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Precision Dairy Farming: The New Era in Dairy Farming

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A B S T R A C T

India has world's largest livestock population and 1st rank in milk production with 187 million tons in 2018-19. Dairy farming is the single largest contributors to Indian GDP with 5.1 % in 2018-19 and annual growth rate in Livestock sector is 4.6%. Indian dairy production is characterized as a low input/low output system. In general, milk productivity of dairy animals is very low in comparison to global standards. The lower milk yield is mainly due to low genetic potential, lack of nutritional feeds and inadequate veterinary services. So, with suitable and scientific approach production efficiency can raise. In this context, Precision dairy farming (PDF) aims to improve individual animal performance, well being and socio-economic status of dairy farmer. Today, traditional dairy farming becomes organized commercial business with technological specializations in every part of the process. Thus, farmers are shifting towards adopting modern dairy farming practices for increase their production. PDF is the use of information and technology based farm management system to record physiological, behavioral and production parameters of individual animals to improve management strategies, profitability and production performance. There are so many important precision dairy farming technologies available globally, which are routinely useful for large and commercial dairy farm. In this direction, the authors have also highlighted the status of adoption in Indian scenario, benefits, challenges and limitations of precision dairy farming technologies. Many developing countries including India are in initial stage in these advance technology, but there are tremendous opportunities for betterment of animal and upliftment of animal husbandry profession.

Introduction

In India, dairy farming is integral part of agriculture and playing back bone role in rural area. India stands in first position in total milk production and total livestock population in world.

Also, dairy farming has become very popular business from tradition Animal husbandry in over last decade. However, narrow profit margin, labour shortage, health issues and other factors in dairy farming has intensified the drive for increasing the production and efficiency.

Advancement in technology has allowed farmers to improve everyday quality of life of their herds. Changes in dairy farm operations can be attributed to tremendous technological progress in genetics, nutrition, reproduction, disease control and livestock management. Philpot (2003) apprehended these changes in describing the Precision Dairy Farming as "technological marvels".

Precision Dairy Farming (PDF)

Schulze *et al.,* (2007) explain PDF as: system is constructed of the following components: a sensor that generates data, a model that gives a physiological interpretation of the data, a management decision making process and finally decision execution.

The PDF systems can be divided into two categories: those used for diagnostic and those used for management and the same sensor can serve both categories.

Bewley (2010) described PDF as 'the use of technologies to measure physiological, behavioral, and production indicators on individual animals to improve management strategies and farm performance'. He also states that the objectives are to maximize individual animal potential while facilitating early disease detection and minimizing medication use.

Eastwood *et al.,* (2012) defined 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".

Objectives of precision dairy farming

Maximizing individual animal potential, detecting diseases earlier - early detection of disease reduces the cost of disease to the farm and increases the length of animals' lives with minimizing the use of medication through preventive health measures (Schulze *et al.,* 2007).Dairy technology playing a vital role in producing high yields and it is making cow comfort and healthier.

Berckmans, (2003) stated that using technologies to monitor farm animals is useful as long as technologies continuously monitor parameters, reliably observe behaviors, and accurately describe behaviors with reliable algorithms.

Technology adoption can improve or maintain animal welfare on dairy farms and help to improve public perception by demonstrating the dairy community's commitment to developing welfare improvement strategies (Rutten *et al.,* 2013).

Cow's challenges in large dairy farm

Finding cow in heat

Identify and treating lame cow

Finding and treating cow with mastitis

Catching sick cow in early lactation

Feed intake monitoring

Rumen health (pH/rumination time)

Body condition

Growth Scenario in Precision Dairy Farming

1970 (Development of individual cow ID) → 1980 (Sensors for disease detection) → 1990 (Automatic milking) → 2000 (Revival of sensor)→ 2010 (New generation of sensor)

Potential Benefits of Precision Dairy Farming

Benefits thought to come from Precision Dairy Farming technologies include increased efficiency, reduced costs, improved product quality, minimized adverse environmental impacts and improved animal health and well-being (Chaudhary *et al.,* 2016).

