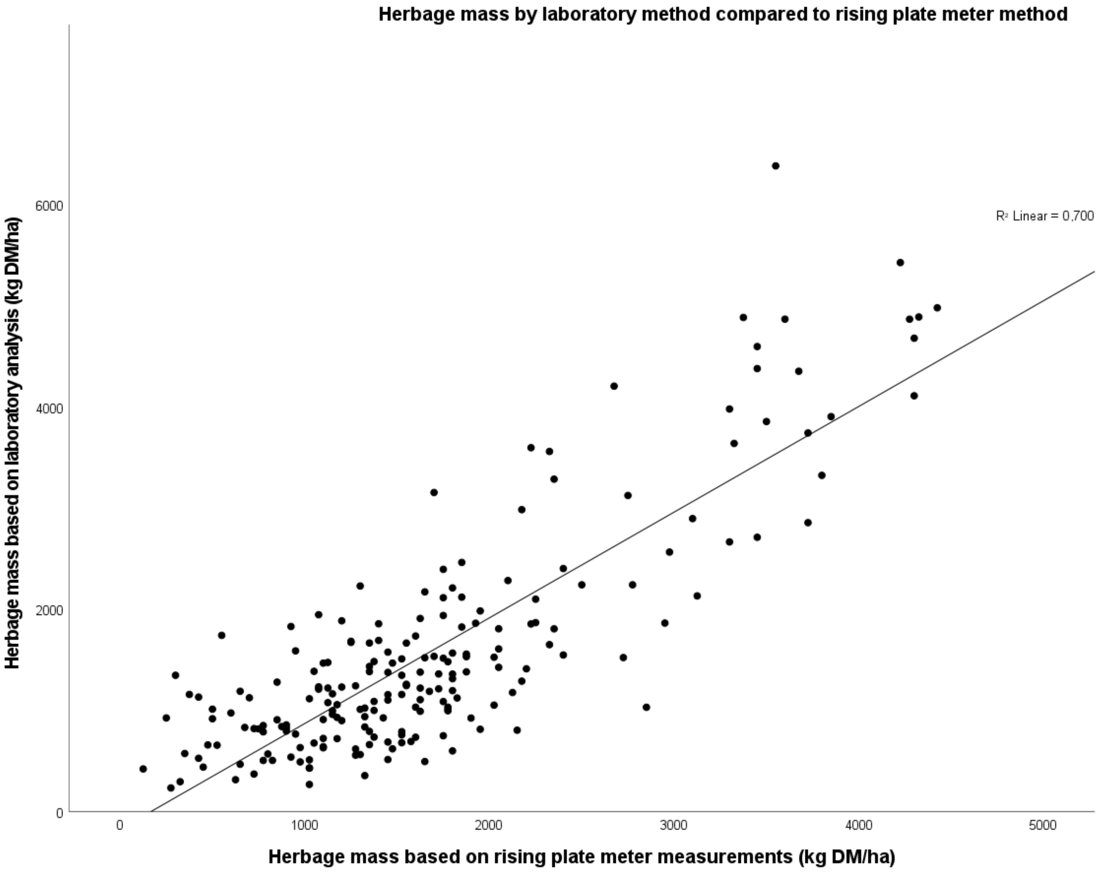

Figure: Result of 205 grass samples compared directly with its corresponding RPM measurement

Conclusion

The preliminary results indicate that the default calibration of the RPM Grasshopper® is reliable to estimate HM under Austrian conditions. Further analyses are needed to explore the results of pastures individually and the influence of botanical composition on RPM measurements.

Health monitoring in dairy goats: Applicability of an in-rumen sensor

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Introduction

Due to the growing demand, global goat milk production increased by more than 20% between 2007 and 2017 (FAO, 2018). Especially the European dairy goat industry has undergone rapid intensification, with specialized dairy goat farms managing on average 1.117, and 730 dairy goats per farm in The Netherlands and France respectively (CBS, 2020; GEB, 2020). Expanding herd sizes and shortage of skilled labour are complicating herd health management. Therefore, nutritional imbalances and metabolic disorders -such as rumen acidosis, lactational ketosis, and hypocalcaemia- are common problems in high-producing goats (Simões and Gutiérrez, 2017).

Developing a Rumen Sensor

To improve animal health and maximize the production potential of dairy goats, a rumen sensor is currently being developed within the project “Bolucap”. The goal of the sensor system is to capture body temperature, general activity (differentiating between walking, standing, and lying down), feeding time and rumination time, and relay this information into actionable advice for the farmer (Fig 1). The bolus sensor data is first internally processed with embedded AI and send over a LoRa network to base stations located in the barn. The data is then forwarded to the cloud where other machine learning data processors covert it to agricultural advice. The rumen bolus measures 70mm in length and 23 mm in diameter, and weighs approximately 65 g.

Survey of Dairy Goat Farmers

A digital survey has been sent out to 80 dairy farmers in Belgium and the Netherlands to assess their pre-purchase considerations and general impressions of precision dairy technologies, including the novel rumen sensor bolus. The survey results will be used for further technology roadmapping and improving the business model.

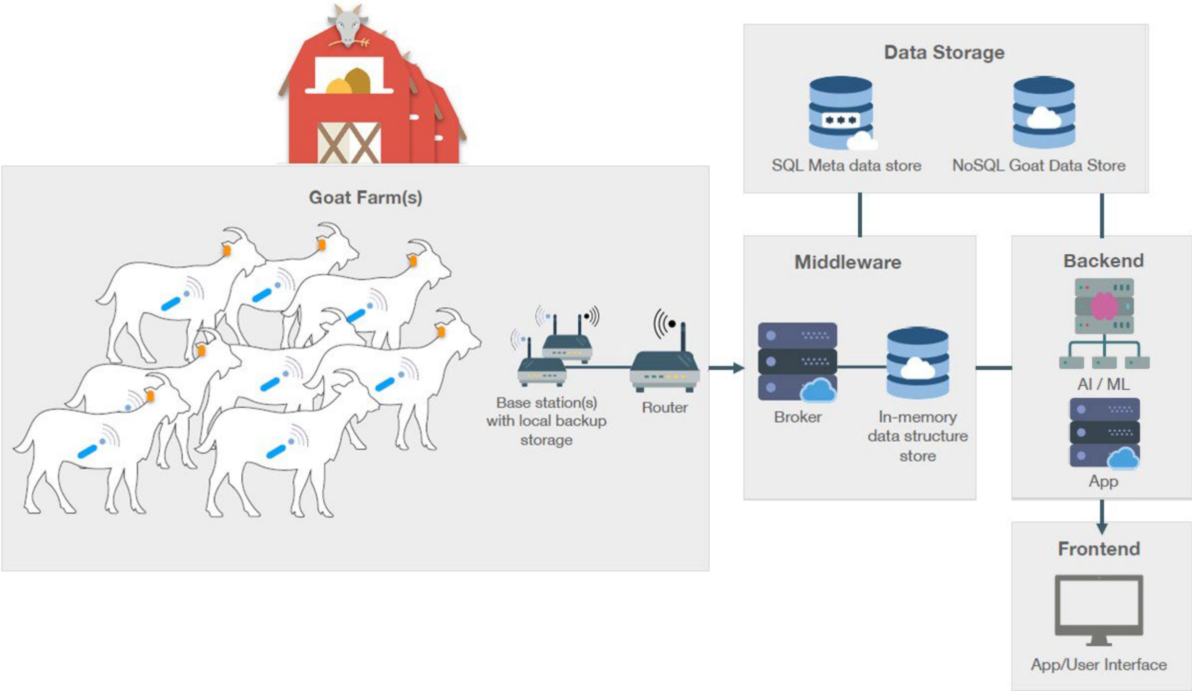

Figure 1. A graphical representation of the Bolucap health monitoring system and data management architecture.

Acknowledgements

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Evaluation of health parameters and rumen motility after administration of a rumen sensor bolus in dairy goats

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Interest of the research

Dairy goat farming is a strong growing branch in agriculture in Western-Europe. Large farms require professional herd management to maximize production efficiency. Two frequently occurring diseases, ketosis and ruminal acidosis, are directly related to the nutrition and can lead to 25-35% milk production loss. However, individual following up of each animal has become unfeasible as dairy goats are usually housed in large groups according to age and/or production level, where 'signal goats' are used to assess the metabolic status and nutritional demands for the entire group. These 'signal goats' can be armed with a sensor bolus located in the reticulum to oversee metabolic parameters such as body temperature, movement, rumen contraction, and food- and water intake.

In this study a bolus with a temperature sensor and accelerometer is administered orally. As seen on radiographic imaging, the bolus will nest in the reticulum. The contractions of the dorsal sac of the rumen and the (peristaltic) contractions in the reticulum occur at practically the same time (Arai et al., 2019). The body temperature will define the general health and the accelerometer data will provide information about the animal's movement and the rumen's contractility. The frequency and amplitude of ruminal contraction in dairy goats is influenced by metabolic diseases such as ruminal acidosis and ketosis, as well as any conditions that causes pain or fever (Giger-Reverdin, 2018).

Objectives of the study

- Evaluation of the functionality of a prototype caprine rumen bolus by placing the bolus (6.3cm x 2cm diameter) in the goats reticulum via oral administration
- Evaluation of the continuous sensor data transmission
- Evaluation of health parameters and gastrointestinal function of the goat after ingestion of a ruminal bolus

Material & methods

The experimental procedures were approved by the Ethical Committee from the faculty of Veterinary Sciences. EC number: 2021-090.

Ten reform non-lactating adult Saanen goats (aged 4-6) weighing 65 to 110 kg are used in this study. The goats are housed in two groups of five animals each (4.8m²/animal; temperature and humidity controlled environment). Fresh water and a total mixed ration is ad libitum available. Seven goats received a bolus and 3 goats did not and (controls). A clinical examination is done SID (RR, P, T, hydratation, lnn, rumen contractions and appetite is measured).

Motion patterns and variation in behavior (walking, foraging, rumination etc) are recorded by continuous surveillance cameras (night/day video capturing, Avigilon). These patterns will be used later on to compare with the recorded data of the bolus and the specific clinical observations.

Results and discussion

- Presence of an intra-ruminal bolus did not influence the rumen motility and
- Did not influence any of the clinical parameters
- Temperature sensors were able to detect normal diurnal fluctuations or aberrant body temperature
- Accelerometers were able to detect the global movement of the goat and
- The ruminating patterns of the goat

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Feeding behaviors collected from automatic milk feeders were associated with disease in group-housed preweaned dairy calves in the Upper Midwest USA

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Introduction

Most US dairy farms house their preweaned dairy calves individually in outdoor hutches or indoor pens. The main reason for this practice is to minimize the risk of disease. However, housing them individually may have detrimental effects on the calf's affective or mental state. Automated milk feeders (AMF) make it easier for dairy farmers to feed calves housed in groups. These feeders offer a more flexible labor schedule and greater behavioral freedom for the calves. Some studies have shown that housing calves in groups can result in increased morbidity and mortality, therefore having automated monitoring tools would be helpful in managing these group systems.

Research has shown that calf feeding behavior changes recorded by AMF software can be used as an indicator of disease. However, those studies were conducted at multiple farms, had a small sample size, or were conducted in other countries. Therefore, the objective of this study was to investigate the association between feeding behaviors and disease in automatically fed group-housed preweaned dairy calves on a large dairy farm in the Upper Midwest USA.

Materials and Methods

Study personnel visited the farm on a weekly basis from May 2018 to May 2019 and visually scored calves for health and collected AMF software feeding behavior data. Calf health scores included calf attitude, ear position, ocular discharge, nasal discharge, hide dirtiness (tail head area), and cough score. Calves scoring >1 were categorized as sick. The use of animals in the study was approved by the University of Minnesota's Institutional Animal Care and Use Committee (protocol no. 1806-36043A).

A generalized additive mixed model (GAMM) approach was used to identify associations between feeding behavior and disease. The final GAMM (n = 599 calves) included the fixed effects of rewarded visits (with milk being offered), unrewarded visits (without milk), total milk intake (mL per day), average milk intake per visit (mL/day), drinking speed (mL per min), interval between visits (min), visit duration (min), and calf age (day).

Results

Feeding behaviors were analyzed for 599 calves representing 3,003 calf score events on the automatic feeder during the milk-fed period. The total number of scores (3,003) included 1,892 healthy and 1,111 sick events. Calves visited the feeder 1 to 11 times daily receiving a milk meal (rewarded visit), with most calves visiting the feeder an average of 3 times and receiving a milk meal with a total of approximately 1,100 observations. Calves visited the feeder 0 to 47 times daily without receiving a milk meal (unrewarded visit), with most calves visiting the feeder an average of 1 time without a milk meal with a total of approximately 200 observations.

Over the entire feeding period, calves consumed 6,446 ± 2,306 mL/d (avg ± SD) and 1,865 ± 575.3 mL of milk per visit. Calves were 38.5 ± 15.9 days of age when receiving full milk allowance (9 L). Calves had a drinking speed of 811.2 ± 331.4 mL/min, feeding for 1.8 ± 3.1 min per visit, with intervals between visits to the AMF of 142.4 ± 125.7 min.

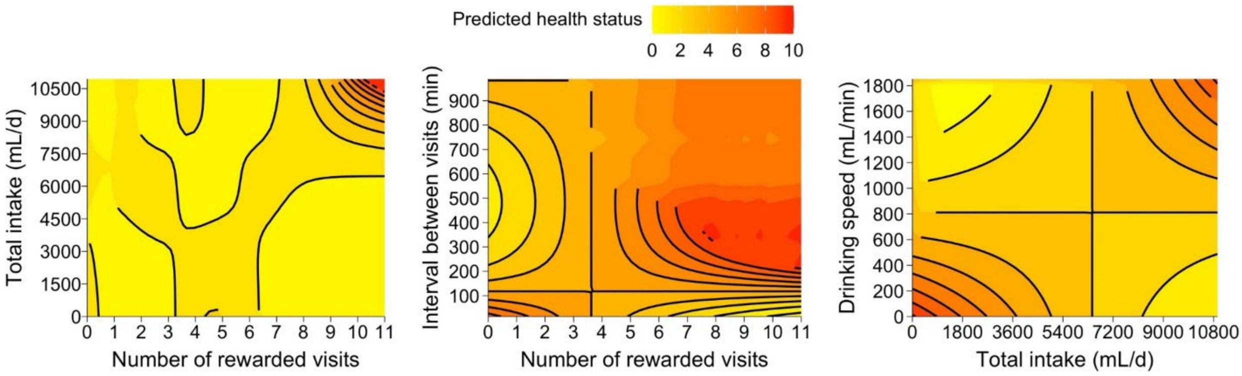
Total milk intake per day, drinking speed, interval between visits, age, and rewarded visits were associated with dairy calf health status ($P < 0.05$). Interactions between total intake per day and number of rewarded visits, interval between visits and number of rewarded visits, and drinking speed and total intake per day were also significant (Figure 1).

Conclusions

Our results suggest that we could use the behavioral traits collected by AMF as a potential indicator of calf disease. We plan to use these variables to develop a predictive model that identifies a sick calf days before a clinical disease event.

In addition, GAMM showed to be a simple and flexible approach to model calf health status, as this approach was able to address non-normal data distribution of the response variable, capture nonlinear relationships between explanatory and response variables, and accommodate random effects.

Figure 1. Predicted health status of dairy calves on the odds ratio scale for the significant interactions: number of rewarded visits and total intake (A), number of rewarded visits and interval between visits (B), and total intake and drinking speed (C).



A B C

Automatic monitoring of suckling behaviour in lactating calves under two feeding alternatives

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Introduction

Rearing a healthy calf up to puberty results in optimal production in further lactations (Kennedy et al., 2011). Therefore, it is necessary to promote animal welfare and health during this short period. Reducing hunger is key during this stage since it is one of the main welfare issues (De Paula et al., 2008; van Niekerk et al., 2021). Suckling rate is a good indicator of hunger in lactating calves (De Paula et al., 2008). Precision Livestock Farming technologies based on continuous behaviour monitoring provide a powerful tool to assess welfare issues. The aim of this work is to evaluate suckling behaviour of lactating dairy calves fed under two different strategies using automatic monitoring devices.

