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PRECISION DAIRY FARMING

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ABSTRACT
Precision Dairy Farming generally refers to excessive use of technologies on individual animals to measure physiological, behavioral, and production indicators to improve management and farm performance. Many Precision Dairy Farming technologies, including Electronic (radio frequency) identification systems and associated management software Automatic recording devices (rumen temperature, pressure, pH) by electronic rumen bolus, Robotic milking systems daily milk yield recording, Automatic body condition scoring milk component monitoring (e.g. fat, protein, and SCC), pedometers, automatic temperature recording devices, milk conductivity indicators, automatic estrus detection monitors, and daily body weight measurements are already being utilized by dairy producers. This review provides preliminary information on the advances in PDF for dairy management.

Key words: Dairy, management, precision, techonology.

INTRODUCTION
Precision Livestock Farming (PDF) is defined as: "the application of process engineering principles and techniques to livestock farming to automatically monitor, model and manage animal production" and converting bio response into relevant information that can be easily applied to different management aspects focusing both on the animal and on the environment (Tullo et al., 2017).

To develop a PLF system, it is necessary to identify and classify the animal bio-response (labelling), i.e., animal behaviours, vocalization and parameters deriving from animals-environment interaction.

The following step is to develop the algorithm to model the target bio-responses and successively, the algorithm should be validated in order to verify if the predictions correspond to reality. In this way it is possible to model, monitor and control animal bio-response and provide accurate feedback to the farmer, thus his ability to keep contact with animals is enhanced.

Dairy cows stay longer in production when compared with any other farmed animals. Moreover, each animal unit is of a high economical value to the farmer. Therefore, for the dairy cow and, consequently, for the farmer, it is important to detect problems as soon as possible and to take action on an individual animal level. Precision livestock farming (**PLF**) systems offer a real-time monitoring and management tool for the farmer. They provide early warning to the farmer, so when something goes wrong during production, the farmer can immediately act on the information (Northon and Berckmans, 2017)

With cameras, microphones, sensors (such as 3D accelerometers, temperature sensors, skin conductivity sensors and glucose sensors), wireless communication tools, internet connections and cloud storage it is possible to automated monitor and control environmental, physiological and behavioral variables, ensuring livestock performance and well-being in relation to their environment without any disturbance or handling (Berckmans, 2014).

The primary goal of PLF is to make livestock farming more economically, socially and environmentally sustainable (Vranken and Berckmans, 2017). PLF can be applied to monitor animal growth and behavior, product yield, endemic disease and the physical environment of livestock buildings including the microenvironment and the emission of gaseous pollutants (Fournel et al., 2017).

WHAT IS PRECISION DAIRY FARMING?

Precision Dairy Farming is the use of technologies to measure *physiological, behavioral, and production indicators* on individual animals to improve management strategies and farm performance.

Many Precision Dairy Farming technologies, including *Electronic (radio frequency) identification systems and associated management software Automatic recording devices (rumen temperature, pressure, pH) by electronic rumen bolus, Robotic milking systems daily milk yield recording, Automatic body condition scoringmilk component monitoring (e.g. fat, protein, and SCC), pedometers, automatic temperature recording devices, milk conductivity indicators, automatic estrus detection monitors, and daily body weight measurements* are already being utilized by dairy producers.

Precision Dairy Farming as "the use of information technologies for assessment of fine-scale animal and physical resource variability aimed at improved management strategies for optimizing economic, social, and environmental farm performance Eastwood et al. (2004)

Precision Dairy Farming, with specific emphasis on technologies for individual animal monitoring, "aims for an ecologically and economically sustainable production of milk with secured quality, as well as a high degree of consumer and animal protection." Spilke and Fahr (2003)

USING AREAS OF PDF TECHNOLOGY

The decision to adopt a technology depends on factors such as management style, familiarity with computers, ease of use, type of housing system, and perceived benefit to cost ratio. Technologies monitoring various parameters are available to farmers and often these technologies fall into categories including:

