The D4Dairy-project – How digitalization and data integration pave the way to dairy health improvement

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Abstract

Lameness in dairy cattle still remains a widespread animal welfare and economic issue. Early detection and prediction of lameness events may help to reduce negative effects for farms. However, integrating lameness assessment into the daily work routine is not feasible for many farms and may be prone to subjective bias for use in genetics. External assessment, carried out by veterinarians or claw trimmers, is often not done regularly and thus lameness may not be detected before it becomes clinical. Lameness is caused by a variety of factors including housing, feeding and management and may be associated with changes in milk performance or behavior. Technical advances and growing digitalization in various areas of dairy farming increased the amount and quality of data availability on farm supporting data-driven decision making. These advances happened incrementally with the consequence that data from different management areas is available in different formats or software programs and thus mainly used to make informed decisions in the respective area. Integrating these different data sources may enable more informed decisions by considering information from other management areas, which would be missed otherwise.

Thus, one aim of the D4Dairy project is the integration of various data to enhance early lameness detection and decision-support on individual farms. Our approach is based on the idea that lame cows show changes in performance and behavior, even before they show clinical signs of lameness. By integrating already existing data from national performance recordings, farm records, veterinary records, claw trimmings and different kinds of milking and sensor systems measuring e.g. activity, temperature or rumination (smaXtec, SCR by Allflex) a decision-support tool for early lameness detection and prediction should be developed. Subsequently, the outcomes of this approach should be used for the definition of auxiliary traits for claw health to be included into the breeding value estimation. Aside from the integration of different farm data this also requires the integration of data across farms, considering different systems, such as husbandry (e.g. free stall vs. pasture), milking (e.g. automatic milking system vs. conventional milking parlor with fixed milking times) or sensor systems (e.g. activity and temperature vs. activity and rumination monitoring).

In our contribution we want to show the steps towards data integration, which challenges we encountered and how we handled them. Furthermore, we present how we aim to use the outcomes for including claw health into the current breeding program and breeding value estimation.

Key words: precision livestock farming, lameness prediction, decision support, data integration, digitalization

Introduction

During the last decades, technical innovations and digitalization emerged in various areas of dairy farming. Besides facilitation of manual work, these technical developments aim at enhancing monitoring of animal health and welfare and supporting farm management by collecting, processing and analyzing data and are often referred to as precision livestock farming (Berckmans, 2017).

The D4Dairy project is a large, transdisciplinary project involving 13 scientific and 30 partners from industry from Austria and abroad. The overall aim is the improvement of animal health and welfare as well as product quality on dairy farms, predominantly on family run dairy farms in Austria, by integrating different data driven information systems and exploiting the opportunities offered by new (digital) technologies. In this paper, we focus on the potential of data integration for lameness prevention in dairy cows with the aim to develop a decision support tool for on-farm application

Lameness in dairy cow remains a widespread animal welfare issue, which also causes additional costs for treatment, lower milk production and higher replacement rates. Early detection or prediction of lameness could help to reduce cow discomfort as well as treatment efforts or culling of animals. However, an external lameness assessment by veterinarians or claw trimmers is not possible or simply too expensive for farms to be carried out on a regular basis. Performing weekly lameness scoring themselves may be too much of additional workload for farmers and thus difficult to implement.

The interaction of a variety of external risk factors from housing, feeding or management and animal specific risk factors such as milk performance or BCS makes it difficult to control lameness prevalence in dairy herds (Lasser et al., preprint). Scientific studies showed that lameness in dairy cows may be associated with changes in milk performance (e.g. Reader et al., 2011) and behavior (e.g. Weigele et al., 2018) in the individual animal. Based on this relationship our aim is to find out if there are other indicators, which may be used to predict if a cow is at risk of developing lameness and how they can be exploited. We hypothesize that these indicators enable early prediction of lameness and ideally also contribute to genetic improvement as auxiliary traits for claw health.

Animals, material and methods

D4Dairy data

With focus on deriving early predictors, we were able to use data from 1 080 cows on 19 farms in Austria. Data came from various farm areas and sources. The different types of data comprised national performance recordings (**NPR**), veterinary records (**VET**), data from claw trimmings (**CLAW**), data from milking systems (**MILK**), sensor data (**SENS**) and farm records (**FARM**) and are described in more detail in Table 1.