Materials & Methods

The study was carried out in a dairy calf ranch located in Titaguas (Valencia, Eastern Spain) from October 9, 2020 to January 30, 2021. Immediately upon arrival to the farm, 30 calves were individually weighed, measured for rectal temperature and an Allflex® Tag cSense™ Flex Ear tag (SCR Engineers Ltd., Italy) was installed. Animals were distributed in two different groups according to milking program: a) group 2T, in which 16 animals received 6L of milk replacer distributed in two episodes of 3L each (morning, 7 to 8 a.m., and noon, 4 to 6 p.m.) and b) group 3T in which 14 animals received 6L of milk replacer distributed in three episodes of 2L each (morning, 7 to 8 a.m., midday, 12 to 13 p.m. and noon,4 to 6 p.m.). Animals were housed individually for 7 ± 2 days after arrival with 2-6 days of life and in pairs until weaning at seven weeks of life. Sensors provided with the number of suckling events and duration for each animal throughout the day. Suckling speed (L/min) was calculated for each animal and episode as the rate between volume offered (L) and the number of minutes devoted to suckling during this episode. Data was analysed using SAS software (SAS inst. Inc.) using a mixed model of repeated measures, considering as effects feeding episode and treatment.

Results

A total of 2,116 suckling events were recorded. Almost 12% were discarded due to false positives (were detected by sensors when the calves did not have milk at their disposal). A summary of suckling rate for each treatment and suckling episode is presented in Table 1.

Table 1: Suckling rate according day moment and number of feedings (mean ± standard error).

Treatment	Daily average	Morning	Midday	Noon	p-Value
2T (3L/episode)	0.475±0.009	0.429±0.010	-	0.535±0.012	<0.0001
3T (2L/episode)	0.401±0.008	0.352±0.013[a]	0.481±0.018[c]	0.433±0.020[b]	<0.0001
p-Value	<0.0001	<0.0001		<0.0001	-

The table is read by columns for the comparison between treatments and by rows for the comparison between events within the same treatment. P value <0.05 means significant differences. Different superscripts represent statistically significant differences between events for group 3T

As can be seen in table 1, there are significant differences (p-value <0.0001) for the daily average suckling rate, where the animals from 2T were faster than animals from 3T. These significant differences (p-value <0.0001) occur for morning and afternoon suckling episodes too, with a higher speed approximately between 0.054 - 0.1 L/min and 0.07 - 0.134 L/min for 2T in the morning and afternoon feeding, respectively. There are significant differences (p-value <0.0001) for suckling time of day, in both groups independently. In addition, the calves with three feedings had a higher sucking rate in the midday feeding compared to the other feedings of the rest of the day.

Discussion

In previous studies (Gerbert et al., 2018 and De Paula et al. 2008), it has been demonstrated that suckling speed is an indicator of hunger in calves. Based on these, results obtained in this study show that animals with two feeding events have a greater feel of hunger because they present a higher suckling rate compared to animals with three feeding events. Although there are no differences between the two treatments in the total amount of milk supplied to the animals, the management of the number of feeding events does have a clear effect on hunger.

In addition, the results obtained show that the time of day also has an influence on the suckling rate and thus, on the feeling of hunger in calves, as was obtained by Appleby et al., (2001). However, Appleby et al. (2001) observed that the animals had a higher sucking rate in the morning, in contrast to the results obtained in this study, whose sucking rate is higher in the afternoon feed. This may be due to the animals feel more satiated in the morning and they have more episodes of rumination at night. Further research is needed to clarify this finding.

Conclusion

In conclusion, the tag sensor is a good instrument to measure suckling behaviour in lactating calves. Furthermore, according to the results, milk offer frequency has a significant influence on the sensation of hunger, causing an alteration in the sucking rate of the calves. Automated behaviour monitoring can be used to assess welfare issues in calf rearing.

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Ruminating behavior of suckling dairy calves under two feeding strategies

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Introduction

Rumination in calves usually starts around the second week of age (Lopreiato et al., 2018), reaching up to 5 hours per day between 4 and 6 weeks of age (Swason and Harris, 1958). Rumination can be altered by the management of the farm (Wilt, 1985). The increase in time of this behavior is associated with a higher consumption of solid feed, which is a good indicator of ruminal development (Schäff et al., 2018). It has also long been associated with livestock health and more recently as an indicator of stressors or animal welfare (Schirmann et al., 2012). In adult dairy cows the detection of rumination through precision livestock systems is fully developed (Schirmann et al., 2009), but this technology is still under development for lactating calves (Costa et al., 2021). The aim of this work is to analyze rumination activity recorded by automatic sensors in dairy calves.

Material and Methods

The study was carried out in a dairy calf ranch located in Titaguas (Valencia, Eastern Spain) from October 9, 2020 to January 30, 2021. Immediately upon arrival to the farm, 30 calves were individually weighed, rectal temperature was measured and an Allflex® Tag cSense™ Flex Ear tag (SCR Engineers Ltd., Italy) was allocated in the right ear of the calves. These automatic sensors allowed to monitor the behavior of the animals during the whole lactation. Animals were distributed in two different groups according to milking program: a) group 2T, in which animals received 6L of milk replacer distributed in two episodes of 3L each (morning, 7 to 8 a.m., and noon, 4 to 6 p.m.) and b) group 3T in which animals received 6L of milk replacer distributed in three episodes of 2L each (morning, 7 to 8 a.m., midday, 12 to 13 p.m. and noon,4 to 6 p.m.). Animals were housed individually for 7 ± 2 days after arrival with 2-6 days of life and in pairs until weaning at seven weeks of life. Regarding behaviour, sensors provided the number of ruminating events and duration for each animal throughout the day. The effect of feeding treatment and age on total daily time spent ruminating were analyzed with a multivariate ANOVA analysis, using Statgraphics Centurion®. Daily rumination patterns were calculated considering the relative daily rumination variations for each animal.

Results

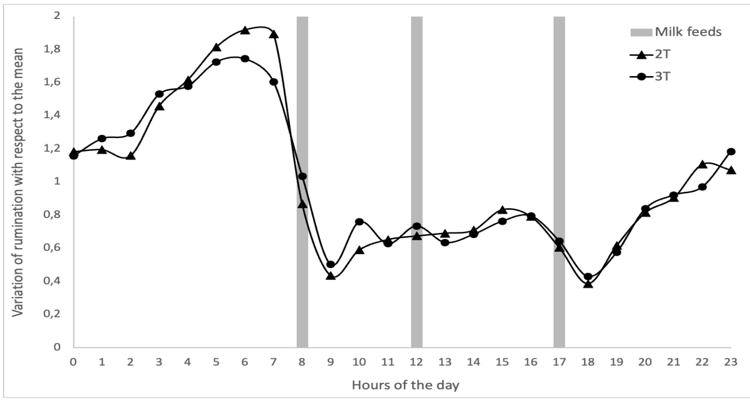
The results obtained did not show significant differences between treatments in the total time of daily rumination. Significant differences were observed (p-value <0.05) in the evolution of rumination time by weeks of age (Table 1). Calves started rumination during the second week of age, increasing the time devoted to this activity until the seventh week, when it began to stabilize. Regarding the daily rumination patterns, as it can be in Figure 1, calves have a greater time dedicated to rumination during the night period (8:00 p.m. - 6:00 a.m.).

Table 1. Total dairy time rumination (mean ± standard error)

Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	P-value
11.7±13.1[a]	35.3±7.3[a]	100.9±5.6[b]	153.4±5.2[c]	216.9±5.0[d]	250.8±4.7[e]	<0.05

Different caption letters represent statistically differences (p<0,05) between weeks.

Figure 1. Daily rumination pattern for both feeding treatments and feeding events



Discussion

There was no effect of the feeding program on rumination behavior. It has been observed a clear evolution of rumination from the second week of age up to the seventh one, coinciding with what was obtained by Lopreiato et al. (2018), which can be an indicator of a good rumen development. An increase in rumination during the night period was observed. This could be related to the positive relationship between rumination and resting behaviors, that increases during the night due to the lower activity in the farm (Wilt,1985). It could be concluded that automatic sensors for behaviour monitoring are a useful tool to monitor rumination in calves. Most of the rumination occurs at night, probably because farm management has a notable effect on calf rest and, therefore, on the rumination pattern. Feeding strategies studied in this work did not affect total rumination time neither rumination patterns.

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Combining location and pedigree data to estimate heritability of social interactions in dairy cattle

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Introduction

Resource-based aggression and sociability are important traits affecting animal welfare for dairy cows. In resource-based aggression, cows approach each other in their competition for resources, such as water or feed (Gibbons et al., 2010; Haskell et al., 2014). Sociability is the willingness to be close to other animals of the same group. Both sociability and resource-based aggression causes cows to be in close proximity to other cows and may be treated as two types of social interactions. Heritability of social interactions for dairy cows have not been investigated thoroughly. Temperament is a factor that might affect social interactions and is known to be heritable in both beef and dairy cattle (Costilla et al., 2020; Haskell et al., 2014). Nevertheless, there are few, if any, studies on the heritability of social interactions *per se*.

The aim of this study was to estimate the heritability of social interactions in dairy cattle in an indoor environment. To this end, indoor locational data collected every second on all cows over a two-week period were used.

Material and Methods

Data was collected from a commercial dairy farm in Sweden that housed around 210 lactating dairy cows in a non-insulated free-stall barn. The barn was divided into two milking groups. One group consisted of cows in mid and late lactation and the other consisted predominately of cows in early and mid-lactation. Each lactating cow was equipped with a tag mounted on the top of the neck collar connected to a real-time location system (CowView, GEA Farm Technologies, Bönen, Germany) automatically collecting individual positioning data of the cows with one-second fix rate. Raw positioning data were extracted from 16 to 29 October 2020. Individual attribute data such as parity, calving date, and tag-ID were provided by the farm and information about breed, insemination records, pregnancy diagnoses, claw trimming records, and pedigree were extracted from the Swedish official milk recording scheme.

The total duration of contacts for each cow and day was calculated separately for two functional areas in the barn, feeding area and resting area. The response variable was computed as the ratio between total duration of contacts and the time spent in the specific area, and is referred to as the *average number of contacts*. Cows closer than 2.5 m from each other were defined to be in contact. Contacts that lasted in total less than 10 minutes per day were removed to reduce noise. Data from the two groups were analyzed separately. The response variable was computed for all individuals present on all 14 days using the connections with all individuals present on each day. Both groups were not constant during the study period, and only responses for animals present in the group during the entire period were consider for the subsequent analysis. The number of individuals present in the two groups on all 14 days were 80 and 83.

Two linear mixed models with the same explanatory variables were fitted, one for each functional area. Fixed effects were date, parity, lactation stage, breed, pregnancy status, estrus, udder health and claw health. Furthermore, level of relatedness was included as a fixed effect nested within breed. The level of relatedness measures how related each cow is with the rest of all the cows in the same group and was computed as the row sums of the additive relationship matrix minus the diagonal element. Random effects were permanent environmental effect and animal effect. The variance matrix for the animal effects was constructed using available pedigree information, and the model was fitted using the pedigreemm (Vazquez et al., 2010) package in R.

Results

The estimated heritabilities for the average number of contacts were larger in the resting area than the feeding area (Table 1), and the repeatabilities were consistent between groups for each of the two defined areas. Cows closely related to other cows in the same group were expected to spend more time together than unrelated individuals, but the fixed effect of level of relatedness was found to be non-significant ($p>0.05$) for both groups and both investigated areas.

Discussion

Using a real-time location system, we have computed the number of contacts a cow has with other group members closer than 2.5 m. The estimated heritability varied between 0% to 20% but in all four models the difference in REML likelihoods were rather low and the estimated heritabilities could not be concluded to be significantly different from 0. Nevertheless, we expect real-time location systems to be an important complement in future welfare monitoring and the possibility to include social interactions in dairy breeding programmes should be considered. We do anticipate future studies within this field since social interactions are important to understand for further development of optimal management and welfare.

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Table 1. Estimated heritabilities (h^2) and repeatabilities (r^2)

	Group 1 (n=80)			Group 2 (n=83)		
	h^2	r^2	$-2\log LR_{REML}$[1]	h^2	r^2	$-2\log LR_{REML}$
Resting area	0.20	0.47	0.14	0.13	0.50	0.17
Feeding area	0.14	0.35	0.24	0	0.36	0

[1]Twice the change in REML likelihood for a model with and without a random animal effect

Measuring brush use in group housed dairy cattle

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Introduction

Mechanical brushes are increasingly used on commercial dairy farms to provide cows with grooming opportunities and improve coat cleanliness. Cows are highly motivated to access brushes (McConnachie et al., 2018) and recent research indicates that a change in brushing behavior may be indicative of changes in health (Mandel et al., 2017), social stress (Lecorps et al., 2020), or negative affective states (Lecorps et al., 2021). Despite the potential relevance of brush use data for management, currently there is no commercially available brush that would collect and provide information on the brush use of cattle. Moreover, little is known about how the positioning of the brush in relation to other resources in the environment, and the cow-to-brush ratio, influences brush use. Our aim was to automate data capture of brush use duration within a group, and then use these data to investigate how group size and brush location influences daily brushing behavior.

Material and Methods

A commercially available electronic brush (Luna, Lely Inc., The Netherlands) was equipped with sensors to detect and record events when the brush arm angle was deflected and the motorized rotation function activated. We measured brush use at two locations in a freestall barn: in the feed alley where cows accessed feed and in the back alley where cows accessed the free stalls. We provided one brush to groups of 60, 48, 36, and 24 pregnant lactating cows in a semi-randomized manner, while keeping the stocking density at the lying stalls and at the feed bunk constant. We measured brush use during 2 study replicates. For each replicate, group size, and brush location, a minimum of 2 days of data were submitted for further analysis. For each day, we determined the average brush use per cow and used this as dependent variable in a linear model to investigate the influence of group size, brush location, and replicate.

Results and Discussion

The total time that the brush was used increased with group size (Figure 1), but even at the highest stocking level tested the brush was used during less than 50% of the day. On average across the study, individual cows used the brush 8.5 ± 2 min (mean ± SD) per day; this value is somewhat higher than reported in previous studies (i.e., 2-3 min/day by Mandel et al., 2017 and 5-7 min/day by DeVries et al., 2007). The average brush use per cow was greatest when the cow-to-brush ratio was lowest (24:1) ($F_{1,55}$=10.4, P=0.002). Moreover, cows used the brush more when it was located in the feed alley ($F_{1,55}$=13.4, P<0.001) compared to the back alley, supporting previous results (Mandel et al., 2013). Although different individuals were tested to avoid habituation, overall brush use was lower during the second replicate, which may be due to consistent individual differences in the brush use between cows (Foris et al., 2021). Current industry guidelines suggest a 60 cows/brush ratio but to our knowledge it is not based on any scientific evidence. Our results suggest that individual cows benefit from lower cow-to-brush ratios by increasing the time they spend using the brush compared to higher cow to brush ratios, including the 60:1 treatment. Placing the brush close to the feeding area may increase brush use but more research is needed to determine the impact of having the brush close to the feed resource on social competition at the feed bunk.

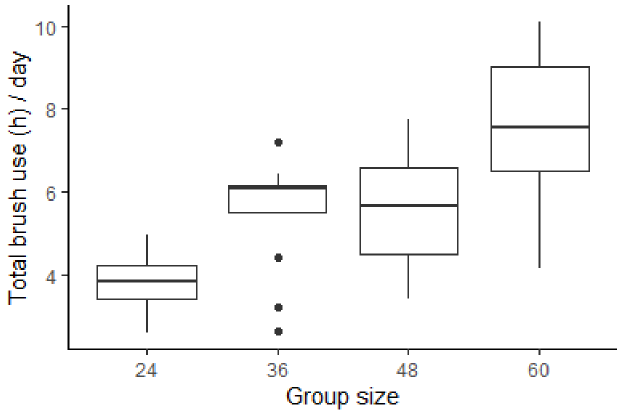

Figure 1. Total daily brush use duration in dairy cow groups of different size. One brush per group was provided and stocking density at lying stalls and feed bunk was kept constant.

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Impact of introducing feed outside of the milking robot on visit frequency and welfare of dairy cows managed in an automatic milking system

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Through TMR feeding methods alone, farms with all-year-round calving patterns often face challenges facilitating the energy requirements of the entire herd; a serious health and welfare concern. There exists a requirement within these systems for individualised supplemental feeding. Within automatic milking systems (AMS), this feeding can be achieved through the milking robot feed station. Factors such as high stocking rates or low free box time may result in lower concentrate consumption than necessary to support the metabolic needs of the cow. Offering concentrate outside of the robot may be an option. However, it is unclear what effect this intervention may have upon the visit frequency of cows within AMS.