PDF give more timely and alert decisions. Singh *et al.,* (2014) explained that Clinical symptoms are typically preceded by physiological responses not seen by the human eye (for example, changes in temperature or heart rate). Thus, by identifying changes in physiological parameters, a dairy manager may be able to intervene sooner.

Ideal PDF technology

Modern dairy farming is constantly looking for new innovations and the advanced can boost milk yields, enhance milk quality and reduce the costs associated with producing the white stuff.

There are certain aspects of farm management which if handled through technology can reduce costs and make operations efficient. Some amazing tools used by some dairy farmers across the world, for making a profitable business.

Explains an underlying biological process

Can be translated to a meaningful action

Low-cost, flexible, robust, reliable

Information readily available to farmer

Farmer involved as a co-developer at all stages of development, not just beta-testing

Commercial demonstrations, continuous improvement and feedback loops

Precision Dairy Farming Technologies

Radio Frequency Identification System

Radio frequency identification (RFID) is one of the advanced and efficient identification technologies in recent years and is widely adopted by various dairy industries (Singh *et al.,* 2014). Electronic identification (EID) systems have provided a technological approach to the previously intuitive process of individual cow management. RFID systems provide accurate identification of cows and linked to pedigree, management events, treatment records, electronic milk meters, computer controlled feeding, automatic sorting and weighing, etc. Radiofrequency tags can be used to record animal events such as heat detection, treatments, calving interval, sire selection, etc. This can result in increased production and profitability by allowing better management of an individual cow's performance through the analysis of the collected data.

Some organized farms in private sector in India have adopted RFID based animal identification and farm automation management system,

Chitale Dairy in Pune, Sangamner Milk Union, Maharashtra, Lakshya Dairy in Haryana and Kopordem Farm at Valpoi in SattariTaluk in North Goa.

Automatic Body Condition Score & Body Weight

Mullins *et al.,* (2019) studied the Body condition scoring (BCS) is a tool traditionally used to assess body reserves of individual animals. Only a few dairy farmers have integrated body condition scoring based on visual evaluation in their daily management strategy mainly because it is fairly time consuming and subjective (Rathod and Dixit, 2020). 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. Body condition scores are often used as a critical measure of how effective feeding is on a farm.

Mullins *et al.,* (2019) evaluated validation of a commercial automated body condition scoring system on a commercial dairy farm with pearson correlation for cattle body condition scores (scale 1 to 5, low to high, n = 343) for continuous and categorical automated camera scoring versus manual scoring averages (MAN).

Daily Body Weight

Measurement of live weight (LW) is an established method for monitoring the performance of intensive and extensively managed cattle. Individual animal LW and estimates of LW change have relatively recently been used as tools to aid in the management of dairy herds. Changes in body composition and LW have been associated with dairy cow health; fertility and milk yield (Alawneh *et al.,* 2010).

Automatic Recording Devices (Rumen Temperature, Rumination, pH)

Determination of ruminal pH, temperature and rumination in animals can be crucial to suppress the occurrence of health problems such as sub-acute rumen acidosis and bloat (Singh *et al.,* 2014). Bolus containing a mote (temperature sensor, processor and radio) was placed in the rumen of a fistulated cow to monitor body temperature and rumen temperature was measured every minute and stored in the internal buffer of the mote. For monitoring ruminal fluid pH, a permanent device in the rumen is required to continuously monitor rumen pH remotely without interfering with the normal behaviour of the animal. Several methods have been developed for automated, non-invasive measurement of chewing activity in ruminants by detection of jaw movements via strain or pressure sensors fitted to a halter (Zehner *et al.,* 2017). Pereira *et al.,* (2019) studied feeding behaviors from Rumi-Watch compared to direct visual observations in crossbred dairy cattle and got significant correlations between these.