Data including NPR, VET, CLAW, MILK and FARM were recorded by farmers, employees of performance-recording organizations and veterinarians and collected in the Austrian central cattle database, Rinderdatenverbund (**RDV**, https://www.rdv-gmbh.net/). SENS from the smaXtec bolus (smaXtec animal care sales GmbH, Graz, Austria) in the cow's reticulum and SenseHub sensors cSense sensor mounted on a collar or eSense ear tag-sensor (SCR by Allflex, Netanya, Israel) were provided by the respective company.

For the specific genetic studies data from 99 farms equipped with automatic milking systems, behavioral sensors and extensive phenotyping on health are available within D4Dairy.

Table 1. – The different types of data available for lameness prediction in D4Dairy.

Name	Description
National performance recordings (**NPR**)	Performance field data recorded by the employees of the performance-recording organizations once a month (milk yield, milk components)
Veterinary records (**VET**)	Standardized codes for diagnoses of clinical diseases (Austrian Ministry of Health, 2010).
Data from claw trimmings (**CLAW**)	Includes diagnoses of claw diseases according to the ICAR Claw health atlas (Egger-Danner et al., 2015) and Lameness scoring: 1 (not lame) to 5 (severely lame) BCS scoring: 1 (emaciated) to 5 (fat)
Data from milking systems (**MILK**)	Milk yield per milking (kg) Milking intervals
Sensor data (**SENS**)	smaXtec: bolus in the reticulum records activity, temperature (°C) and drinking cycles and generates indices (activity, temperature, estrus) and alarms (e.g. estrus, immanent calving) SCR by Allflex: ear tag or sensor mounted on a collar records activity (walking and resting), feeding and rumination in minutes and generates indices (estrus, activity, health) and alarms (health, distress, over heat)
Farm records (**FARM**)	Animal specific data such as date of birth, age at first insemination, lactation number, calvings, inseminations, data on farm equipment, operational structure and management practices

All these data are highly sensitive and thus data security has to be guaranteed. Therefore, all farmers had to sign an agreement that data from their farms may be used in the project, all project partners agreed to Agreement pursuant to Art. 26 of Regulation (EU) 2016/679 (General Data Protection Regulation) and all partners that receive data out of this data pool have to sign a material transfer agreement with the consortium leader.

General approach for lameness prediction

As already stated, our approach is based on the relationship between lameness and the change in performance and behavior in cows. Performance is reflected in the changes in daily milk yield of the cow, which is retrieved from the milking systems. If automatic milking systems (**AMS**) are used, which a cow can access at any time during the day or night, milking intervals may also serve as additional indicator for a change in behavior or performance. The main information on behavioral changes however may be seen from the sensor data. Data on activity is provided by both systems, smaXtec and SCR. Various studies indicate that lame cows may show less activity and longer lying bouts (e.g. Weigele et al., 2018). Thus, the sensor data should help finding how behavioral patterns change in cows, which develop lameness.

The aim is to develop a decision support tool for farms, which is able to predict if a cow is at risk of developing lameness, based on these data. Changes in milk yield and behavioral patterns may however also have various other causes such as estrus, immanent calving or other diseases. Furthermore, lameness is a multifactorial disease and the risk of cow becoming lame may thus be influenced by different farm conditions. Therefore, data on farm conditions, management, reproduction, diseases and treatment will also be considered in the prediction.