This study investigated the effects of provisioning concentrate feed outside the robot, hypothesising that visit frequency would be reduced. Data were obtained from a 48-cow herd newly transferred to an AMS. Cows in treatment group 1 received 80% of their concentrate ration in the robot feed unit and 20% in an out-of-parlour-feeder, whereas treatment group 2 received 20% of their concentrate in the robot and 80% in the out-of-parlour-feeder. Preliminary results indicate that there was no significant difference in average weekly visit frequency between groups in weeks 1-4 ($p>0.05$), nor in total standing time or number of lying bouts between groups in weeks 1-4 ($p>0.05$), or in total lying time in weeks 2-4 ($p>0.05$). This suggests that high-yielding cows may be offered supplemental feed outside of the robot without concern for reduced milking visits, further enhancing the PLF capabilities of AMS.

Faecal cortisol metabolites and behavioural indicators of stress during the transition from conventional to automatic milking in multiparous dairy cows

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Over the last 15 years, Automatic Milking Systems (AMS) have become increasingly popular throughout the world, as they guarantee lower manpower costs while increasing milk yield (Jerram et al., 2020). AMS are also claimed to improve the well-being of farmers and cattle. However, the training for AMS and the effects of the transition from traditional to automatic milking on cattle health and welfare are still a matter of debate. Over the years, several studies have indeed been carried out to evaluate stress responses in herds subjected to voluntary milking with AMS, but results were sometimes discordant. Hypothesizing that the transition would be challenging for multiparous cattle, the aim of this study was to document faecal cortisol metabolites (FCMs), rectal temperature (RT) and behaviour in this dairy category from the installation of AMS to two months after its regular use. Twentynine multiparous Holstein-Friesian cows (3 ± 1 parities) reared on an organic dairy farm in Northern Italy were monitored before the AMS installation, after one month of habituation (i.e., cows could freely enter and eat into the AMS), during the first 3 days of AMS (i.e., cows were forced to enter and were fed and milked into the AMS), after one and two months of regular AMS use. The occurrence of specific behaviours was recorded for each cow using the one-zero sampling method by direct observation while each cow was into the AMS, while RT and faeces were taken shortly afterwards. FCMs were determined by an 11-oxoaetiocholanolone EIA. While RT remained always within the normal range, FCMs showed a significant increase already after the habituation and did not return to baseline levels even after two months ($p<0.001$; Table 1).

Table 1. Concentrations of faecal cortisol metabolites measured on the day of installation of the AMS (T0), after one months of habituation (End), and after one and two months of automatic milking in evaluated cows (n=29).

Time	Mean	Standard Error of Mean
T0	16.81^{b}	2.20
End of habituation	32.25^{a}	3.91
One month automatic milking	40.46^{a}	5.66
Two months automatic milking	32.49^{a}	4.81

Different superscript letters indicate differences with $p<0.05$.

Conversely, the proportion of cows showing tremors and/or freezing ($p<0.001$), kicking ($p<0.05$), and elimination behaviours ($p<0.001$) was maximal during the first day of AMS and significantly decreased over time, and was minimal after two months when all cows entered freely into and ate in the AMS (Table 2).

Table 2. Absolute and relative (in brackets) frequencies of the behavioural variables recorded of cows inside the AMS.

Phase	Time	Eating	Elimination (urination/ defecation)	Tremors and/or freezing	Kicking
Habituation period	T0	5/14 (35.7%)[b]	7/14 (50.0%)[a]	0 (0.0%)	0 (0.0%)
	1 week	18/21 (85.7%)[a]	3/21(14.3%)[b]	0 (0.0%)	0 (0.0%)
	2 weeks	16/18 (88.9%)[a]	3/18 (16.7%)[b]	0 (0.0%)	0 (0.0%)
	3 weeks	14/15 (93.3%)[a]	0/15 (0.0%)[b]	0 (0.0%)	0 (0.0%)
	End	25/27 (92.6%)[a]	2/27 (7.4%)[b]	0 (0.0%)	0 (0.0%)
	time effect *p*-value	<0.001	0.009	-	-
Automatic milking	Day 1 (training)	27/27 (100.0%)[a]	4/27 (14.8%)[a]	9/27 (33.3%)[a]	11/27 (40.7%)[a]
	Day 2 (training)	26/27 (96.3%)[a]	6/27 (22.2%)[a]	4/27 (14.8%)[a]	6/27 (22.2%)[ab]
	Day 3 (training)	25/27 (92.6%)[a]	5/27 (18.5%)[a]	0/27 (0.0%)[b]	4/27 (14.8%)[bc]
	Day 60	26/26 (100.0%)[a]	0/26 (0.0%)[b]	0/26 (0.0%)[b]	1/26 (3.8%)[c]
	time effect *p*-value	0.340	<0.001	<0.001	0.032

Different superscript letters within each column indicate differences with $p<0.05$.

While behaviour seemed to indicate a rapid adaptation to the AMS, FCM concentrations suggested that even after two months the cows maintain some level of distress. This result agrees with previous findings on hair cortisol, which appeared to return to pre AMS levels about 10 months after AMS installation (Jerram et al., 2020). Overall, from our findings it seems that the transition to AMS is challenging for multiparous cows and their health and welfare should be closely monitored for at least two months.

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Accelerometer based monitoring of behaviour of cows with restricted access to pasture compared to confined conditions

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Introduction

Grazing is often seen as beneficial for the wellbeing of dairy cows compared to indoor housing, but animal welfare is still a complex topic in livestock farming. Faecal cortisol metabolites (FCMs) are indicators of adrenocortical activity, which can be used for the assessment of the wellbeing of animals. Monitoring of animal behaviour, particularly of lying and rumination times, is also considered as useful for assessing the health and welfare status. Cows with permanent indoor housing show different behavioural patterns than cows continuously kept on pasture. In this study, two different accelerometer systems were used to classify lying and rumination behaviour of dairy cows in the barn and on pasture. We hypothesised that even restricted access to pasture would alter the time budget of dairy cows.
The objectives of this study were 1) to compare the lying and rumination behaviour of lactating dairy cows with temporary access to pasture to their behaviour in the barn and 2) to gain insights into adrenocortical activity under those changing conditions.

Materials and Methods

The study was conducted at the Teaching and Research Farm of the University of Veterinary Medicine Vienna, Austria. On the farm, approximately 80 Fleckvieh cows are kept in a free-stall barn with cubicles. Ten lactating cows were enrolled in the study, which took place during four non-consecutive weeks throughout the grazing season in 2020. During the measurement periods, the cows were equipped with the following two sensor systems: Data loggers (HOBO Pendant G logger, Onset Computer Corporation, Bourne, MA) were mounted on the animals left hind legs for capturing standing and lying times. SMARTBOW ear-tags (Smartbow GmbH/Zoetis LLC, Weibern, Austria) were permanently tagged to the right ear of each cow to classify behaviour into rumination, standing, lying, inactive, active and high active. The first measurement week took place prior to the first time the cows had access to pasture and served as a reference period (RP). Sensor data was recorded continuously and faecal samples were collected twice daily on five consecutive days to establish individual baseline values for each cow. The second measurement period took place in July (TPjul) and the third as well as the fourth in September (TPsep). Each period consisted of four days a week, on which cows were moved to pasture in the morning for 2-5.5 hours. Climatic conditions were measured in the barn and on pasture throughout the study. FCM were analysed in all faecal samples by using an enzyme immunoassay first described by Palme and Möstl (1997).

Results

For the analysis of daily lying and rumination times, four days had to be excluded due to technical issues and rainy weather conditions. Consequently, data were available for four days of RP, four days of TPjul and five days of TPsep. The average daily lying time (mean ± SD) of the ten study cows was 591 ± 103 min/day throughout the study period. There was a significant difference ($p = 0.006$) between the daily lying times during RP (619 ± 99 min/day) compared to TPjul (548 ± 101 min/day). The mean difference between RP and TPsep (605 ± 97 min/day) was not significant ($p > 0.9$). The average daily rumination time was 510 ± 71 min/day. There was a significant difference ($p = 0.003$) in daily rumination times between RP (545 ± 64 min/day) and TPjul (494 ± 66 min/day) as well as TPsep (496 ± 72 min/day). The medians of the FCM levels were 20 (14 – 23) ng/g in RP, 18 (14 – 26) ng/g in TPjul and 22 (14 – 36) ng/g in TPsep, respectively. The percentage of FCM values that were more than twice as high as the baseline value (calculated for each cow as the median of individual values from the RP), were 3 % in TPjul and 25 % in TPsep. Such high values were seen only in five cows.

Discussion

This study yields evidence that restricted turnout to pasture (small group, few hours/day) alters the time budget of dairy cows significantly in terms of lying and rumination behaviour. The fact that most of the increased FCM levels compared to the RP were found in TPsep suggests that the lower daily lying time in TPjul was no sign of overall decreased animal welfare. The above mentioned increases in FCM levels could only be observed in half of the study animals. Thus, we consider that cows reacted individually to the changing conditions in this study. As there is evidence that heat stress can influence lying times (Cook et al. 2007) and also FCM levels (Rees et al. 2016), we will further analyse correlations of those parameters with the climatic data that was recorded during this study. This could lead to an explanation why lying behaviour was significantly decreased in July but not in September compared to confined conditions. Further studies should investigate sensor data and FCM levels under stressful conditions to investigate correlations in more detail.

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Association of behavior with subclinical ketosis in transition dairy cows

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The objective of this study was to characterize the relationship between behavior and subclinical ketosis (**SCK**) in transition dairy cows. A study was conducted on a commercial dairy farm in Slovakia (2,600 cows; 11,500 kg). A total of 5,090 Holstein dairy cows (1,874 primiparous and 3,216 multiparous) calving from January 2020 until December 2021 were enrolled. Behavior (active, inactive, feeding, rumination) was recorded minutely using an automated monitoring system (Smarttag Neck, Nedap Livestock Management, Groenlo, the Netherlands) from 7 d before calving until 7 d after calving. Cows were monitored for SCK twice within the first 10 DIM using a ketone meter (Precision Xtra, Abbott Laboratories, Abbott Park, IL, USA). Cows with β-hydroxybutyrate (**BHB**) ≥1.2mmol/L in any of the two samples were considered to have SCK and treated orally with 250 mL propylene glycol for 5 d. Cases of retained placenta, metritis, milk fever, mastitis or dislocated abomasum within 30 DIM were also recorded. Cows were categorized into 1 of 3 groups: healthy cows (**HLT**) that had no SCK or any other recorded health problem (n = 3,471); cows with SCK (hyperketonemia, **HYK**) with no other health problems within 30 DIM (n = 1,152); or cows (**HYK+**) that had SCK and one or more health problems (n = 467). Minutely behavior data were summarized by day and comparisons were made between HLT, HYK and HYK+ using the GENLIMIXED procedure in SPSS. Each model contained time relative to calving, parity (primiparous vs. multiparous), SCK status (HLT vs. HYK vs. HYK+), and time * SCK status as fixed effects. All 4 different behavioral traits were affected by SCK status and there was an interaction of time * SCK status (Figure 1). Overall, feeding time was 272 ± 0.4 min/d, 246 ± 0.8 min/d, and 216 ± 1.3 min/d for HLT, HYK, and HYK+, respectively. Rumination time was 388 ± 0.5 min/d, 353 ± 0.9 min/d, and 318 ± 1.4 min/d for HLT, HYK, and HYK+, respectively. Inactive time was 742 ± 0.8 min/d, 809 ± 1.5 min/d, and 876 ± 2.3 min/d for HLT, HYK, and HYK+, respectively. Active time was 18.6 ± 0.1 min/d, 16.4 ± 0.2 min/d, and 15.3 ± 0.3 min/d for HLT, HYK, and HYK+, respectively. There was a more pronounced effect of SCK status on postpartum behavior than on prepartum behavior. These results suggest that behavioral monitoring across the transition period might contribute to identification of SCK and other health problems in primi- and multiparous cows.

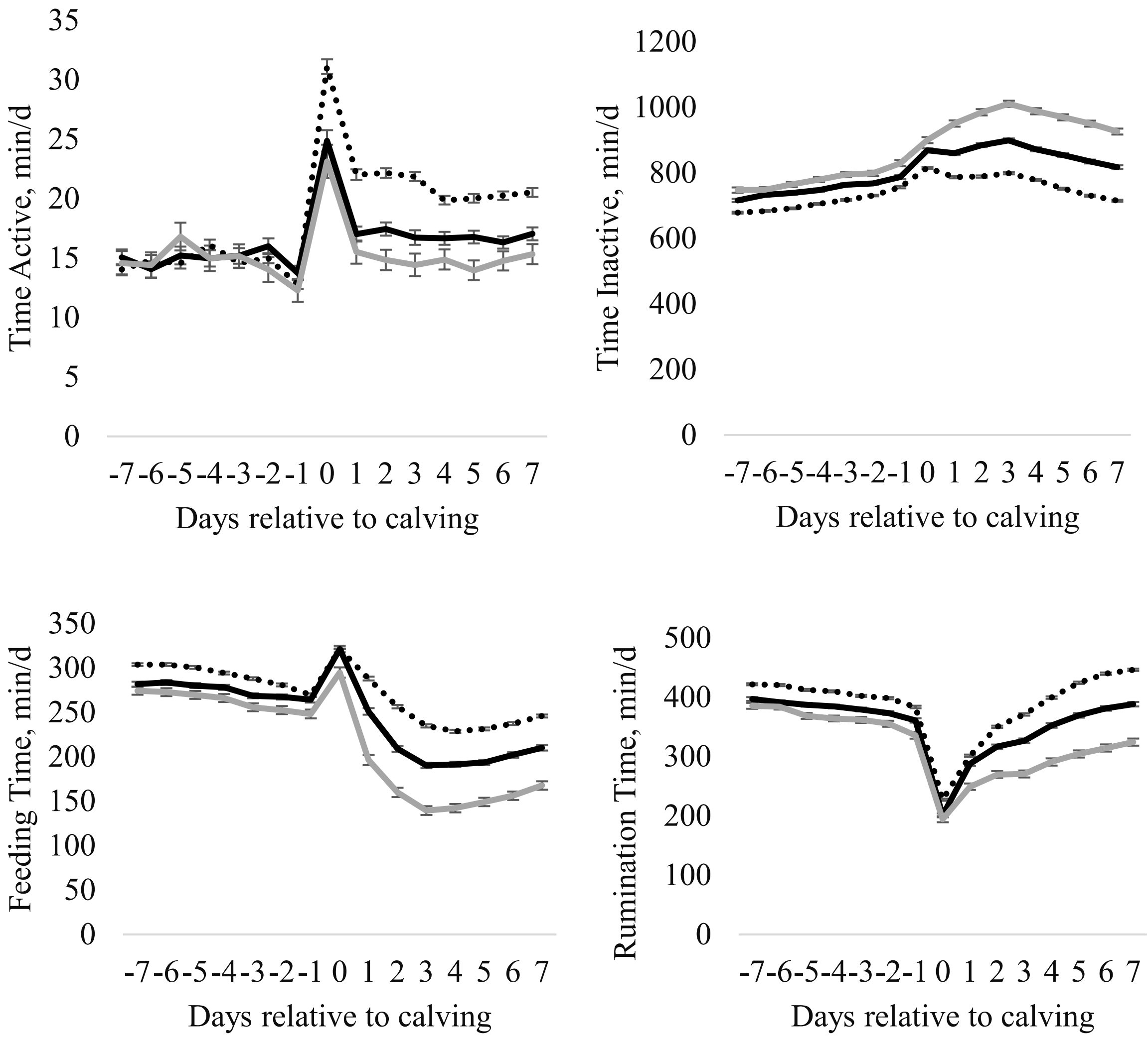

Figure 1. Association of behavior (min/d; time active, time inactive, feeding time, rumination time) with subclinical ketosis (SCK) in transition dairy cows using a neck mounted monitoring system. Cows were categorized into 1 of 3 groups: healthy cows (dotted line) that had no SCK or any other recorded health problem (n = 3,471); cows with SCK (black line) with no other health problems within 30 DIM (n = 1,152); or cows (grey line) that had SCK and one or more health problems (n = 467).