Animal Nutrition	: Individual feeders, mixing equipment, and water supplies
Milk Production	: In-parlor controls and monitors
Animal Health	: Mastitis, rumen health, metabolic disorders, and body temperature
Fertility	: Estrus and calving detection
Environmental	: Temperature and milk line vacuum

POTENTIAL BENEFITS OF PRECISION DAIRY FARMING

Perceived benefits of Precision Dairy Farming technologies include;

- *Increased Efficiency,*
- *Reduced Costs,*
- *Improved Product Quality,*
- *Minimized Adverse Environmental Impacts, and*
- *Improved Animal Health and Well-being.*

These technologies are likely to have the greatest impact in the areas of;

- *Health,*
- *Reproduction, and*
- *Quality Control.*

Realized benefits from data summarization and exception reporting are anticipated to be higher for larger herds, where individual animal observation is more challenging and less likely to occur (Lazarus et al., 1990).

The use of precision technology is increasingly providing farmers with the means to reduce labor requirements and improve management of large herds (Bewley 2010, Eastwood et al. 2012 and 2015).

LOCATION OF ENGINEERED DEVICES FOR IN SITU DATA COLLECTION IN A COW: (Caja et al, 2016)

- *Ear tag*
- *Halter*
- *Neck collar with counterweight*
- *Reticulo-rumen bolus (in reticulum)*
- *Eear leg pedometer*
- *Upper tail ring*
- *Tail head inject*
- *Vaginal bolus*

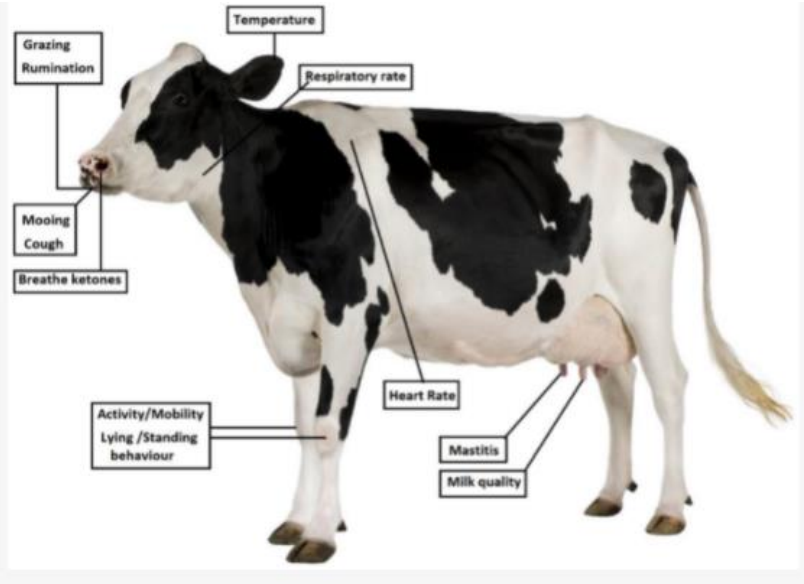

Fig. 1. Technical components of the RumiWatch noseband sensor (Nils Zehner)
Areas to monitor a dairy cow

TECHNOLOGIES USED IN PDF

Science and technology offer opportunities for further innovation in dairy production. Some of the precision farming tools that may have value on dairy farms in relation to feeding and nutrition, monitoring of animals or herd are as follows:

Milk yield and milk electrical conductivity

Electrical condutivity of milk are used to predict clinical mastitis and when treatment is initiated early (Milner et al. 1996). Milking systems that provide data on milk production and milk electrical conductivity provide in-depth information on each animal. It was observed that significant changes in milk yield and electrical conductivity could be observed as early as 10 days before diagnosis of an adverse health event (Lucas et al. 2009). It was demonstrated that the effect of diseases on milk yield started as early as 5 days before diagnosis of a disease and lasted for more than 140 days post diagnosis (Bareille et al.2003).

Walking activity

Daily walking activity can be used as a tool for early detection of various potential disorders in dairy. An automated system called "Pedometer" that helps in scrutinizing both walking activity and milk production in a dairy farm. The tool could be used to observe dairy cows in their daily movements, including milking, eating, standing, and lying, and can detect changes in this measurement (Edvard and Tozer, 2004).

