Internet of cows – Opportunities and challenges for improving health, welfare and efficiency in dairying

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Abstract

With the growing world population, climate changes and the simultaneous increase in the demand for animal products challenges such as production efficiency, animal health, resilience and environmental impact are becoming increasingly important. Social sensitivity for animal welfare, appropriate feeding and housing and food safety is of increasing concern as well. Those changes in the production circumstances as well as the need for economical sustainability are reflected in broadening breeding goals. At the same time, new technologies are revolutionising the dairy industry. In addition to achievements in omics technologies (e.g. genomics, metabolomics), information and communication technologies (e.g. Internet of Things, sensor technology) are also finding their way into modern dairy herds. Instead of punctual measurements, sensors record animal behavioural patterns that allow drawing conclusions on animal health, animal wellbeing and welfare. The large amount of data generated by monitoring and the integration of various already existing data sources thus promise completely new insights into animal health and welfare. Optimised processes e.g. feeding improve efficient use of resources and reduce the daily workload of farmers. Better trait defintions are expected to result in higher heritabilities and higher genetic gain. Traditional data pipelines with information from performance recording in combination with indicators for metabolic disturbances, such as veterinary diagnoses, feeding information, test of ketone bodies, body condition score, and mid-infra-red spectra have existed for some time. With regard to metabolic disorders, they already provide more precise possibilities to predict health status than some traditional traits such as fat-protein-ratio. For claw health, information from claw trimming, veterinary diagnoses and lameness scoring has only been partly made available. Sensor technology provides alarms based on irregularities of normal behaviour for early detection of disordes. Advanced methodology offers the possibility to combine various environmental information and genomic background to gain new insights into the occurance of or susceptibility to disorders. To explore these opportunities, the big challenge is the integration of different data sources. In practice, data are often generated by different hardware and software products, which makes data integration more difficult due to different data exchange formats of the communication partners involved. Traits are defined differently by different products. Volume, velocity, variety and veracity of data are topics to consider. It is therefore necessary to create structures to bring these data sources together in order to provide farmers with maximum support for herd management. Another challenge of data integration from different sources is compliance with legal data protection regulations, since this is often associated with lack of clarity in practice. Cooperation between different partners and integrating different data is the precondition for successfully applying advanced data technologies based on complex trait definitions. Based on the COMET-project D4Dairy steps to overcome these challenges are presented.

Keywords: data integration, health, welfare, advanced data technologies.

Introduction

Growing world population with currently 7.5 billion, and 9.7 billion to be expected by 2050 (UNO, 2015)), demands for higher efficiency and sustainability. Climate change needs to be approached by reducing emissions but also by developing strategies that improve resilience on the levels of individual animals, farms, and the entire sector. Increased consumer concerns for food safety, animal health and animal welfare add to the urgency of these issues. Economic constraints result in growing farm sizes with pressure for optimization and sustainability and increased workload on farmers. Enormous technological progress and a rapidly increasing number of farms with various types of automation (automatic milking systems, animal sensors and feeding systems, ...) are observed worldwide. A recent survey amongst Austrian farms in the project D4Dairy showed that more than 30% of the farms with more than 50 cows are equipped with a milking robot and animal sensors with further expected increase. These advances offer many new possibilities and have the potential to change traditional structures within short time. A recent example is genomics where with decreasing prices for genotyping animal breeding has changed substantially in no more than ten years (VanRaden, 2019). Progeny testing has been widely replaced by genotyping and selecting calves for providing the next generation. Herd genotyping projects with more and more females being genotyped offer huge additional potential for the future. Advances in OMICS technologies with different technical tool boxes will give more insight in the origin of diseases (Wagner, 2018). A large variety of miniaturized low-power smart sensors in combination with low-power wireless communication and embedded data analytics is the base for implementation of highly integrated „real-time" alarm and decision support tools.