Automatic Milking Systems: Online modules and training

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Automatic Milking Systems (AMS) arrived in Australia in 2001, followed by 13 years of successful AMS R&D through the FutureDairy Project (www.futuredairy.com.au). In 2017 FutureDairy commissioned a series of in-depth interviews with farmers and service providers to better understand the Australian AMS experience and to develop a training and extension strategy for AMS. In response, in 2018 the Australian dairy industry established Milking Edge (https://bit.ly/MilkingEdgeProject), a project run by the NSW Department of Primary Industries together with Dairy Australia and DeLaval, that ended in April 2022. The overall objective was to 'support industry to consider, invest and operate AMS successfully'. One of the aims of this project was to generate AMS training for farmers, farm staff and service providers wishing to expand their knowledge and understanding of the technology and its integration in dairy farming systems.

The project team, in collaboration with key industry stakeholders, developed a series of eight online information modules:

1. *AMS generalities*: history, progression and adoption of the technology, the key concepts and major differences with conventional milking systems.
2. *Reproductive performance*: main management practices for reproduction in an AMS farm including heat detection, mating and breeding.
3. *Incentive management*: insight into all factors that can be managed on-farm to encourage voluntary cow traffic in AMS (either pasture-based or indoors).
4. *Milk quality and animal health*: factors that impact milk quality and herd health including cleaning of the dairy and equipment, cooling, monitoring through the use of sensors, and some key examples of what farmers are achieving.
5. *Labour and farm routines*: principles behind labour and farm routines, including those tasks that do not change much, those that change considerably, activities that are no longer required, and the new and different tasks. It describes what a day might look like and provides some AMS farm case study examples.
6. *Infrastructure and layout*: describes the processes and options involved in setting up an AMS farm whether this is from a greenfield site or a retrofit of an existing dairy, both pasture-based and indoors. It includes farm layout, laneways, gates, robot area and treatment facilities.
7. *Assessing system performance*: what to monitor on an AMS farm (cow and robot-related KPIs) with insights into targets and factors that impact the KPIs.
8. *Economic performance*: principles behind economic and financial performance, including answers to key questions and common perceptions related to productivity and profitability.

These information modules are now hosted online on Dairy Australia's online learning platform, Enlight, a web-based learning management system that can be accessed anytime on a computer, tablet or mobile. There is no cost associated with accessing them, and those interested can choose to complete one or more modules to suit their individual needs or preference. Each module takes around one hour to complete, and participants can start and stop them at any time and revisit them as many times as they want. The individual online information modules were released between September 2019 and May 2021 and can be accessed here: https://bit.ly/milkingedgemodules.

In addition to the self-paced online modules, the project also created and facilitated a full AMS Training Course. The course ran over 10 weeks and involved taking participants through all eight modules, coupled with Q & A sessions featuring AMS farmers and service provider speakers, as well as practical exercises to compliment the theoretical learning experience. In 2021, three courses were run online due to the COVID-19 pandemic, starting in March, July and September. The aim in the future is for these to be delivered either face-to-face or in a blended delivery model. A certificate of completion was issued to those who successfully completed all the requirements of the course. A short promo of the training course can be found here: https://bit.ly/MilkingEdgeTraining.

Uptake of both the online modules and the training course has been much greater than originally expected. By April 2022, a total of 233 people had registered in the learning management system and 181 (78%) completed an enrolment form that enabled them to start accessing individual modules. Amongst participants, 23% were farmers, 10% farm staff, 42% service providers, 21% researchers/students and 5% other. The majority (76%) were from Australia, but there were people from 12 countries.

By April 2022, a total of 126 participants (70% of those that enrolled) had done at least one module. Of those, 63 people (35%) had completed one module, whereas 30 (17%) had completed all eight modules. *AMS Generalities* had the greatest uptake (121 participants – 96% of those that enrolled), whereas *Assessing system performance* and *Economic performance* have had the lowest uptake (33 participants – 26% of those that enrolled).

Feedback from the modules has been very positive. Most participants (76%) felt their level of knowledge at the completion of the learning module was either Good or Extensive [Highest module = *Labour and farm routines* (85%); Lowest module = *AMS Generalities* (63%)]; 94% either agreed or strongly agreed that the course content was relevant and the length appropriate given the information provided [Highest module = *Labour and farm routines* (100%); Lowest module = *Incentive management* (87%)]; and 90% mentioned the module was either adequate or extremely engaging [Highest module = *Assessing system performance* (97%); Lowest module = *Infrastructure and layout* (84%)]. Participants also made comments such as '*engaging in its presentation style, modern, clear and concise*', '*information delivered in a simple yet detailed manner*', '*thoroughly informative*' and '*concepts are clearly explained step by step*'.

Recent surveys and anecdotal evidence collected in Australia indicate a strong level of interest and potential adoption of AMS into the future. Initiatives like Milking Edge are key as they provide independent support and assistance to farmers and service providers and enable better decision making around the consideration, purchase and implementation of AMS. The AMS online information modules and training are an excellent resource for farmers considering investing in AMS, those looking at working on AMS farms, those that work with farmers that have invested in AMS or those interested in technology.

Improvement of the electrical conductivity measurement system of milk that compensates for temperature effect using neural network for inline mastitis detection devices: A preliminary study

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Mastitis is one of the most important diseases negatively affecting cost, production and profit in dairy farming. Milk electrical conductivity (EC), the most commonly used detection tool for mastitis, is increased during subclinical mastitis (SCM) and intramammary infection (IMI). This increase basically results from an increase in sodium and chloride concentrations. However, electrical conductivity can be affected by non-mastitis-related variations like temperature in particular. The mobility of ions increases when the temperature increases hence the conductivity rises. Especially in winter conditions, the milk coming out of the udder during milking cools rapidly until it reaches the conductivity measurement sensor. Therefore, while measuring the conductivity of milk, the conductivity at the reference temperature should be calculated by compensating the effect of temperature on conductivity.

We aimed that in this preliminary study electrical conductivity measurement provides an accurate and stable regardless of temperature effect using artificial neural networks, ANN. In this study, the ANN was trained with 1500 samples, 75 milk samples with 40-20 degrees Celsius (°C) range. The ANN model was tested with 100 different milk samples and the conductivity values at the reference temperature were determined with an average error of EC 4.6%. The lowest margin of average error (3.9%) was in the milk samples between 25-30 °C, the highest (5.4%) was in the milk samples between 20-25 °C.

Comparison of clustering analysis methods in assessment of productivity parameters in dairy cows milked by Automatic Milking Systems

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The introduction of automated milking systems (AMS), or milking robots, in the early 1990s represented one of the major headways in dairy farming techniques. During each milking, automatic sensors allow monitoring of the udder health and the milk quality by providing detailed information about each cow, which was not easily obtained with previous conventional systems (Jacobs & Siegford, 2012). However, the extensive collection of data through the AMS has led to an exponentially growing amount of data, and the amount of information available is becoming too much to process. Data integration is necessary to use these data to their fullest potential, and to make the resulting information accessible to the farmers (Cockburn, 2020).
Machine Learning (ML) algorithms present an approach to analyzing such datasets. ML approaches include Cluster Analysis that encompasses different methods and algorithms for grouping observations of similar kinds into respective categories (Frades & Matthiesen, 2010). The concept of similarity in these algorithms include two properties: the homogeneity amongst objects belonging to the same cluster and the heterogeneity amongst objects of different clusters (Everitt et al., 2011). These properties are not intrinsic to the data, they depend on how the similarity and dissimilarity are mathematically defined. The results of these different algorithms tend to be the same if the structure of the data is linear and well-defined. However, if it gets more complex, different algorithms will be likely to highlight diverse aspects of the data and, thus, to outcome a different result.
The present work compares different clustering algorithms to analyze the milk production in an AMS farm over four lactation periods. The main goal is to find a clustering structure that is representative of the information on the milking production over the time. The following variables for each lactation period are used in the analysis: Average daily milk production (kg/day), Separated milk (%), Average milking frequency (milkings/day), Average milking Rate (kg/minute), Refusals by milking, Errors/100 milkings, Days in lactation, Previous dry days, Average protein, fat and lactose composition (%). The first lactation period has 190 observations, the second has 109, the third has 52 and the fourth has 30. The analysis is performed with the R Software (R Core Team, 2020) with seed 1111. The following clustering algorithms are compared: (i) Hierarchical Agglomerative Clustering with Ward and Ward D2 closeness methods; (ii) K-means and Partitioning Around Medoids (PAM), (iii) Self-Organizing Maps (SOM) and (iv) Fuzzy K-means. The number of clusters and the other hyperparameters of the algorithms are defined based on two clustering internal criteria, the Silhouette and the Dunn indexes. The Silhouette Index (Rousseeuw, 1987) ranges from -1 to +1 and it combines the cohesion and the separation of each data point. The cohesion is calculated as the mean distance of the data point to all other points of the same cluster. The separation is the distance of the data point to all points of the closest cluster. The Dunn Index (Dunn, 1974) ranges from zero to infinity and considers the relation between the smallest distance between the observation and the observations that belong to other clusters and the largest intra-cluster distances. As the two criteria underline different aspects of the clusters, usually they do not give the same result. Therefore, the first step in the proposed analysis is to identify the number of clusters (k) that have the best values for both indexes. After that, to

choose one amongst the select solutions, the plots of the silhouette index of all observations are analyzed. The higher the silhouette index, the better the observations are clustered. Negative indexes indicate that the observation is miss-classified. It may be due to the low similarity with its own cluster or due to the close proximity to other clusters. Figure 02 exemplifies these plots for K-means with *k = 7* and PAM with k = 6. In this case, the K-means with *k = 7* is chosen because it has less observations with negative silhouette values.

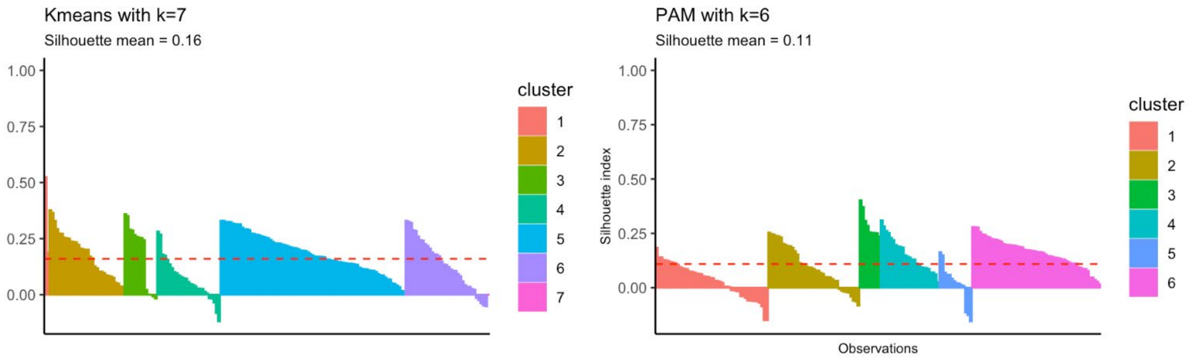

Figure 02: Silhouette index of each observation using K-means with 7 clusters and PAM with 6 clusters. Each bar is the silhouette index of an observation.

This procedure was performed for each of the compared algorithms with data of the first lactation period. The following clustering solutions were selected: hierarchical clustering with 11 clusters (silhouette = 0.10 and Dunn = 0.14), K-means with 7 clusters (silhouette = 0.086 and Dunn = 0.15), SOM with 8 clusters (silhouette = 0.12 and Dunn = 0.19) and Fuzzy K-means with 2 clusters (silhouette = 0.15 and Dunn = 0.08). As the goal of the analysis is to verify the clusters structure over time with focus on milk production, the final solution to be chosen will also depend on the distribution of the milk production variable in each cluster over all lactation periods. This analysis is in progress.

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Modelling the impact of a software module for gradually reducing milk yield before dry-off on udder health and economics

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Dry-cow management is an important aspect in the control of mastitis on dairy farms. A high milk production at dry-off increases the risk of an intramammary infection (IMI) during the dry period. Common methods of cessation of lactation, such as a reduction of feed or milking frequency have shown to be beneficial in reducing IMI after dry-off. However, these methods are time consuming. Current technology does allow for more advanced methods. Therefore, the aim of this study is to compare the effects of automated milk reduction (software module[1]) before dry-off with common methods of cessation of lactation as well as with abrupt dry-off.

An existing bio-economic model on the economic impact of milk yield at dry-off was adapted to include the automated milk yield reduction software. The model stochastically simulates udder health related to milk yield during a period of 10 days before dry-off until the next lactation. Two IMI probabilities were modelled: the probability of IMI at the moment of dry-off (which is independent on the milk yield at dry-off) and the probability of IMI during the dry period (which is dependent on the milk yield at dry-off) (Figure 1). When IMI at dry-off did not cure, or new IMI during the dry period occurred, there was an IMI at calving that could lead to subclinical or clinical mastitis. Costs and benefits associated with all interventions and occurrence of mastitis after the dry period were modelled. Input values were based on scientific literature, farm data and expert opinion. Simulation of the dry-off methods includes abrupt cessation, software module, gradual milking and gradual feeding. Milk yield reduction was modelled for each method. Net costs were calculated by subtracting milk revenue and reduced feed costs during the 10-day period before dry-off, from costs of applying each gradual milk cessation method, costs of dry-off treatment and costs of mastitis during the subsequent lactation (Table 1). In total 10.000 iterations were used for each method of gradual cessation.

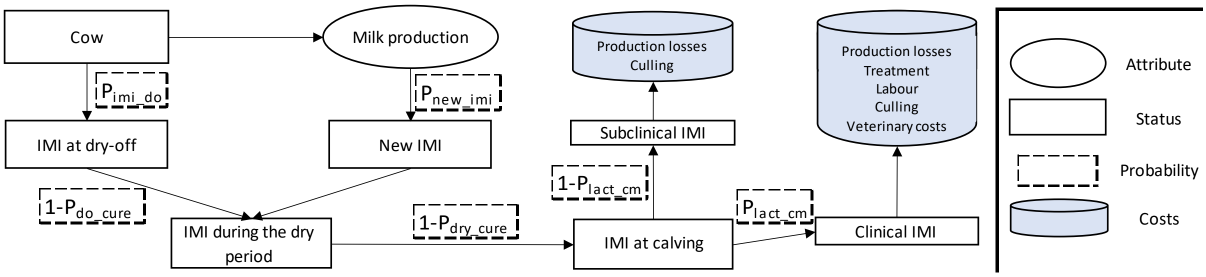

Figure 1. Overview of the bio-economic simulation model, with P_{imi_do} = Probability of IMI at dry-off, P_{new_imi} = probability of a new IMI during the dry period, P_{do_cure} = probability of cure IMI at dry-off, P_{dry_cure} = probability of cure of IMI during the dry period, P_{lact_cm} = probability of IMI at calving to be clinical

[1] AutoDry: GEA Farm Technologies GmbH, Bönen, Germany

Table 1. Overview of physiological and economic results, including 0,05 and 0,95 percentiles

Item	Abrupt cessation	Software module	Gradual milking	Gradual feeding
Milk production at dry-off (kg/d)	20.6 (17.7; 23.8)	12.8 (10.8; 15.0)	12.4 (10.7; 14.4)	12.4 (10.7; 14.4)
Total milk production in 10-day gradual period (kg)	209 (179; 242)	162 (138; 189)	142 (122; 165)	141 (121; 164)
Cows with new IMI (%)	23.1	18.6	18.4	18.4
Cows with IMI at calving (%)	24.9	17.4	17.6	17.5
Revenue				
Milk revenue before dry-off (€)	75 (64; 87)	58 (50; 68)	51 (44; 59)	51 (44; 59)
Reduced feed costs due to IMI (€)	18 (0; 175)	13 (0; 162)	13 (0; 164)	13 (0; 163)
Costs				
Feed at gradual period (€)	29 (27; 31)	25 (23; 27)	23 (22; 25)	17 (17; 17)
Costs of ITS/antibiotics at dry-off (€)	14 (12; 26)	14 (12; 26)	14 (12; 26)	14 (12; 26)
Labour at dry-off (€)	0 (0; 0)	0 (0; 0)	37 (37; 37)	73 (73; 73)
IMI in dry period[2] (€)	1.2 (0; 0)	1.0 (0; 0)	1.0 (0; 0)	1.0 (0; 0)
IMI in new lactation (€)	83 (0; 500)	57 (0; 479)	59 (0; 484)	58 (0; 482)
Other costs[1] (€)	0 (0; 0)	3 (3; 3)	2 (2; 2)	2 (2; 2)
Net costs (€)	35 (-42; 305)	29 (-25; 284)	72 (17; 328)	102 (47; 358)

[1]Costs of software module (AutoDry) and fences.