Main challenges for implementation

Teaching the craft of data integration to machines

As a first step, the different data sets given in Table 1 were merged manually using the statistical software programs R version 4.0.5 (R Core Team, 2021) and SAS 9.4 ((SAS Institute Inc., 2016). In the course of this process, different parameters, formats and time scales were aligned and data were checked for duplicates, inconsistencies and implausible values. The information from this merging process should be used for the development of an algorithm to automate data reading and merging and to establish a control mechanism to guarantee for data quality. Along the way, we encountered various challenges, some of which were to be expected whereas others were not as foreseeable. One issue we were aware of having to deal with was the alignment of different recording intervals, time periods and also time zones. Sensor data for example were generated every ten minutes for each animal whereas lameness assessment was performed once every few weeks. This implied that sensor data and data from milking systems were assigned a time-date format whereas diagnoses and lameness assessments were recorded for a date only. Thus, we began exploring the data by using daily averages for the sensor data to fit the other data sets. Figure 1 illustrates the development of average daily activity and inner body temperature (smaXtec sensor system) of a cow including information on lameness scores, calving and insemination events and diagnoses.

However, the detection of changes in activity and temperature patterns may need a higher temporal resolution than daily average values. This may also require exact time stamps for some events such as beginning of calving or some metabolic diseases, which cause changes in activity or inner body temperature immediately or in a known relative time to this event (Adams et al., 2013; Burfeind et al., 2011). However, the latter may not always be easily available.

Information on parameter from herd mates will help to consider effects on changes in e.g. activity relevant for all the herd mates (Pfeiffer, 2020). To some extent, this is already considered in the indices calculated by the sensor software (e.g. activity indices).

One tool to predict them all?

The main goal of this work is the development of a decision support tool for dairy farms to predict if a cow is at risk of developing lameness. For this purpose, we developed a regression model using potential lameness predictors from the different data sets to best predict lameness events. Scientific studies with the aim of predicting lameness focused either on prediction at farm or herd level depending on farm-based data (e.g. Warner et al., 2020) or investigated the predictive potential of sensor or performance data only for cows of one farm and one type of sensor or milking system (e.g. Borghart et al., 2021; Grimm et al., 2019; Van Hertem et al., 2013). However, the present study aims at developing a prediction model, which applies to a variety of farms and thus will have to combine the prediction based on changes in sensor data and performance with the presence or absence of herd risk factors based on individual farm conditions. For example, if cows are put on pasture during summer or are kept in free stalls all year round may additionally influence the risk of developing lameness (Hernandez-Mendo et al., 2007). At the same time, provision of pasture may influence activity patterns themselves and thus has to be considered to avoid bias. Furthermore, activity patterns vary between farms with AMS and farms with conventional milking parlors and fixed milking times. Our regression model therefore has to be detailed enough to produce the best possible prediction for the individual farm while at the same time

being general enough to be applied to a variety of dairy farms.

Are you up-to-date?

A decision support tool for dairy farms has to be able to provide real-time decision support. Hence, actuality and continuous data provision are crucial for lameness prediction. However, data are recorded at different frequencies: sensor data is provided more or less continuously, milking systems usually record data twice a day, milk performance recordings as well as claw trimmings and lameness assessments are performed every few weeks and veterinary diagnoses and treatments depend on disease events. Thus, the system has to be able to consider this in the process of data retrieval, merging and providing information to the farmers. To enable that, a respective technical infrastructure is being developed in other work packages within the D4Dairy-project.

Auxiliary traits for genetic improvement?

The outcome from advanced technologies like precision livestock technology and advances in computational statistics (e.g. Artificial Intelligence, BigData) holds the promise that new parameters will be available also for breeding purposes (Heringstad et al. 2020). Besides the variety of systems, parameters and specifications of these new technologies interfaces to the databases used for genetic evaluation are largely missing. Within D4Dairy, auxiliary traits for prediction of claw health and other health complexes will be derived from indicators for health events based on validated sensor data in conjunction with other relevant information. Genetic parameters and their genetic correlations to already existing traits within the Total Merit Index will be estimated and based on the result a concept for inclusion of these novel indicators in routine genetic evaluation and breeding programs will be elaborated.

Conclusions and outlook

Challenges in the development of a decision support tool for lameness range from integrating different kind of data from different areas of dairy farming to the development of a suitable prediction model fitting various farm conditions. Currently, we are still working on the development and validation of the lameness prediction. Cooperation across different work packages is in progress comprising sensor data validation, model development, machine learning approaches for disease detection and technical solutions. Finally, as soon as promising predictors for lameness are available their genetic potential related to lameness and claw disorders and will be assessed.

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