Many new phenotypes are being generated more or less automatically by different sensors and robotic systems. Artificial intelligence algorithms are deriving a wide range of predictors. Presently many systems are still stand-alone solutions with no or a low level of integration or communication between different data sources (Rutten *et al.* 2013). A survey conducted in Austria by farmers and veterinarians (Perner *et al.* 2016; Weissensteiner *et al.* 2018) revealed the importance of linkage of data. Farmers do not want to record the same information more than once nor do they want to have many systems for displaying the information. They expect the best service out of their data. The challenge is to link different data sources and knowledge across disciplines. Novel statistical approaches and machine learning techniques are needed to harmonize, integrate, and make sense out of such heterogeneous data. Multi-actor approaches are required to exploit these new possibilities towards the common aim of improving animal health, welfare and sustainability.

Current situation

Animal breeding has a long tradition of recording data and organising herd- and animal specific data in big central databases worldwide. The level of data integration differs across countries and organisations. Data from animal registration, performance recording and specific data related to breeding (conformation, marketing, ...) are routinely gathered; health data are becoming more and more integral part for breeding and herd management. Genome data and predictors based on advanced technologies like mid-infra-red spectra are increasingly available. Data from claw trimmers, labs, bulk milk from dairies, data from slaughterhouses and animal health organisations are partly centrally available. Presently, there is little communication between the new systems provided by the technology providers.

However, these data reside often in isolated silos along the value chain from production to the consumer with no or little communication across the chain. As of now, the potential of these systems in regard to efficiency or optimised tools has therefore been barely exploited. It follows that there is an urgent need for data linkage.

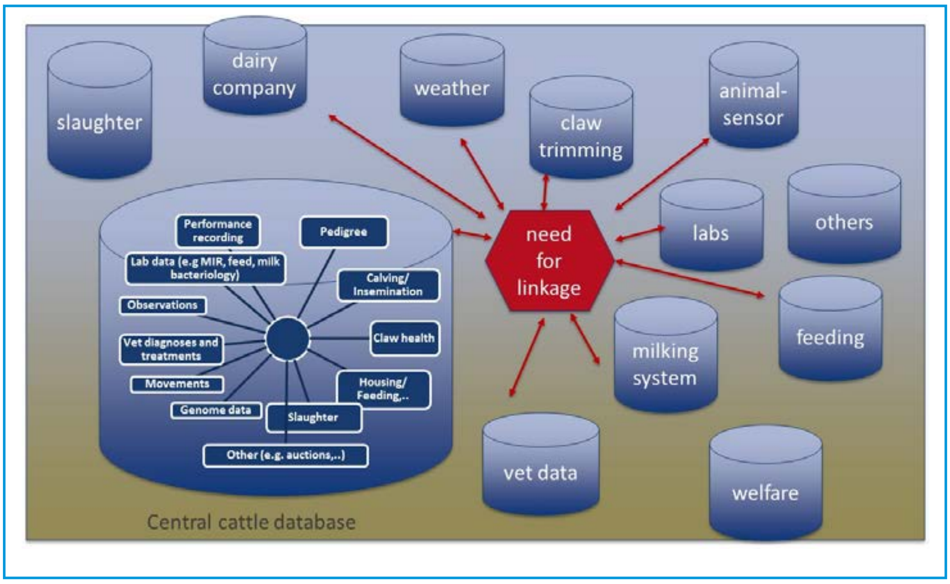

Figure 1. Overview over data sources within dairy cattle husbandry.

Opportunities

Due to recent technological advances, many novel phenotypes are coming up. Sensors measure activity in terms of lying or eating times, rumination and ph-values in the rumen, etc. Stangaferro *et al.* 2016 showed that based on reduction of rumination time ketosis can be predicted already 5 days in advance. The detection rate in this study was 91%.

A high level of data integration offers new possibilities of advanced methods of analysing data. Rutten *et al*. 2013 pointed out that so far little communication is between existing data streams and sensor systems. The potential of integrating various data sources (herd information, environment, economic aspects, etc.) to generate advice based on decision support tools is highlighted. If various data streams (ranging from the level of animals over herds to the environment, ...) are integrated, advanced statistical approaches are often required to make datasets captured across multiple scales of space and time "talk to each other" (Kivelä *et al.*, 2014). Approaches that computationally derive multi-layer networks from separate datasets can indeed disentangle causative relationships for diseases (Klimek *et al*., 2015). These networks serve as highly context-dependent book-keeping systems on what gene, metabolic pathway, or toxicogenomic substance interacts with which other for how long, how strong, and under which conditions in order to learn more about disease-causing relationships, going beyond mere correlations (Zanin *et al*., 2017). Beside more insight in risk factors and reasons for diseases, the new information is also expected to be more effective in genetic improvement of low heritable traits like health traits. The new information available almost in real time offers also now possibilities for decision support and monitoring of animal health and animal welfare.