[2]Costs of occurrence were found at the 0.99 percentile.

Simulation results are separated in physiological and economics output values and provided in Table 1. Total milk reduction in the gradual period was 8.3 kg for the software module and 8.7 kg for both gradual milking and gradual feeding. Lowest average net costs per cow were found for the software module. The difference is mainly caused by the costs for IMI in the new lactation, costs of labour for gradual milking and gradual feeding and the milk revenue in the gradual period. The sensitivity analysis showed that increased probability of infection, reducing milk price to €0.25 and reduced yearly milk yield by 2000 L increased average net costs. In all scenarios, except for reduced infection rate, average net costs were lower for the software module compared to abrupt cessation.

Previous studies on the economics of dry-off often looked only at costs, therefore the inclusion of revenue in this study makes it difficult to compare results. Furthermore, cows with IMI at dry-off were treated with antimicrobials, resulting in a small addition of IMI at dry-off on the total IMI during the dry period. New IMI values of this study are in line with previous conducted studies, however, some studies found higher IMI values when milk yield was high at dry-off, possibly indicating that the linear function used in this study produces too low values. Also, inclusion of the combination of gradual milking and gradual feeding would have been an interesting addition to this study. The results show that the software module is economically a more interesting option compared to other methods of drying-off, while reaching similar physiological results as the other gradual methods.

A decision-support system for automatic milking systems

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Introduction

There are multiple variables that impact the physical and economic performance of automatic milking systems (**AMS**) (Tremblay et al., 2016). Despite AMS being available for almost 30 years, no decision-support system (**DSS**) has been developed to assist farmers with planning or management decision-making. A DSS integrating key biological processes with farm economics could provide new ways of understanding current performance, identifying potential areas for improvement, boost confidence in decision-making and assist with planning to minimise risk. This study presents the development and evaluation of the Integrated Management Model (**IMM**), the world-first DSS designed for pasture-based AMS.

Material and Methods

This IMM was developed as part of Milking Edge, a project run by the NSW Department of Primary Industries in partnership with Dairy Australia and DeLaval to support the successful adoption of AMS in Australia. It is freely available and can be accessed online at https://bit.ly/MilkingEdgeAMSTool. This DSS comprises a web-based user interface (Figure 1) that is backed up by a series of empirically determined predictive equations derived from the main drivers of productivity and profitability identified for pasture-based AMS (Gargiulo et al., 2020). The IMM is also based on stochastic simulations and optimisation modelling. Equations and models included were developed and evaluated using a novel dairy farm dataset available for the years 2015 to 2020. Data comprised annual physical and economic variables collected from 18 AMS farms across the main Australian dairy regions and monthly physical variables from 28 AMS farms located across Australia, Ireland, New Zealand, Chile and Argentina. Farms used for the models were pasture-based and milked between 120 and 360 cows. Following the development phase, 11 AMS farmers tested the DSS and provided feedback on the usefulness and ease of use with a technology acceptance model framework (Davis, 1989). The IMM's usage was also evaluated during the first six months since its launch (August 2021 to January 2022) by embedding a Google analytics tag into the website.

Results and Discussion

The IMM can be used by dairy farmers to simulate physical scenarios and optimise the performance of AMS. The evaluation of this DSS showed that the accuracy of the equations and simulations to predict physical variables, such as milk harvested per robot or milking frequency per cow, was relatively high (2-14% differences between observed and predicted values). For farms with herd sizes between 120 and 360 cows, the DSS can determine with confidence ($P < 0.05$) the relative changes in profitability when key physical variables change. On average, AMS farmers rated the IMM four out of five points in usefulness and ease of use. The most valuable aspects of the DSS were the ability to perform optimisation simulations and compare modelled scenarios against commercial farm data. The website traffic analytics indicated that 486 users across 31 countries had utilised the tool in the first six months since its launch. Most users accessed through a desktop device (73%) and were located across Australia, the United States, the Netherlands, Germany and Canada (81%).

Figure 1. Overview tab of the AMS Integrated Management Model (IMM)

Conclusions

The IMM is a world-first interactive, user-friendly DSS developed for pasture-based farmers operating or considering investing in AMS. It can be used to plan and assess performance by allowing the simulation of physical and economic scenarios. It can also compare predictions against commercial farm data. Since its launch, it has been widely utilised across multiple countries. Future work should focus on expanding the databases with more farms of diverse characteristics (e.g., barn systems), developing new models to improve predictions (e.g., mechanistic or machine learning) and enhancing the experience for mobile users.

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Detection of the change in lying and standing behaviors in pregnant cows with vaginal pressure sensor

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Introduction:

Calving is the most complex event that occurs routinely on dairy farms and highly affects a cow's physiological state. The health and welfare of both cows and calves must be ensured for profitable and sustainable livestock farming. For this reason, the estimation of calving time is extremely important for herd management in dairy farms. The aim of this study; it is the detection of lying and standing behaviors that occur close to calving in the prepartum period with the vaginal pressure sensor.

Material-Methods:

In this study, an intravaginal device was placed in a pregnant Holstein cow after laboratory tests were completed to determine the accuracy of the sensors. With this device; vaginal pressure data were recorded regularly for 5 days. Recordings were taken with the camera system to verify the sensor data and changes in animal behavior. By comparing the data with the camera recordings, the activity parameters (lying time, standing time, etc.) were created.

Results:

In the analysis of determining the behavior of lying / standing according to the pressure, the size of the area that stands below the line of vaginal pressure was 0.998, the specificity value was 99.57%, the sensitivity value was 98.65%, and the cut-off point was 937.9 ($p < 0.001$). While the cow is lying down, an increase of approximately 30-40 mbar has been observed according to the pressure data measured when the cow is standing. According to the data of the pressure sensor; lying time, standing time, lying frequency, and lying bouts could be determined. In these results, it was determined that there was a 38% increase in standing behavior, 45% decrease in lying time, 21% decrease in lying bouts and 87.5% increase in the frequency of lying on the calving day compared to the previous days.

Conclusion:

As a result of the analysis, regular data flow was provided from the sensors designed intravaginally without data loss. It can be said that the classification made by the ROC curve method is highly compatible with the real situation. By using vaginal pressure data it has been observed that important warning systems can be created to determine the calving time. It is important to carry out a more comprehensive study in determining the time of calving with these sensor technologies in terms of data accuracy.

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Development of a thermoregulatory model for predicting cow physiological responses under various thermal environments

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Introduction

When a dairy cow is exposed to temperatures that exceed its thermal comfort temperature and it has to do a lot of effort or even cannot dissipate enough heat to maintain her body thermal balance it can get in a state called heat stress. The thermoregulatory mechanisms of dairy cows for losing heat consist of three main routes; sensible heat loss from the coat surface to the environment, evaporative heat loss from the skin surface and respiratory heat loss. When heat production cannot be balanced by heat loss, the remaining heat is stored in the body resulting in an increased body temperature. A higher body temperature will result in a higher sensible heat loss by the increase in temperature difference between the skin surface and the environment. However, an increase in body temperature will negatively affect health and welfare of dairy cows. A model that could predict the heat balance under different thermal conditions would be very beneficial to predict and to prevent heat stress in dairy cows. The objectives of this study are to develop a dynamic thermoregulatory model to predict the temperatures of body core, skin and coat of dairy cows by integrating and improving the equations from the previous studies. The model was evaluated by comparing the predicted values with the measured results from climate-controlled respiration chambers.

Materials and methods

The model is based on the energy balance equations at body core, skin and coat nodes. At the body core, the heat is produced by metabolism (HP, W), and the heat is lost via respiration and conduction to skin. The rest of the core energy is stored and causes the core temperature to rise. The energy balance equation at the body core node is:

$$d(M_b c_{pb} T_b)/dt = HP - A_s\,(q''_{resp} + q''_{b\_s})$$

The energy balance equation at the skin node is expressed as:

$$d(M_s c_{ps} T_s)/dt = A_s\,(q''_{b\_s} - q''_{s\_c} - q''_{evap})$$

The energy balance of the coat layer assumes that the heat stored in the coat is small and could be neglected:

$$0 = q''_{s\_c} - q''_{cv} - q''_{lw}$$

The mass of the skin segment (M_s, kg) is calculated according to Smith and Baldwin (1974). Coat mass is ignored. The heat capacity of the body core segment and skin segment is assumed to be the same as 3472 J kg^{-1} °C^{-1}. The daily heat production is calculated according to the equation from CIGR (2002) with correction of air temperature:

$$HP = 5.6 \times M^{0.75} + 22 \times Y_m + 1.6 \times 10^{-5} \times D_p + 4 \times (20 - T_a)$$

where M is the cow body mass, kg; Y_m is milk yield, kg/d; D_p is pregnant days.

The experimental data was from the study by Zhou et al. (2022a) conducted in the climate-controlled respiration chambers at Wageningen University. Heat production was recorded every 15-min intervals. Rectal temperature, skin temperature, coat temperature, respiration rate, sensible and latent heat losses were collected three times a day at 0600, 1000 and 1800 (Zhou et al., 2022b). In totally, there were 456 measurements. From each treatment, one cow was randomly selected for testing the model (comprising 26% of the measurements), and the remaining cows were used for training the model (comprising 74% of the measurements).

Results

The tissue resistance ($r_t, m^2\,°\mathrm{C}\,W^{-1}$), sweating rate ($SW, J\,g^{-1}$), respiration rate ($RR, breath\,min^{-1}$), tidal volume ($V_t, m^3\,breath^{-1}$) and exhaled air temperature (T_{ex}, °C) were fitted using training data:

$r_t = -0.005\,T_s + 0.195$

$SW = 0.312\,e^{0.173T_s}$

$\mathrm{RR} = 1.5 \times 10^{-5}\,e^{0.41T_s} + 21$

$V_t = 0.0591\,RR^{-0.674}$

$T_{ex} = 0.50T_b + 0.21T_s + 9.54$

For the testing dataset, the mean of the predicted body core temperature was 0.11°C higher compared to the observed temperature and the RMSE was 0.30°C. The RMSE was 1.2°C for skin temperature. The model was likely to overestimate the body core temperature after longer exposure to warm conditions and the skin temperature could be predicted with higher accuracy when the ambient temperature was getting higher.

Conclusion

In this study, a thermoregulatory model was constructed to predict the dynamic change of body and skin temperatures under various conditions with relatively high accuracy.

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Development of Lying Behavioral Classification Using a Self-Developed Movement Detection Sensor for Dairy Cows in Tropical Country

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<u>Introduction</u>

One of the most significant behaviors of the dairy cow is lying. It's a useful indicator since the difference in lying behavior could be related to health status, reproduction, animal welfare, or farm management. Several technologies have also been imported and deployed in Thailand. But, small dairy farms (the majority of the Thai dairy farms) cannot afford to spend much investment. Furthermore, the development process influences the performance of implemented technology, such as the difference in device configuration, the position of attached devices, and the difference in pre-processing step (Riaboff et al., 2019). Moreover, environmental factors, as well as farm management parameters, may influence the manifestation of cow behaviors (Deming et al., 2013). As a result, technology should be appropriate for each type of dairy farm in terms of functionality, cost, and performance. Our research aims to develop a cow behavioral classification system utilizing a self-developed 3-axis accelerometer and gyroscope and apply it on Thai dairy farms.

<u>Material and Method</u>

The study included ten dairy cows (75 - 87.5 percent Holstein-Friesian) maintained in an experiment barn between July and December 2021. The Institutional Animal Care and Use Committee (IACUC) report number 2031047 approved all procedures. Acceleration and rotational velocity from cow movement were detected (with 1 Hz) by a 3-axis accelerometer and gyroscope combination sensor and transmitted through LORA signal by the transmission module to cloud database servers. Professional observers classified all movement data using Closed Circuit Television (CCTV) to distinguish between lying and non-lying. Several techniques were used to reduce noise and incorrect timestamps during the data preparation process. For the feature extraction procedure, the dynamic (magnitude) of movement data was created as a feature in the model construction. Furthermore, the resampling method was commonly utilized for window generation to create computed values from each parameter. Lying classification model development (Figure 1) consists of training, validation, and prediction phases. The training phase aims to build the classification model utilizing movement data and label data from observation. In this study, seven supervised

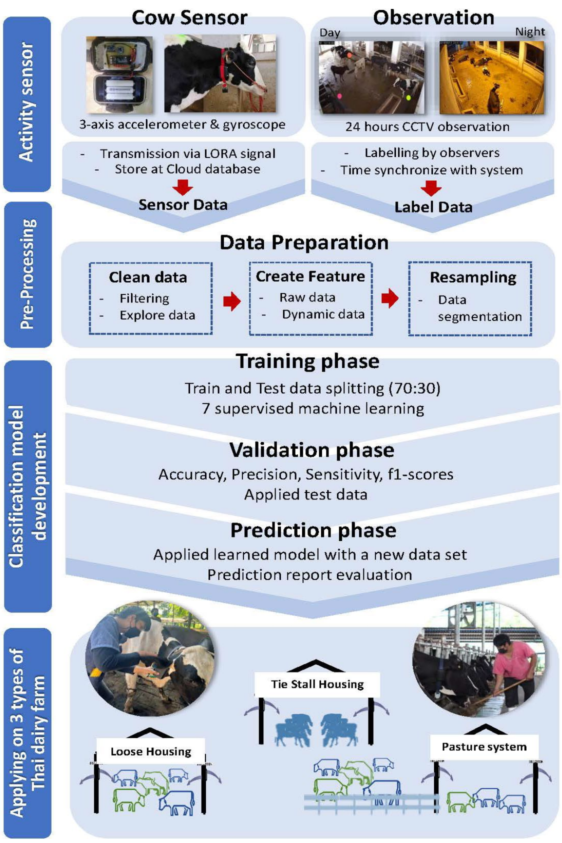

Figure 1: Framework of classification model development

machine learnings were used to develop classification models: Logistic Regression, Linear Discriminant Analysis, K-Nearest Neighbors, Decision Tree Classifier, Naive Bayes Classifier, Support Vector Machine, and Random Forest Classifier. In the validation phase, an evaluation matrix consisting of accuracy, sensitivity, precision, and f1-scores, was applied to evaluate the model's performance. During the prediction phase, monitoring data (new dataset) were applied to the learned model, and then the result was evaluated via an evaluation matrix with a set of monitoring data. The selected models were tuned by hyperparameter and tested by using 10-fold cross-validation.

Result and Discussion

It was discovered that Random Forest Classification (RF), Decision Tree Classification (CART), and K-Nearest Neighbors (KNN) were the top three models which produced the highest accuracy score with results of 0.94, 0.91, and 0.90, respectively. The accuracy score of the model was reduced when the model was applied with monitoring data (Figure 2), according to the results of the performance comparison of Random Forest Classification (RF) between testing data and monitoring data. When the model's performance in each feature and window on testing and monitoring data was compared, it was discovered that the dynamic features (0.94, 0.90) could yield a greater score than the raw data using (0.87, 0.85). Furthermore, it was discovered that the range of data (windows) of 1 minute was the best data interval that did not affect the model's performance (Figure 2). Furthermore, the model was able to identify the cattle lying behavior of monitoring data similarly to the label data and calculate lying duration (LD) in each required time window (2 hrs. intervals were applied in this study) as demonstrated (Figure 3), which revealed that LD, calculated from the model prediction, was clearly decreasing during estrus (estrus period was indicated by estrus observation score and confirmed by Ultrasonography). Furthermore, this model will be applied to three types of Thai dairy farm management to improve the system's suitability for the differences in each farm's environment.

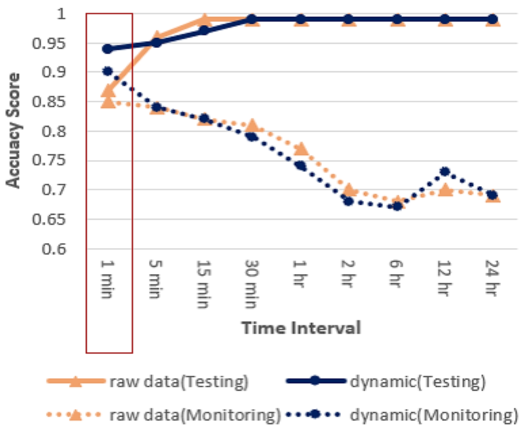

Figure 2: Comparison of accuracy, using raw data (Triangle marker) and dynamic feature (Circle marker) by time interval, compared between testing data (Solid line) and monitoring data (Dash line).