Estrus detection systems

In the late 1980's and early 1990's, research into the use of pedometers to detect estrus was carried out (Holdsworth and Markillie 1982, Redden et al. 1993). More recently, 3D-accelerometers are becoming available and are used to detect estrus (Valenza et al. 2012, Lovendahl and Chagunda 2010) and assist in undertaking estrous synchronization. Besides these activitybased automated estrus detection systems, other systems are also available, for instance, a progesterone measuring system (Friggens and Chagunda 2005). The detection system may be combined with a system to optimize the time of insemination. For some individual cows it can be economically beneficial to extend the time of insemination (Steeneveld et al. 2012). Besides these activities based automated estrus detection systems, other systems are also available, for instance, a progesterone measuring system (Friggens, 2005). The detection system may be combined with a system to optimize the time of insemination. For some individual cows it can be economically beneficial to extend the time of insemination (Steeneveld et al. 2012).

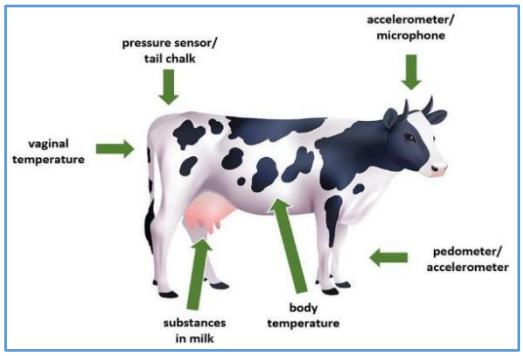

Fig.2. Estrus detection aids for dairy cattle
Source: uploaded by István Fodor

Automatic Body Condition Scoring

Body condition scoring (BCS) is a method to evaluate fatness or thinness in cows that can be utilized to adjust dairy herd nutrition and improve the health of the cow. It is usually determined visually and manually by experienced experts to calculate body reserves and conducting body condition scoring and evaluate each animal. Roche et al 2009 stressed out the significance of body condition score for animal. Automated Body Condition Scoring (BCS) through extraction of information from digital images has been demonstrated to be feasible; and commercial technologies are under development. Ferguson et al. 2006 assessed the ability to assign a BCS to a dairy cow directly from digital photographs.

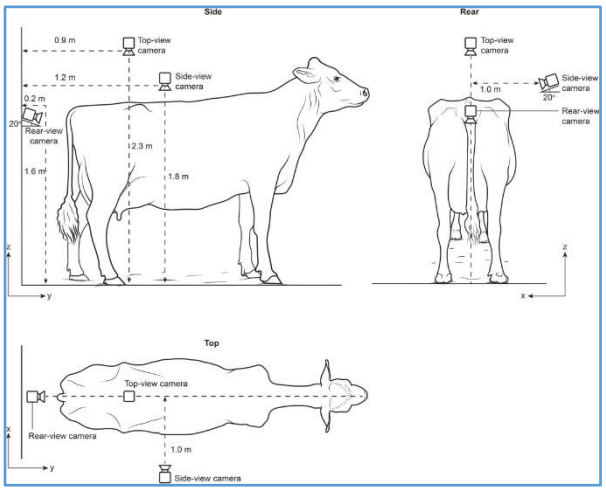

Fig3. Image recording setup showing the mounting positions and angles of the three cameras (Song et al. 2019)

Feed Intake

The health and productive output of dairy cows can be closely correlated to individual cow feed intake. In order to monitor feed intake on a daily basis is important for management. This kind of indication would help to suggest intervention that could reduce the risk of different ailments. It is suggested that cows with big drop in dry matter intake just before calving may be at risk for metabolic disease such as fatty liver and / or ketosis (Grummer, 1995)

Several studies have focused on feeding behaviour in terms of feed intake and production using commercially developed equipments which are readily available for monitoring activity at the feeder. Using an electronic feed monitoring system, Sowell et al. (1998) found that healthy animals spent more time at the feed bunk than morbid animals, and a greater percentage of healthy animals visited the feed bunk immediately following feed delivery.