There is the need to collect data, to integrate it and generate information, to analyse and generate knowledge and finally to provide support for decisions to farmers and other stakeholders that their action will result in better animal health, welfare and more sustainability (Figure 2). Process optimisation becomes possible when systems are communicating and exchanging information. For instance, optimised feeding will result in cost saving as well as more efficiency and sustainability in production. Beside better tools, a key factor is the reduction of work load for the farmer.

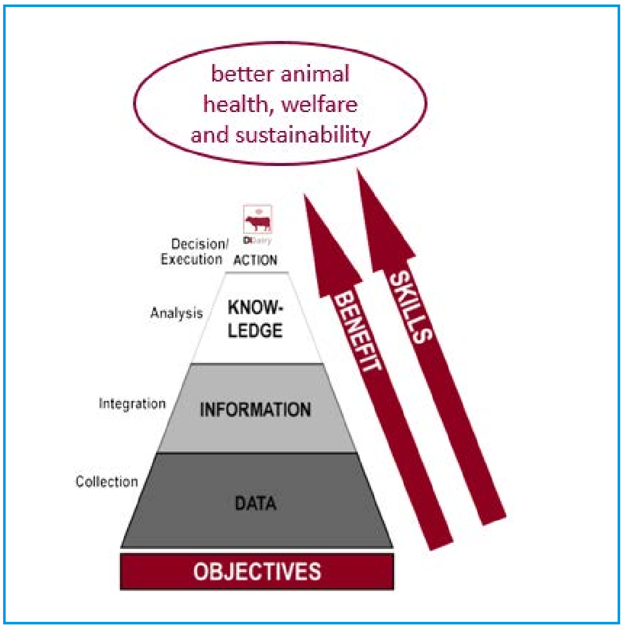

Figure 2. From data collection to decision support to improve animal health, welfare and sustainability.

Challenges

Interoperability of systems

Many different hardware and software systems underlying different standards and parameter definitions, leveraging different technologies and proprietary data analysis methods are available worldwide. The challenge is that this information has to be recoded in the right time in the right place. Moreover, it needs to be available without violating data privacy, transparency and data protection concerns of farmers, technology providers and data users. The key approach to overcome these challenges is by means of data sharing platforms. Examples of the state-of-the-art data exchange platforms are Nordic Cattle Data Exchange, JoinData or 365 Farmnet and others (Papst *et al*. 2019). To use these systems and truly benefit from the functionalities they offer the data providers and farmers need to develop trust in these technologies.

Data integration and data communication

The challenge with regard to data integration and data communication is beside the technical network also the harmonisation of data to address the issues of different data formats ("36 C" vs. "100100 Celsius"), data meaning and interpretation ("36 C" vs. "96.8 F"), and data quality ("36 C" vs "36.7 C"). The main challenge is to get access to the data. The question of data protection plays an important role, but also serves business and privacy interests (Römer, 2018). Standardization initiatives by ICAR are crucially important to address these challenges above and to reduce the redundant work of all involved partners. It is particularly important that the developed standards are used in practice!

Comparability of results / Standardisation

To meaningfully combine the data from different sources the key question is whether e.g., the results from different labs are comparable, and the results from different sensors are comparable. The study on harmonisation of bacteriological findings (Obritzhauser *et al.* 2019) revealed the importance of harmonisation of various steps in the lab processes to ensure comparability of the results. Harmonised coding is one issue but the source of the trait definition needs to be taken into account as well.

Data privacy protection

Another challenge of data integration from different sources is compliance with legal data protection regulations, since this is often associated with a lack of clarity in practice. Cooperation between different partners and integrating different data is the precondition for successfully applying advanced data technologies based on complex trait definitions.

Within the COMET-project D4Dairy the mentioned challenges and possibilities are approached and solutions for various examples are being developed.