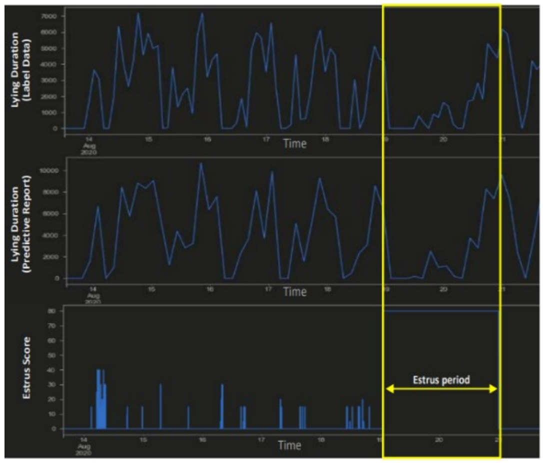

Figure 3: Lying duration, calculated from label data and prediction from the classification model in the period of estrus (yellow box).

Acknowledgment

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Effects of hydroponically sprouted cereal grains on apparent nutrient digestibly, production, and enteric methane emission in lactating dairy cattle

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Introduction

The increasing negative influence of abiotic factors on crop production coupled with the fragility of the global animal feed supply chain accentuates the importance of investigating hydroponically sprouted cereal grains (HG) for implementation in the dairy industry. Recent technological advancements in the local chain agricultural technology sector have produced automated systems that overcome traditional pitfalls of hydroponic fodder production while further reducing the environmental footprint of the practice (Jenkins & Diaz, 2021; Newell et al., 2021). With significantly improved nutrient composition when compared to typical forages, research investigating the effects of HG produced on the automated HydroGreen vertical farming (GLS808, HydroGreen Inc., Sioux Falls, SD, USA) system in lactation dairy cattle is warranted.

Methods

Jersey cattle (n = 344) averaging 108 days in milk (DIM) were randomly assigned to one of two pens in a commercial dairy setting. Treatment pens (n = 2) were balanced for days in milk (DIM), milk production, milk components, and age to ensure uniformity throughout the experiment. Dietary treatments consisted of a control and a treatment group (15 % HG in a DM basis) which were randomly assigned and delivered continuously for an eight-week comparison period; diets were balanced for metabolizable energy, neutral detergent fiber, and crude protein content (Table 1). Throughout the comparison period multiple metrics were recorded to investigate the inclusion of HG on lactating dairy cattle nutrient digestion, milk production, milk components, and enteric methane emission. Nutrient digestibility was assessed through weekly sampling evaluating total-tract nutrient digestibly following previously published commercial protocols (Schalla et al., 2012). Production was evaluated through daily milk weights and weekly milk composition sampling on an individual animal basis (M6700, GEA, Düsseldorf, Germany). Enteric methane emission was assessed through an open path laser methane sensor following previously published protocols (LMmBE, Tokyo Gas Engineering Solutions, Tokyo, Japan) (Sorg, 2022).

Results

Multiple variables measured in the experiment indicated positive and highly statistically significantly changes with the inclusion of HG (Table 2). On a percentage basis, enteric methane mission was estimated to reduce 24% when corrected for energy corrected milk (ECM) production along with 5% improvements in feed efficiency. Likely resulting from increased nutrient bioavailability, striking reductions in methane flux coupled with valuable increases in energy corrected milk production were reported. Results highlight the potential value and production advantage of HG generated on novel local chain agricultural technology solutions.

Table 1. Nutrient composition of total mixed treatment diet (HG included) and control diet along with hydroponically sprouted cereal grain product (HG)

	Treatment	Control	HG
		(% of DM)	
Dry Matter, %	46.5	47.8	22.4
Crude Protein	17.5	17.4	15.7
Neutral Detergent Fiber	27.6	27.6	24.3
Acid Detergent Fiber	14.6	14.5	13.2
WSC*	9.0	7.9	49.2
Net Energy of Lactation**	6.8	6.8	7.7

*Water Soluble Carbohydrates, **MJ/kg

Table 2. Statistical analysis of nutrient digestion, milk production, milk components, feed efficiency, and enteric methane emission flux (CH_4).

	Treatment	Control	SEM	DF	Contrast	p-value	Unit
OM Digestibility	66.2	66.9	1.2	24	-0.8	0.678	% OM
NDF Digestibility	45.8	41.7	1.4	24	4.1	0.044	% NDF
DM Intake	24.1	24.4	0.11	62	0.3	0.065	kg
Milk	36.6	35.7	0.06	20470	0.9	0.000	kg
Fat	1.88	1.80	0.01	1248	0.08	0.000	kg
Protein	1.36	1.32	0.01	1248	0.08	0.000	kg
ECM	46.7	45.1	0.06	20470	1.60	0.000	kg
Feed Efficiency	1.94	1.85	0.01	62	0.09	0.032	ECM kg^{-1}
CH_4 Flux	357	454	2	20182	-97	0.000	g day^{-1}

SEM = Standard error of the mean (SE), DF = degrees of freedom.

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Exploring machine learning to identify key variables in automatic milking systems

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Introduction

Improving efficiency in areas such as pasture utilization, labor efficiency and robot productivity in pasture-based automatic milking systems (AMS) is key to improving the profitability of these systems, which could then increase the interest and uptake of this technology (Gargiulo et al., 2020). Improvements in both the average time spent in the AMS and the number of successful milkings per cow per day has been associated with increased milk production per robot per day, however, those variables tend to be inversely related (Tremblay et al., 2016). The objective of this study was to identify the physical variables that have the greatest impact on robot productivity of pasture-based AMS.

Materials and methods

This research was part of Milking Edge, an Australian dairy industry project by NSW Department of Primary Industries, Dairy Australia and DeLaval supporting AMS adoption. A dataset collected between 2019 and 2021 containing monthly physical information from 12 commercial pasture-based AMS farms from Australia and New Zealand was used in this study. The variables selected for the analysis were milking time (h/robot.d), milk flow (kg/min), time in robot (min/milking.cow), days in milk (d), intake ration (kg/d), herd milking frequency (milkings/cow.d), calving system and the number of pasture allocations. Robot productivity was categorized, according to the monthly average milk harvested per robot per day, as belonging to either high productivity (≥ percentile 75) or low productivity (< percentile 75) groups. Cross-validation was performed using 70% of the data to train the model and 30% for testing. A model was fitted using the random forest machine learning algorithm. The number of trees was 500, and the function used to measure the quality of a split was the Gini impurity criterion. Accuracy metrics were used to assess the performance of the method. The analyses were performed in Python version 3.6 (Python Software Foundation. Python Language Reference. Available at http://www.python.org) using scikit-learn libraries.

Results

A high level of accuracy was achieved using random forest algorithms to discriminate high vs low robot productivity. A weighted accuracy of 83% was achieved from cross validation of the dataset. Variable importance analysis illustrated that milking time was the most important variable impacting the classification of the robot performance (Figure 1).

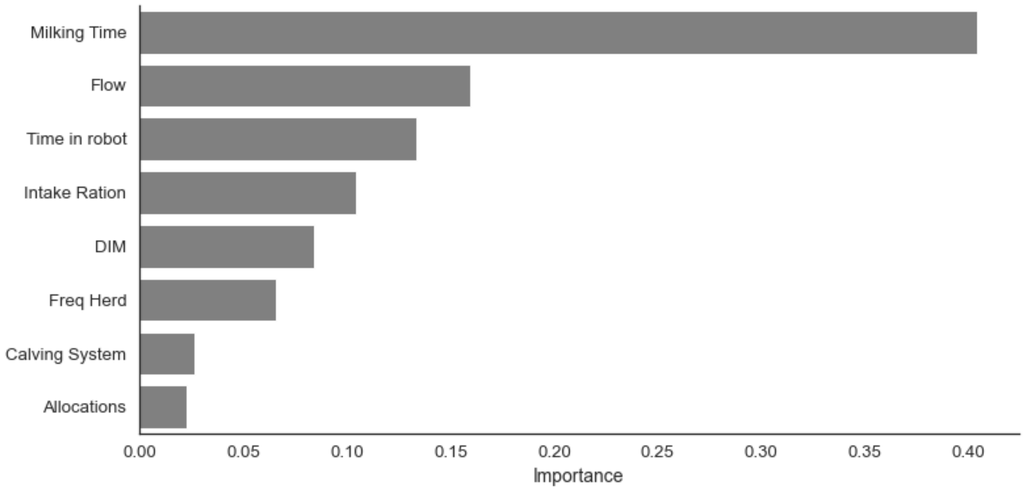

Figure 1. Variable importance plot showing the eight variables used for the classification of robot's productivity categorized as either high (equal to or greater than the 75 percentile of milk harvested monthly) or low (less than the 75 percentile of milk harvested monthly).

Conclusion

In AMS, milk harvested per robot is mainly explained by the milking time. Reproductive strategies (calving system) and pasture management (allocation) have low impact on milk harvested. Moreover, machine learning algorithms such as random forest provide the ability to explore the relative importance of variables with high classification accuracy.

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Feeding and Energy Efficiency MIR (FE-MIR) predictions for dairy farming

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Abstract

Mid-infrared (MIR) spectrometry is a non-expensive and routinely-used method for major milk components and also for fine milk composition analysis. Due to the detailed milk composition which can be approached thanks to the MIR spectroscopy which is using the infrared light from the electromagnetic spectrum it is shown specific absorption patterns when it is sent through a milk sample and caused frequency dependent interactions with the chemical bonds of the chemical milk components. A major provider of MIR services is European Milk Recording (EMR), an umbrella organisation created by former OptiMIR milk recording organisations (MROs), which offer MIR standardisation and predictions. EMR's members are continuously supporting the creation and maintenance of MIR models by collaborating and participating in research projects. MROs having access to milk MIR spectra and prediction models have been increasingly integrating these predictions into services for dairy farmers. During the last decade researchers from different projects underlined the possibility of spectral predictions of milk main components such as fatty acids or minerals, milk biomarkers such as ketone bodies in milk or inflammation indicators or complex components such as energy deficit, ketosis, mastitis, CH4 or pregnancy with the help of MIR spectral data. The basis for these equations is formed by biochemical correlations with fatty acid synthesis during animal metabolic processes in the rumen and corresponding relationships between fatty acid patterns and the characteristics such as: methane emission, energy balance, energy efficiency and feeding efficiency. The changes in fatty acid patterns and other parameters, even at the lowest concentration, can be represented in the milk spectra and used to estimate these traits from the milk. Within the framework of the eMissionCow and ReMissionDairy projects and with the data provided by optiKuh, existing calibration equations have been optimised and new equations were developed. Further developments of the farmer reports were made and improvements in the farm management is in progress. With the estimated values determined from these equations, it is possible to make statements on animal groups as well as herd or farm level on feeding according to needs and on the effect on the climate. In the context of international work and the evolving population, this rapidly developing field of research requires the inclusion of further reference data and a continuous updating of the calibration equations.

Keywords: mid-infrared spectrometry, MIR spectra, health monitoring, energy balance, feed efficiency, methane, CH4, dairy cattle

Introduction

In various projects, the regional association for performance testing in livestock breeding of Baden-Wuerttemberg (LKV-BW) is engaged in the further development of milk performance testing. In the background are the topics of animal health and robustness, climate change, digitalisation and biotechnology. The main tools that have been used are MIR technology, sensor technology, data integration and genetic engineering. In the areas mentioned, however, no basic research is being carried out, but rather the aim is to transfer existing knowledge into practice. Currently, work is being done on a report that shows the energy balance, energy efficiency, feed efficiency and methane emissions per cow with the help of the MIR data from the monthly milk performance test. The important message from the project OptiMIR was that not only the main components can be analysed with the MIR spectrometer, but also fatty acids (Grelet et al., 2014), minerals, lactoferrin (Soyeurt et al., 2011), BHB, acetate and citrates (Grelet et al., 2015). Complex traits could also be assessed, and models for ketosis (Grelet et al., 2016), energy deficiency (McParland et al., 2011, Smith et al., 2018) and methane emissions (Dehareng et al., 2012) were developed. More and more MIR spectral data has created the basis or possibility to revolve the feed management on the farm. Consequently, the objectives of the eMissionCow and ReMissionDairy projects will be pursued and further elaborated with the help of the FeMIR (Feeding and Energy Efficiency MIR) report. Innovative feeding management could be the future for the next generation: in the ReMissionDairy Project the influence of feeding on methane and nitrogen emissions is being investigated. The goal is the development of a practical web application that supports the farmer in feeding management. Feed efficiency and farm profitability can thus be increased. The methane determination for the individual cow via the milk performance test milk sample plays an important role in this. The improvement of feed efficiency in dairy cattle through breeding leads, on the one hand, to improved production efficiency in milk production and, on the other hand, represents a measure for active climate protection, since higher feed efficiency results in lower greenhouse gas (GHG) emissions per product unit. Here, too, methane determination for the individual cow via the milk performance test milk sample plays an important role. The objective of this paper was to show the new and innovative spectrometric tool FeMIR for Baden Württemberg datasets. The aim of FeMIR is the monitoring of the animal metabolism status with the help of the milk quality and to evaluate the usability of MIR indicators in order to improve early energy and feed efficiency on cow/farm level.

Material and methods

Under the leadership of the Walloon Agricultural Centre Gembloux, supporting project partner in eMissionCow, a MIR calibration equation for estimating methane emissions from dairy cows was developed in collaboration with the EU projects OptiMIR [1], METHAGENE [2] and GplusE [3]. Methane emissions measured with the SF6 method and in respiration chambers form the reference data for this equation. In order to gain access to this calibration equation and make it applicable for the whole of Germany, respiration chamber measurements were carried out with 20 lactating Simmental cows and different feed variants at the research farm FBN Dummerstorf. According to a fixed experimental design, the non-weaning cows were adapted in groups of four cows each to the two different feed rations (maize and grass silage based) with regard to potential methane emission; two cows each to one of these rations. Measurements were taken in the respiration chambers over 48 hours and two 24-hour methane emission values were calculated from these. As a result, 16 daily methane measurements were generated from four cows on two divergent feed rations each. With 20 cows and the required five runs, there are thus 80 measured values. In the respiration chambers, the cows were milked at stall and at

12-hour intervals. The individual milking samples and the bulk samples from two milking each were analysed in the laboratory of the LKV Nordrhein-Westfalen e.V. and LKV Baden Württemberg and the milk spectra were read out. The international methane calibration equation was extended to include measurements from Simmental cows, which are now also represented in this equation and have increased the variability of the data and thus the robustness. The underlying calibration model was run with a 10-fold cross-validation on a subset of 1,203 samples. With an RPD value of 1.8 (Tab. 1), the model is able to distinguish between groups of cows and between high and low methane emission levels.

Tab.1: MIR calibration models for methane emission and feeding ratios

	Unit	#LV	Ø	SD	SEC	R2c	SECV	R2cv	RPD
Methane emission	[g/d]	12	402,30	97,00	50,0	0,73	54,0	0,69	1,80
Energy balance - NEL	[MJ/d]	12	1,97	16,98	8,27	0,75	8,27	0,75	2,05
Standardised							7,53	0,84	2,50
Not standardised							8,08	0,76	2,00
Energy balance - ME	[MJ/d]	12	0,85	23,07	8,99	0,85	8,94	0,85	2,58
Standardised							8,42	0,89	3,05
Not standardised							9,06	0,84	2,48
Energy consumption - NEL	[MJ/ EMC]	7	4,69	0,62	0,27	0,81	0,28	0,81	2,27
Standardised							0,28	0,81	2,31
Not standardised							0,28	0,80	2,25
Energy consumption - ME	[MJ/ EMC]	7	7,67	1,03	0,39	0,86	0,39	0,91	2,66
Standardised							0,39	0,91	2,69
Not standardised							0,39	0,91	2,64
Feed efficiency	[ECM/ DM kg]	10	1,55	0,25	0,09	0,90	0,08	0,89	3,13
Standardised							0,08	0,90	3,13
Not standardised							0,08	0,88	2,97

#LV= number of latent variables
SD= standard deviation
SEC= standard error of calibration
R^2c= coefficient of determination of calibration
SECV= Standard error of cross-validation
R^2cv= Coefficient of determination of cross-validation
RPD= Ratio of SD to SECV. RPD values of less than 2 allow the comparison of cow groups and the differentiation of high or low values. RPD values between 2 and 3 allow applications as coarse screening. RPD values between 3 and 5 allow applications with a finer screening.