Robotic Calf Feeding

Singh *et al.,* (2014) reported that robotic calf feeding system consists of the following four parts:

The calf feeder unit that mixes milk replacer with water

The processor for controlling the feeder and data processing

The transponder around the neck of the calf for identification

The milk feeding stall where the calf drinks the milk

Computerized automated feeders can feed whole milk, milk replacer, or combinations of the two to individual calves in a controlled manner according to a predefined feeding plan. This technology provides individual animal data that can be used to more precisely manage the herd. Each calf as identified by their EID. Automated systems for feeding calves controlled by computer are in great demand because of the benefits of saving labour (Mihaela and Mugurel, 2017).

The benefits of the automatic nutrition are: accelerated growth rate, a better development of the rumen, manage individual calves, constant and precise temperature milk, flexible hours feeding, weaning without stress, flexibility of work, time economy, suitable for farms of all sizes, reliable and low maintenance.

Feeding Behaviour and Feed Intake

Overton *et al.,* (2002) reported that feeding behaviour of dairy cows traditionally has been determined using intensive research procedures,

such as direct observation and time-lapse video recording. Automated recording devices for measuring feeding behaviour and feed intake of cattle are being used more and more widely (Chizzotti *et al.,* 2015). The development of automated monitoring systems that can continually and accurately quantify feeding behaviour could provide an early warning tool for efficient monitoring and control of modern and automated dairy farms. Abnormal feeding and drinking behavior and decreased activity are often considered to be indicative of more general problems.

Develop a system for automated dry matter intake monitoring by using machine vision (3D imaging). Inexpensive system for monitoring feed intake for multiple animals and automatic recording of feed disappearance. Allow for more precise feeding and quantify individual animal intake (Shelley, 2013).

Automated Feeding System and Feed-dropping Control Unit

Feeding is often the biggest expense on any dairy farm. The labour costs related to and the feed itself amount to up to 70% of any farms' production costs. Making feeding methods more efficient does not just save costs, it increases milk yields. Automated feed units provide a variety of benefits to farms, including reduced labour, cost savings, removal of possibility for human error, and of course the ability to automatically calculate and provide the required amount of feed for cows to sustain or increase in their milk production.

Feed bins that have the ability to automatically drop a designated amount of feed into the feed trough of each individual cow have been demonstrated to be highly effective in dairy farms. Calculations are made according to lactation stage, pregnancy, yield, and body condition.

The system can both mix and deliver feed to the cows with limited intervention. It begins with an automated feed mixer, which is the only part that might need to be manually fed by a human. The unit mixes feed and, using a conveyor, fills a rail-suspended feed wagon when demanded by the computer interface that runs the system.

Robotic Milking

Milking robot is a part of automatic milking system, having a sensor system to locate the position of the teats and a manipulator to attach the milking unit to the teat. Robotic milking parlour standardized milking routine takes place completely free of stress. The cow steps calmly straight onto the rotary milking parlour. In seconds, the Milk-Rack attaches the teat cups. The entire milking process takes place in the protected environment of the liner, from cleaning and stimulation to individual quarter milking and dipping.

Singh *et al.,* (2014) studied the Sensor systems for milking robots identified several distinct sensing tasks as below

Animal identification

Teat location

Monitoring Automatic Milking System functions

Ensuring proper machine function

Protecting people and animals from injury

Measuring milk quantity and composition

Monitoring other aspects of Animal health

Somatic Cell Counter

Monitoring of SCC concentration in milk is the most implemented indicator to monitor mastitis, especially, in subclinical forms (Addis *et al.,* 2016). In general, SCC values above 200,000 cells/mL of milk are considered an indication of inflammation and subclinical mastitis. Color variation (red, blue, and green) sensors have been included in some automatic milking systems to detect blood in milk

and color pattern changes in infected quarters. Spectroscopy or the measurement of changes in light, (visible, near-infrared, mid-infrared, or radio frequency) has been applied in commercial sensors systems to identify changes in milk constituents including SCC and mastitis-causing pathogens (Brandt *et al.,* 2010).

Automated Estrus Detection

Estrus behavior in dairy cattle is accompanied by increase in physical activity and automated activity monitor systems are useful tools for detection of estrus. Benaissa *et al.,* (2020) reported that to detect estrus in high density livestock farms, farmers increasingly rely on automated systems using sensors (e.g., accelerometer, pedometer, pressure sensor etc.) for the collection and the interpretation of animal data. Kiddy was the first to use leg mounted pedometers to determine whether physical activity related to estrous varied enough compared with non-estrus animal. Activity seems to increase during heat, activity meters can detect heat by measuring the (increase in) activity of the cow by using accelerometers.