Project D4Dairy

D4Dairy's overall goal is to provide digital support to dairy management via a data-driven, networked information system, exploiting the potential of advanced technologies and advanced data analysis (mid-infra-red spectra, genome information, etc.) to further improve animal health, nutrition, animal welfare and product quality. Based on the COMET-project ADDA the existing network along the milk value chain was extended by technology providers and science partners with the focus on new technologies to the D4Dairy consortium. In D4Dairy, 13 scientific partners and more than 30 industrial partners are working together towards common goals. The project duration is 4 years ending in 30.9.2022 with a budget of 5,5 million Euro.

The 4D Concept

Digitalisation: Optimisation of dairy industry production processes along the value chain with the exploitation of new digital possibilities.

Data Integration: Integration of farm data (central cattle database system, sensors, automated feeding systems, housing climate) and further integration of external data (e.g. slaughter data) with the aim of developing meaningful herd management tools for prevention and production control, quality assurance and workload reduction.

Detection: The application of new methods (big data analyses, results from MIR milk spectral data, antimicrobial resistance analyses) enables risk factors and informative parameters to be investigated and derived for early detection of diseases and/or treatment efficacy.

Decision support: Data-based decision support tools are developed, e.g. whether or not an animal should be dried off with antibiotics. Data on the pathogen status at the farm, disease history of the animal, environmental factors, … are processed electronically and a proposal, e.g. for vets, is prepared.

The project is organized in 2 areas and 9 subprojects where research is based mainly on a common dataset based on 100 farms with a high level of automation. Precondition for sharing data for the respective research question is trust of the farmers and involved data providers. Transparent legal arrangements and the accompanied technical solutions are the base for data driven research in the project. An overview of the research topics is given in Figure 3. More detailed information can be assessed under *www.d4dairy.com.*

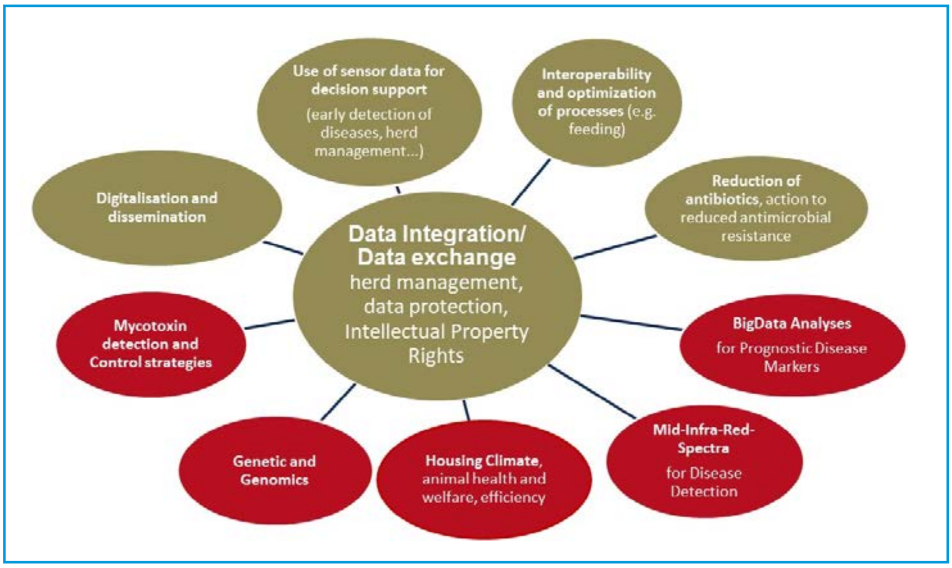

Figure 3. Overview of the main research topics within the D4Dairy project.

Conclusions

There are many new opportunities due to technological advances with the expectation to get better and more efficient tools for prevention, early detection as well as improving animal health, welfare and efficiency in general. Communication between systems can improve the benefit of these technologies for the farmer. Farmers do expect communication between systems while taking privacy and data protection seriously. The technical challenges due to interoperability of the systems, data exchange, and data harmonisation in the context of business interests of the involved parties and data protection regulations need to be solved to exploit the opportunities and benefits of Big Data analysis.

Multi-actor approaches are important. The key to success is a win-win cooperation with shared benefit. The overall aim is that „Internet of Cows" will benefit the farmer and the community by improving health, welfare and sustainability in dairying.

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