The spectral data set was first standardised according to the OptiMIR/EMR method and after data preparation 177 value pairs could be added to the international data set and evaluated with the "glmnet" R package. The Legendre polynomial data based on days in milk (DIM) for the 212 OptiMIR wavelengths of the spectral data were used as input variables. Calibration equations were calculated for the estimation of the energy balance based on the Net Energy Lactation (NEL) and Metabolic Energy (ME) scoring systems. These are the results of a collaboration between the German optiKuh project consortium with its 12 experimental farms and the German Association for Performance and Quality Testing (DLQ). Between 2014 and 2017, a feeding experiment in these experimental farms with weekly milk sampling and corresponding feeding data in high resolution provided the reference data for the calibration equations (NEL, ME). For the evaluation, approximately 26,000 energy balance records with additional feeding parameters on NEL basis and approximately 29,000 energy balance records with additional feeding parameters on ME basis were available for the creation of the calibration equations for energy balance, energy efficiency and feeding efficiency. Standardised as well as non-standardised MIR spectral data from FOSS and Bentley FTIR analysers were used (Dale et al., 2019). Following the same methodology and using the same optiKuh feeding experiments, energy efficiency reference values and MIR spectra were combined in the eMissionCow project. Calibration equations for energy efficiency NEL and ME as well as feed efficiency were then generated with a cross-validation experiment from all experimental farms with around 1,511 animals. The calibration equations for energy balance, energy efficiency and feeding efficiency were generated with the reference data of the 12 optiKuh trial farms and the corresponding milk spectra, which were available in standardised and non-standardised form. The RPD value, which is the ratio of the standard deviation of the reference data to the standard error of the MIR estimates, differs between the models created in this way by up to 0.5 (Tab. 1). These parameters can then be calculated for routine milk performance testing spectral data, among other things, and also support breeding in the development of new efficiency breeding values.

Results and Discussion

For the MIR models created in the eMissionCow project for methane emission, energy balance, feed efficiency and energy efficiency, concepts for new reports and herdmanager modules were designed and evaluated. So far, the EMIR report (energy balance report) has already included the energy balance estimates, KetoMIR and the fatty acid and the fatty acid profiles have been reported and compared with the population means. In the new and innovative FeMIR report, which is the result of the eMissionCow and ReMissionDairy projects, and uses the MIR spectral data from the monthly milk performance test milk sample, parameters like energy intake, energy consumption, feed efficiency and methane per kg ECM are shown in tables and graphs. The report provides information on the extent to which the milk fat originates from newly formed fat from the feed (F-DeNovo) or how high the milk fat percentage is that comes from body fat mobilisation (F-Preform). It also shows the energetic condition of the individual cow. The energy balance (EB) is used for this purpose. This is the difference in energy between the feed energy consumed and the energy needed for the cow's maintenance requirements, milk production and growth. Another value that is displayed is the energy consumption (EE). The energy consumption indicates how much energy in MJ NEL is needed to produce one kg of energy corrected milk (ECM). Another important question is also answered in the report. How much feed or, how much energy from feed does the cow consume. With the energy intake value (EA) in MJ NEL per animal and day the answer can be provided.

The question of feed efficiency (FE) is also of interest. Feed efficiency describes the ratio of the daily milk yield of energy corrected milk (ECM) to the daily dry matter intake of feed in kg. The FeMIR report also gives the methane emission per cow. There are two key figures for this. The first is grams of methane per animal per day (CH4) and grams of methane per kg of energy-corrected milk per day (CH4-ECM). Through the projects mentioned above, the data basis was created to develop MIR calibration equations that are statistically very reliable. Comparisons between groups of cows are possible and even individual animal monitoring.

Because of this data reliability, the FeMIR report is a new innovative working tool for the LKV members. The FeMIR report is currently being analysed and evaluated by farms, breeders and consultants of the LKV Beratungs- und Service GmbH in a field test. With the help of the field test, the use of the new features of the performance test will be proofed in practice. Another aim of the field test is to develop new advisory concepts based on this report. The report will be available to our member farms from autumn 2022 and will be accessible in the Herd Manager.

Conclusions

With the FeMIR report, the energetic situation of the herd can be described well over all lactation stages. The animals' metabolism can be easily monitored with this new tool. This also facilitates the assessment and control of the feed regime. The applications developed with the help of the latest technologies will help dairy farmers to improve feed efficiency and minimise emissions on their farms. The newly developed efficiency indicators will be established in agricultural practice. The application software for the presentation of the results will be optimised for access via browser-based web applications or mobile applications. Corresponding modules are to be implemented in the LKV Herd Manager and in the LKV App. Through the planned practical application of the newly developed efficiency parameters in routine milk recording consultation it can be used to improve feed efficiency on farms and reduce methane emissions. Thus, the demands of politics and society with regard to the reduction of climate-impacting emissions from livestock farming can be met proactively.

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Findings on a survey of training techniques for heifers in Automatic Milking Systems

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Introduction

Heifers are an important component in all dairy operations, providing the replacement stock for the milking herd. In an Automatic Milking System (**AMS**), particularly those operating with voluntary cow traffic, it is critical that heifers adapt well to the system if they are to be successful long-term producers. While it has been reported that heifers are capable of rapidly adapting to AMS (Jago and Kerrisk, 2011), have a reduced pre-milking wait time (Scott et al., 2014) and visit the robot more frequently than their multiparous counterparts (Ketelaar-de Lauwere et al., 2000), questions remain regarding the different ways farmers train their heifers in AMS. Furthermore, at the Milking Edge AMS Farmer Gathering held in Australia in 2019, farmers raised this issue as a key area for improvement on-farm.

Materials and Methods

Milking Edge is an Australian dairy industry training and extension project that commenced in 2018 to 'support industry to consider, invest and operate AMS successfully'. It is a partnership between NSW Department of Primary Industries, Dairy Australia and DeLaval. To gain an understanding of the training strategies used on-farm to introduce, familiarise and support heifers in adapting to AMS, Milking Edge commissioned a 48-question survey. This was distributed online to AMS farmers in Australia and overseas. Questions focused on identifying training strategies for heifers before and after calving, as well as highlighting other on-farm activities farmers use in order to support heifer adaption to AMS (e.g. during calf rearing).

Results and Discussion

There were a total of 62 responses, received from farmers across ten countries, with 19 (31%) responses from Australia. The majority (84%) had two or more years' experience operating AMS.

In most cases farmers weren't necessarily giving targeted or individual training to heifers, but instead appeared to introduce heifers to various aspects of the system while continuing to do other activities around the farm.

Almost 75% of respondents trained their heifers, and this was done either pre-calving (18%), post-calving (39%) or both pre and post-calving (18%). Pre-calving training typically took four weeks or less, and for 58% of respondents it was conducted within four weeks of calving. The most common techniques during pre-calving training were to provide heifers with access to feed in the robot (91%), expose heifers to smart gates (86%) and one-way gates (82%) and hold heifers within the robot box with gates closed (77%). Just over half of farmers (59%) kept heifers with the main milking herd during pre-calving training. Post-calving training saw a larger variety of techniques used, with the most common ones including manually encouraging cows into the robot (49%), keeping heifers separate from the main herd (43%) and manually attaching cups (31%).

A priority lane (area used to by-pass the queue of cows in the main herd waiting to be milked) was used by six (27%) respondents who were training heifers pre-calving, while 15 (24%) respondents training post-calving used a priority lane or robot. All respondents who used a priority lane during pre-calving training had pasture-based systems, while six of the post-calving farms were indoor systems and nine were pasture-based systems.

The vast majority of farmers mentioned that their training methods or protocols were self-taught (86%), followed by consulting other farmers (45%) and equipment providers (32%).

Conclusion

Results from this survey suggest farmers tend to familiarise heifers not only with the robot but also with the rest of the farm system. Given some farmers are using priority areas (e.g. a priority laneway or robots, or pre-milking area), there may be a need for future work to focus on the dairy design and creating flexible working areas which could be beneficial not just in training heifers but in general operation. There is an opportunity for extension and adoption programs to more clearly communicate to farmers current and future knowledge in this area.

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If data is the new fuel we need data refining standards: The VirtualVet experience

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The current revolution in agricultural systems sometimes characterised as Agriculture 4.0 is being driven by the use of digital data to improve agricultural efficiency and the transparency of provenance of food supplies from farm to fork. Data is created both by sensors in automated systems such as milking parlours and by humans performing animal husbandry and veterinary tasks. In farm conditions the means of reporting complex data such as the diagnosed animal health conditions and the associated thousands of treatment names applied by injection, intramammary infusion, pourons etc mitigate against accurate data recording. Across the EU and most developed countries concerns about antimicrobial resistance have created a mandatory reporting system for veterinary treatments of animals. An old adage of computing is garbage in = garbage out (GIGO) and inconsistencies in spelling and lags between treatment and data entry mean that much farm saved data is unsearchable and thus unusable for monitoring and control purposes. Since 2015 when VirtualVet was launched as a smartphone app we have developed methods that reduce the amount of data needed on farm to five items of animal treatment and these can be collected by messaging app methods (text, audio and images) in the milking parlour or animal treatment area. The data is then aggregated at the server with available sources such as databases of animal tags, veterinary treatments and supplier data. Regular audits of the data quality are conducted to improve training and feedback to stakeholders. Where necessary, data curators call back to farmers to clarify any inconsistencies and confirm accuracy. Farms benefit by automated treatment records and the supply chain can audit treatment data remotely thus reducing travel times. In future we will begin automated diagnostic information as it becomes available but as long as humans do animal treatments we will need flexible systems and a data curation data to ensure accuracy.

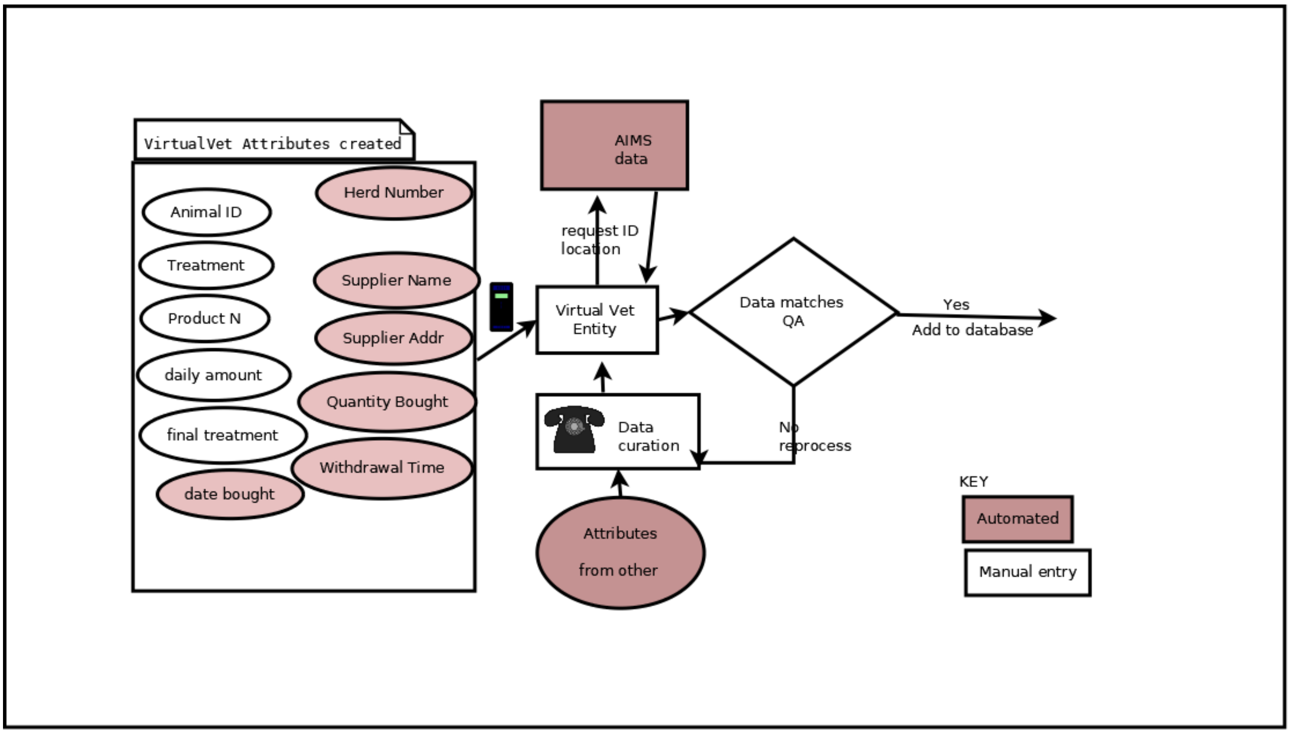

Figure 2: The aim of the system is to minimise the amount of data to be entered at the farm to five items, all the rest is automated with a curation layer to ensure quality

Importance of low daily risk for the prediction of treatment events of individual dairy cows in need with sensor systems

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Assisting herd managers in identifying animals with health problems to ensure their welfare is an important task of precision livestock farming. Numerous studies have already developed and evaluated models for classifying cows in need of treatment for mastitis and lameness using machine learning methods, but few have addressed positive predictive value (PPV) and its implications for practical application. The objective of this study was to investigate the importance of the frequency of occurrence of the rare event "treatment for mastitis respect. for lameness" per cow and per day for the applicability of classification models in practice. For this purpose, developed machine learning models for the classification of mastitis respect. Lameness treatments were applied using 417,000 records per cow and day contained animal individual sensor data. Our models achieved good AUC values (0.80) for mastitis classification (0.68 for lameness classification). But because of the low daily risk for these treatment events (3.6% and 5.6% per day), the PPV did not exceed 7% for both treatment events. Various criteria were designed to isolate the high-risk group records with the goal of increasing the frequency of days with treatment. Restriction to cows with previous mastitis or lameness treatment achieved the highest increase in PPV only to 20% and 15%, respectively. It can be concluded that this level of a known low daily risk of an event per animal remains the critical factor influencing the prediction, that even limitations are not sufficient to reduce the high number of false alarms to a satisfactory level.

In dairy cows is there a relation between reduced lying time measured with PLF sensors and increase salivary biomarkers of stress and immunity?

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Welfare of dairy cows is still an issue and a growing concern in the EU and worldwide. Dairy cows spend, per day, between 9 and 14 hours lying down; they prioritize this behaviour over others maintenance behaviours such as walking or feeding. Time spent lying down has been demonstrated to be a meaningful behaviour and any change in this behaviour may be a symptom of a stress situation (i.e. housing condition, stocking density, inadequate facilities) or health issue (i.e. mastitis, lameness, ketosis). For this reason, lying time is considered a useful indicator for the assessment of dairy cows' health and welfare. Currently, PLF technology (e.g., accelerometers) permits to monitor continuously lying behaviour.

The present study aimed to evaluate if changing in lying behavioural time-budget can be correlated to milk production, SCC and a panel of salivary analytes including analytes of stress (cortisol, total esterase (TEA), alpha-amylase and lipase), immunity (ADA total and isoenzymes) and tissue damage (CK).

Lying time of 15 cows, housed in a commercial intensive free-stall dairy farm, were monitored with accelerometery collars for three months. Saliva samples were taken from each animal on days 1, 45 and 90. Monitored cows were between 3 and 9 years old (mean 4 years), of various calvings (min 1; max 6) and at different lactation stages.

A two-step cluster analysis identified three clusters based on the duration of lying behaviour: 24.4% of the cows were assigned to the first cluster, 53,3% to the second and 22,2% to the third. Dairy cows in the first cluster showed a longer mean duration of lying behaviour (11,62+/-0,6 hours) compared to the other two clusters, 9,71+/-0,6 and 7,61+/-1,0 hours respectively. Dairy cows in group 3 showed significantly higher levels of alpha-amylase, CK and ADA2 compared to the other two clusters (Kruskal-Wallis test; $p<0,05$). Additionally, cows in group 3 tended to have a higher milk production ($p=0,095$) and a higher SCC ($p=0,091$).