Parturition Sensor

Several parameters have been identified to predict calving events. Pedometers and accelerometers may have a future in calving prediction (Borcher and Bewley, 2015).

Using technologies to predict difficult calving through behavioral changes may allow for special procedures or treatments to be implemented, reducing stress that may otherwise be caused by difficult calving (Miedema *et al.,* 2011).

Status of precision dairy farming in India

In India, few farms/ organizations have adopted precision technologies which were developed with the help of Indian and foreign companies in dairy farming sector. In the year 2000, the National Livestock Identification Scheme (NLIS) made the use of RFID tags that provide accurate identification of cows and are linked to pedigree, management events, treatment records, electronic milk meters, computer-controlled feeding, automatic sorting, weighing etc.

National Dairy Development Board (NDDB) has developed an Information Network for Animal Productivity & Health (INAPH), a desktop/ net book / android tablet-based field IT application that facilitates the capturing of real time reliable data on breeding, nutrition and health services delivered at farmer's doorstep. COWEL is a computer-based decision support system that contains attributes regarding housing and management conditions.

AFIMILK is an innovative management system which provides a professional and comprehensive tool to make day-to-day herd management decisions. SARSA Green in West-Bengal has developed the Geographical Information System for integrated dairy farm management which helps in integrating the whole dairy farm in a more precise way to get correct information about various aspects.

Mumbai Veterinary College under the leadership of Dr. Abdul Samad developed software, known as Herdman, which was used in conjunction with the animal Radio Frequency Identification Device tags (An active RFID tag) and cell phones' text messaging capability, in order to access information regarding cows and buffaloes. Farm Tree is another handcrafted tool to enrich dairy farmers with the ability to use data to unleash massive economic value across the dairy farmers in different Indian states.

Potential Limitations of PDF

Information obtained from precision dairy farming technologies is only useful if it is interpreted and used effectively in decision making.

Slow adoption rate due to uncertain return on investment, high fixed costs of investment and information acquisition.

Table.1

Data Compared	p-Value	r	n
Continuous camera vs. MAN	<0.001	0.78	343
Categorical camera vs. MAN	<0.001	0.76	343

Table.2 Currently available engineered devices for monitoring oestrus

Oestrus activity behaviour	Device location
Cow Manager, SensOor, AgisAutomatisering (Harmelen, NL)	Ear
Cow Alert, Ice Robotics (Edinburgh, Scotland, UK)	Leg
Cow Scout, GEA (Düsseldorf, DE)	Neck or leg
Activity meter, De Laval (Tumba, SW)	Neck
Silent Herdsman Afimilk (Kibbutz Afikim, IL)	Neck or leg
Heat Seeker, BouMatic (Madison, WI, USA)	Leg
GyuhoSaaS Fujitsu (Fukuoka, JP)	Leg
Heat Phone, Medria (Chateaubourg, FR)	Neck

Animal ID may sometime read errors.

Equipment failure may occur because often they are sophisticated to handle, low temporal resolution, and require good visibility of the subjects.

Data transfer error may be due to over-supply of data, and the time-consuming handling of software programme.

Lack of validated research results concerning the effects of application, high capital input and high costs.

Applicable to a restricted spatial area.

PDF is a new golden era of dairy industry. PDF technologies provide tremendous opportunities for improvements in individual animal management on dairy farms. Combined, all devices will provide data that measures cow comfort, which can then be extrapolated to make changes in the dairy's facilities. Cow comfort can lead to better overall health, which lowers the cost of animal care and/or treatment and can increase animal longevity and boost milk yield.

Future Vision

New era in dairy management. Exiting technologies available and in development. New way of monitoring and improving animal health, well-being & reproduction. This analytic tools will be source of competitive advantage and economic and people factors will determine adaptation and success.

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