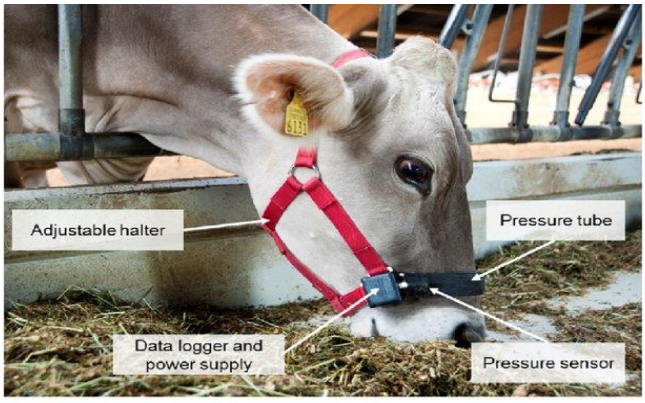

Fig.4. Controlling feeding behaviour by equipment. This figure was uploaded by Nils Zehner

Rumination Collars

A rumination collar uses a microphone to measure a dairy cow's rumination to help ensure a smooth transition period. Changes in rumination can be an early sign of calving diseases, negative impacts of recent ration changes, cow comfort, etc. Knowing normal rumination patterns for your specific dairy cow can help mitigate the effects of manageable stressors, such as heat stress. The data can be used to help dairy producers treat those cows and minimize any negative impacts.

Rumen Bolus

A rumen bolus measures rumen temperature and pH levels to help identify any systemic infections that need to be treated. If a rumen bolus tells a dairy producer that a cow's pH is dropping, it is a sign that a total mix ration (TMR) isn't mixed thoroughly, sorting is taking place, or a ration change is having negative impacts. This can help a producer make appropriate changes to their dairy cattle nutrition program.

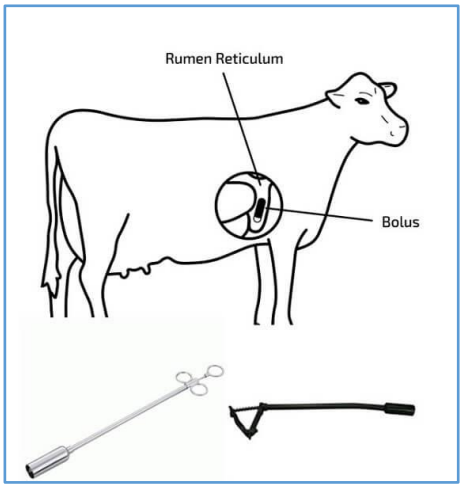

Fig. 5. Application of rumen bolus

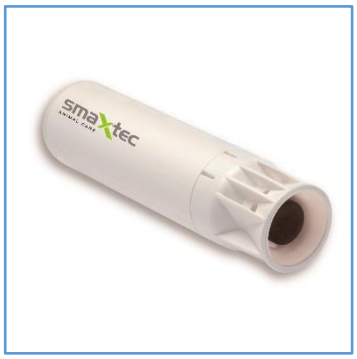

Fig. 6. Rumen Bolus

CONCLUSIONS

Precision Dairy Farming technologies gives tremendous opportunities for improvements in individual animal management on dairy farms. Combined techonological devices will provide crucial data that measures cow comfort, which can then be extrapolated to make changes in the dairy's facilities. PLF will offer new opportunities to increase the efficiency and sustainability to dairy farming to improve the health and welfare of animals and to support traceability across the entire supply chain by providing to the consumer with some assurance of food safety.

Using advanced sensitive Technologies in dairy practices provides benefits to the farmer. However, obtaining of the desired benefit from the systems is only possible with their effective use. Animal related large amounts of data obtained on many subjects, pertaining to herd management and to individual animals unless it is used continuously in decisions to be made, advantage of dense data flow will not. On the other hand, these systems users' hardware and must be able to use the software effectively.

Precision dairy farming technologies provide tremendous opportunities for improvements in individual animal management on dairy farms. In the future, Precision Dairy Farming technologies may change the way dairy herds are managed.

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