The results pointed out that changes in lying behaviour, measured by PLF technology, are a promising indicator for the identification of welfare and health issues in dairy cows. The synergy between behaviour measured using PLF technology, physiological parameters and production indicators can be a feasible and innovative approach to dairy cow welfare assessment.

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Ketosis and Energy Balance milk MIR spectral predictions – Practical Application

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Ketosis, a metabolic disorder, is associated with milk characteristics and can be measured through Milk MIR spectra at individual level. When a cow suffers from Ketosis the food consumption and metabolic energy balance is decreasing while body fat mobilisation is increasing. This has negative effects on milk yield and health status of the dairy cow. The underlying idea was to build prediction models based on the dairy cow's veterinary ketosis diagnosis milk MIR spectra from routine milk recording and energy balance data. The KetoMIR-2 model was developed on 810,496 spectra from 10,079 herds in D4Dairy project. The energy balance models (ME and NEL) were developed based on ~30,000 spectra from German research farms from OptiKuh project. The objective was to improve KetoMIR-1 model and to validate energy balance models together with milk recording organisation feeding advisors for an improved dairy herd management and better MRO services. The aim was to identify variables that were positively or negatively associated with ketosis and to give advice based on energy balance and KetoMIR. It has to be underlined that the KetoMIR was built for a period of 5 to 120 days after calving, while the energy balance models were created for the complete lactation period. Statistical computation was made in R software by using "glmnet" library. From the MIR spectra a subset of 212 wavenumbers was used which have been standardised and treated with a first derivative. The KetoMIR model probability showed high correlation with energy balance, blood BHB and milk yield. The strong correlation with ketosis indicators justified the construction of a 3 class scheme based on thresholds applied to ketosis probability in order to provide the farmer with a traffic light colour indicator. The KetoMIR index, EB predictions and fatty acid group MIR predictions have been successfully used by dairy herd management advisors in order to detect general feed deficiencies in the late and early lactation transition period at herd level. For this purpose a special monthly milk recording report has been created called EMIR (EnergyMIR). Within the D4Dairy project models were evaluated and optimized for use in routine herd management and breeding evaluation.

Matching animal activity, health and climate data to improve dairy cows' welfare

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The KLIMACO project is dedicated to building up and supporting climate resilience in livestock farming in the Upper Rhine region and thus aims to identify and promote the implementation of adaptation strategies to climate change. For this goal 21 partners from France, Germany, Switzerland and Luxembourg have joined forces, including advisory, research and teaching organizations. The project is divided into five main work areas: animal welfare and animal health, CO2 and methane, agroforestry, energy and feeding. The aim of this working groups is to develop strategies and recommendations for livestock farmers to adapt to climate change and thereby prevent risks. Dairy cows in particular react to heat stress with lower feed intake and declining performance, and even health problems such as inflammation of the uterus and udder and reduced reproductive performance. The SESAM tracking system at final stage is monitoring: walking, standing, lying, eating and ruminating of dairy cows. Since mid-summer 2020, at LKV Baden Württemberg, SESAM sensor data, animal health issues and also climate data are registered and combined together to get a better monitoring and decision support on managing the dairy cows' farms. Meanwhile due to the end of SESAM project it is possible to predict within the 1st level algorithm behavior patterns and health data from GMON Rind BW, dairy cows' activity patterns for events such as 'in heat', calving and other health issues such as milk fever, lameness, mastitis, metritis, ketosis and cyst or cycle disorders. For each model were registered more than 80 % sensitivity and specificity, with exception for mastitis and mortellaro, where the sensitivity and specificity were around 70%. The next steps are to combine the 2nd level algorithm with climate data in order to better identify behavioral changes prior to events such as „in heat" and calving. The significant diseases that were predicted, with external validation, showed more than 75% in specificity and sensitivity are lameness issues such as mortellaro, limax, udder disease such as mastitis, and after calving issues such as ketosis, milk fever and metritis. Further developments for farmer reports are planned and improvements in the SESAM 2nd level algorithm are in progress. With the estimated values determined from these equations, it is possible to make statements on animal level as well as herd or farm level on feeding according to needs and on the effect on the climate.

Modelling the economic value of using activity and progesterone measurements in reproductive management on Dutch dairy farms

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Introduction

The correct and timely detection of oestrus is an important factor in dairy farming profitability. Good reproductive performance serves as a basis for optimal milk production of the herd, while failure to conceive is an important reason for involuntary culling. The most traditional and common method of oestrus detection is by visual observation. However, more and more precision tools for detecting oestrus are becoming available. Activity meters (3d accelerometers), for instance, are widely used by dairy farmers. Also, on-line progesterone (P4) measurement systems are available or under development. For farmers investing in such sensor systems, it is important to know their cost-effectiveness. The investment costs and consumables associated with novel technology should be weighed against improvements in reproductive performance. For this reason, it is important to evaluate the added-value of progesterone measurement in combination with activity meters. The objective of this study was to evaluate economically a P4 measurement system.

Method

A qualitative partial budget was developed to evaluate the economic effects of using a P4 sensor system in combination with activity sensors. This partial budget provided the elements that needed to be modelled for a cost-benefit estimation. Consequently, a novel stochastic bio-economic simulation model was used. This model simulates cows in daily time steps providing a partial gross margin (Edwardes et al., 2022). Based on the partial budget, the model was adapted to enable an economic evaluation of the sensor systems. Specific reproduction related costs included in the model were costs for insemination, culling, replacement heifers, feed, activity meters and progesterone measurements. Returns consisted of milk revenues. The model was used to simulate four different scenarios: visual observation (as a default scenario), activity measurements only, P4 measurements only and combined activity and P4 measurements. The model was developed using existing scientific literature and expert knowledge from the sensor development team as well as structured interviews with farmers.

Results and conclusion

Preliminary results show a positive difference of €24, €42 and €76 per cow per year for activity sensors, P4 sensors and the combination of both respectively, when compared with the default scenario (visual observation). The variables with the largest impact were milk revenues and the costs of culling. The costs of insemination and feed costs had the lowest impact. These results show that investment in activity measurements, P4 measurements or both for oestrus-detection, can increase profitability of a dairy farm. Information obtained from the activity meters and P4 measurements can also be used for health monitoring which was found to be valued by farmers from their interview responses.

Table 1 – Technical results of simulation model of 120 dairy cows.

	Visual	Activity	P4	Activity + P4
Milk production (L/cow/year)	9,607	9,743	9,775	9,813
Average number of open days	133	116.53	114.96	113.54
Calving interval (days)	417	401	399	397
Number inseminations (/herd/year)	184	342	291	228
Number total culls (/herd/year)	28.74	31.17	29.07	25.14
Number culls fertility reasons (/herd/year)	8.15	10.27	7.18	3
P4 measurements (/cow/year)	X	X	48.01	40.05

Table 2 – Economic results of simulation model of 120 dairy cows in euros.

	Activity	P4	Activity + P4
Milk returns	6,030	7,425	9,079
Cost cull	671	-228	-1,893
Cost feed	421	596	836
Cost insemination	2,209	1,396	481
Cost P4	0	577	571
Depreciation sensors	1,900	800	2,700
Interest sensors	418	176	594
Total	590	4,107	5,790

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Precision Livestock Farming technologies in Italian dairy cattle farms

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Introduction

Today's animal husbandry faces complex challenges due to increasing farm size, labor shortage and growing consumer demand for environmental, animal welfare and food safety concerns. Precision Livestock Farming (PLF) technologies can support the farmer in managing large herds and meeting these expectations (Tullo et al., 2019). In Italy, in the last years, a rapid process of modernization of livestock farms has started, especially in the dairy sector, with the introduction of sensors and automatic management systems. However, the propensity of Italian farmers to implement new technologies seems still limited. The recent report of the Italian National Institute of Statistics (ISTAT, 2021) states the percentage of livestock farms using precision instruments does not even reach 40% of the respondents.

Aim

The aim of the study was to provide an overview of the diffusion of PLF tools in Italian dairy cattle farms, to study motivations, benefits and limits of technological investments from the point of view of farmers and to identify the main factors influencing the spread of technology.

Methodology

An online questionnaire was distributed from November 2020 to June 2021 via a website dedicated to the technology in dairy cattle farms. The questionnaire consisted of five sections for a total of 53 questions, 33 open-ended and 20 multiple-choice. Automatic monitoring solutions of different aspects were investigated: milk yield, milk flow, milk electrical conductivity, milk color, milk quality, somatic cell count, bioindicators in milk, animal body condition, activity, rumination, weight, lameness and dry matter intake. For each of these aspects, different scores were assigned as follows: a) presence at the time of the interview of the PLF solution at the farm (Diffusion Rate Score, DRS): no=0; yes=1; b) time elapsed since the adoption (Adoption Time Score, ATS): scores from 1 (less than 1 year) to 5 (more than 5 years). Moreover, farmers were asked to indicate three PLF tools, among the systems currently implemented, in order of priority from the point of view of farming management improvement. A score was assigned to each tool identified (Utility Rate Score): score 3 for the most useful, 1 for the least useful. The entire dataset was analyzed using SAS software (Version 9.4, 2012). GLM procedures were performed to assess the relation among different DRS and ATS and farm characteristics.

Results and discussion

The questionnaire was filled in by 52 dairy farmers, most of which (79%) from Lombardy. About 35% of the respondents were under 40 years old and about 50% between 40 and 60.

Activometers and milk yield monitoring sensors are the most common tools and farmers consider PLF solutions for the estrus detection as the most useful, in line with the results of Abeni et al. (2019). Despite the already widespread use of these sensors, the attention in these two areas, fertility and milk yield, seem to be still high: a lot of farmers declare an interest for future technology investments in these fields. High level of PLF technologies at the farm, quantified by DRS, is significantly linked to the interest in decreasing human workload and to the passion of the farmer for advanced technology ($P<0.05$). In more than 50% of high-tech dairy farms the farmer is under 40, only 10% of them are run by farmers over 60 years old. Farms that had been adopting technology for the longer period of time (high ATS) are larger than others ($P=0.056$). Both parameters (DRS and ATS) are significantly related to the number of daily milking ($P<0.01$ and $P<0.05$, respectively): in most cases the adoption of technologies is linked to the presence of automatic milking systems. Automatic milking systems are mainly adopted by under 40 years old farmers. Farms with high level of technology (high DRS) and those with PLF solutions since a longer time (high ATS) do not show significant differences in terms of milk production, mastitis frequency and reproductive efficiency compared to the others. Among the reasons limiting the investment in technology from the farmer's point of view, the most cited are the cost, the time needed to check data and the difficulties in interpreting results. The last motivation is much more important for over 60 years old breeders but less for under 40 ones.

Conclusion

In conclusion, Italian dairy farmers seem to have a growing interest in PLF, especially for managing reproduction and monitoring milk yield, but there are still obstacles that hamper the diffusion of technologies at the farms. Therefore, further improvements and efforts are needed by both researchers, industry and extension services to increase the propensity for PLF in dairy farms, both responding better to farmers' needs and supporting them to use technology more efficiently.

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Impact of genomic breeding strategies on disease incidence and costs

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Objective:

To measure the expected reduction in incidence of eight health events and their associated costs, in response to a breeding strategy designed to maximize a multi-trait genomic selection index (Dairy Wellness Profit $, DWP$, Zoetis) when executed across a 10-year period.

Methods:

A deterministic model was developed to simulate changes in the dairy herd parity structure over time given a specified breeding and selection strategy for improving the herd's average merit for DWP$. Inputs for the hypothetical herd are displayed in Table 1. Expected genetic progress for DWP$ was modelled for two scenarios: 1) using genomic results to take decisions; and 2) using parent average to take decisions. Genetic progress for DWP$ was calculated using the inputs of the breeding and selection strategy (percent retained, average DWP$ values of sires and dams, semen type used, etc.) plus expected herd removals. The expected response to selection for DWP$ was used to model the expected change in genetic merit for the eight health events which was then coupled with the corresponding odds ratios were used[6] to calculate the expected annual change in disease incidence. Economic costs for each disease were estimated based on published data, adjusted for inflation, and standardised for milk price (mastitis). Input costs per case of disease were: mastitis (€399[4]); metritis (€208[1,3,4]); retained placenta (€276[1]); displaced abomasum (€483[1]); ketosis (€199[1,3]); lameness (€309[1,3]); twinning (€184[2]); and abortion (€541[5]).

Table 2. Initial herd structure and breeding strategy inputs

Female age	Inventory	Average Female DWP ($)	Semen/breeding allocations (%)[1,2]			
			Embryo donor	Dairy breed	Beef breed	Embryo recipient
1 – 12-month-old heifers	500	220	-	-	-	-
12 – 24-month-old heifers	465	200	2.0	74.0	0.0	24.0
1st lactation cows	350	180	0.5	93.5	0.0	6.0
2+ lactation cows	650	150	0.0	80.0	20.0	0.0

1. Sire PTA was set to DWP$ = $500 for all semen not allocated to embryo transfer (ET)
2. Embryo donors were set to 12 progeny/head/year; ET sire PTA was set to DWP$ = $450

Results:

At the completion of 10 years, the average female DWP value was 716 for the genomic index strategy, and 427 for the parent average strategy. Table 2 displays the changes in herd-level disease incidence and associated annual costs after 10-years. Genomic index strategy annual costs totalled for the 8 diseases were €22.87 per lactating cow per year less than the parent average strategy, equating to a total annual saving of €25591 for the herd in year 10.

Table 2. Herd-level disease incidences and associated annual disease costs after 10 years

Disease	Initial incidence (%)	Incidence at 10 years (parent average, %)	Incidence at 10 years (genomic index, %)	Relative reduction (%)	Annual disease cost savings /cow (€)	Annual disease cost savings /herd (€)
Mastitis	29.2	28.0	24.8	11.4	12.67	14184
Metritis	10.0	8.7	7.5	13.7	2.48	2776
Retained Placenta	5.0	5.0	4.6	7.2	0.99	1104
Displaced Abomasum	2.6	2.3	2.0	12.6	1.39	1554
Ketosis	5.7	5.1	4.2	17.2	1.75	1958
Lameness	16.9	17.8	17.0	4.7	2.58	2890
Twins	3.3	3.4	3.1	6.6	0.41	456
Abortion	11.6	11.8	11.7	0.9	0.60	669

Conclusions:

Selection and breeding strategies using DWP$ can enable producers to accurately improve the genetic merit of their herd for both production (milk, fat, protein) and a reduced incidence of common diseases; thereby resulting in tangible economic benefit, reduced use of antimicrobials, and improved animal welfare.

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6. Zoetis data on file

Why do goats bleat?

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The development of Precision Livestock tools is of great relevance for the continuous and non-invasive monitoring of farm animals. Until now, the use of these tools in dairy farming has taken hold in cattle breeding (Zebari et al., 2018; Viazzi et al., 2014; Tullo et al., 2019), remaining marginal in the breeding of small ruminants. The use of machine learning technologies, such as the automatic analysis of vocalizations, is being developed for pigs (Manteuffel et al., 2017), but it represents a completely new and unexplored field in goats. The ongoing VOCAPRA project (Multidisciplinary approach for setting up a continuous monitoring system in goat farms by means of vocalization analysis, Rural development 2014-2020 for Operational Groups, in the sense of Art 56 of Reg.1305/2013) aims at increasing human understanding of goats' vocalizations by collecting the bleats emitted by more than 300 dairy goats reared in four farms in northern Italy. To achieve this goal, 18 sensors collect acoustic data, which are then processed thanks to intelligence techniques (neural networks and/or decision trees), in order to extrapolate the bleating of goats from a pool of generic sounds. Up to now, a sample of 2000 bleats has been collected and associated to the contexts in which they were emitted (e.g. feed distribution, social isolation, injuries). The acoustic parameters of these vocalizations (duration, intensity, tone, etc.) are then analyzed to identify those that can be associated with the different emission contexts. Thanks to this pool of vocalizations referred to known contexts, we are currently developing an IT tool (smartphone application), which will allow farmers to receive real-time notifications on what is happening in their farm and therefore to intervene promptly in case of need.

As part of this conference, we would like to propose an interactive poster to test the ability of participants to interpret goats' vocalizations. To this aim, participants will be asked to listen to some audio tracks of goat bleatings emitted in known contexts and to associate each bleating to the situation in which it was emitted. Participants will be also interviewed by administering them a questionnaire to evaluate their level of empathy towards animals. This will then allow us to correlate the ability to interpret vocalizations to the level of empathy and other individual characteristics, such as age, sex and level of experience with animals.

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