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Precision Dairy Farming: A Boon for Dairy Farm Management

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Abstract:- In India, dairy farming is integral part of agriculture and playing back bone role in rural area. India stands first position in total milk production and total livestock population globally. Improving animal welfare on the farm can amplify profits, as it has the potential to reduce costs related to healthcare and poor yields and as such, improve the sustainability and efficiency of dairying (Cozzi *et al*., 2008). Advancement in technology has allowed farmers to improve everyday quality of life of their herds. Precision dairy farming (PDF) aims to improve individual animal performance, well being and socio-economic status of dairy farmer. Thus, farmers are shifting towards adopting modern dairy farming practices to 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 several precision dairy farming technologies available globally, which are routinely useful for large and commercial dairy farms such as electronic identification systems, automatic body condition scoring, automatic recording and milking systems, daily milk yield recording, milk component monitoring, daily body weight gain measurement, automatic calf feeding systems, pedometers, milk analyzer, calving detection etc.

Precision dairy farming technologies provide tremendous opportunities for improvements in individual animal management on dairy farms. 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. Many developing countries including India are in initial stage in this advance technology, but there are tremendous opportunities for betterment of animal and upliftment of animal husbandry profession. Effective coordination among the public sector, private sectors and farmers is, therefore, essential for implementing precision dairy farming to achieve fruitful success.

Keywords:- *Dairy Farming, Precision Dairy Farming Technologies, Information and Technology, Individual Animal Management, Profitability.*

I. 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. The dairy industry in the developing world has undergone profound changes over recent decades. Economic pressures, technological innovations and consumer demands have contributed to the evolution of the global dairy industry. Economic pressure demands increased efficiency of dairy production, which came with high-yielding dairy cows and large flocks. Almost the next three decades, the demand for different types of meat and animal products is expected to rise by over 70% worldwide. This means that there is more animals must be produced using the available land, water, and other natural resources. Second more than half of the world's population is connected to the internet either through computers or smart phones. It is estimated that farmers need to increase production by 70% over the next 50 years to meet the growing global demands of meat and animal products (Rojas-Downing *et al.,* 2017).

Today, traditional dairy farming becomes organized commercial business with technological specializations in every part of the process. In India, the dairy industry is continuously rising and faces shortage of skilled man power, and at present, about 20-25% milk is handled by organized sector and 75-80% milk handled by unorganized sector, so there is need to adopt advanced technologies like PDF for quality milk production and supply of safe and hygienic milk to consumers. Thus, farmers are shifting towards adopting modern dairy farming practices for increase their production. Advancement in technology has allowed farmers to improve everyday quality of life of their herds.

Precision dairy farming (PDF) aims to improve individual animal performance, well being and socio-economic status of dairy farmer. Different scientists, academics, researchers define Precision Dairy Framing (PDF) in a number of ways. Simply, it can be defined as the potential use of technologies to optimize the contribution from each of the animals in a dairy farm. Through “per animal approach” one farmer can deliver better results in terms of quantity and quality for more sustainable dairy farming. PDF is the use of information and technology based farm management system to record physiological, behavioral and

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production parameters of individual animals to improve management strategies, profitability and production performance. 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. PDF refers to the use of technologies that makes farmers less dependent on human labour, supports them in their (daily) management and helps them to improve their farm profitability (Kamphuis *et al.,* 2015). Recently the concept of precision dairy farming has been introduced for monitoring of individual animals through sensor-based management tools and robotic equipment that automatically delivers individual cow management applications. The 'Precision Dairy Farming' can offer a new 'technological marvel' in dairying in coming scenario.

II. MAJOR CHALLENGES IN LARGE DAIRY FARMS

Quality milk production, Estrous detection, Calving detection, Animal tracking, Identification of lame cow, Early mastitis detection, Identifying sick cow in early lactation, Feed intake monitoring, Rumen health, Body condition.

➢ *Benefits of Precision Dairy Farming*

The PDF has a number of benefits that are often not immediately apparent and require additional management expertise, time investment and money to realize. The PDF will maximize the economic, social and environmental returns to farms. Some of the important benefits include:

- **Maximizing individual animal potential**
- **Lactation:** Technologies are used in measuring the daily milk yield, individual milk components (fat content, protein content, lactose) and color (as an indicator of cleanliness). It helps in increasing efficiency, reducing costs, improving product quality, minimizing adverse environmental impacts.
- **Reproduction:** It also helps in monitoring automatic estrus-detection, vaginal mucus electrical resistance and progesterone (Borchers and Bewley, 2015).
- **Feeding habits:** It helps in monitoring feeding behavior, jaw movements, ruminal and reticular contractions and ruminal pH.
- **Locomotion:** PDF helps in monitoring gait, animal positioning and activity, lameness and lying behavior.
- **Vitals:** PDF helps in monitoring respiratory rate, heart rate and body temperature.
- **Body condition score:** Adipose tissue deposition, musculature, daily body weight measurements are assessed by use of technologies associated with Precision dairy farming.
- **Early detection of disease**: PDF helps in early detection of disease which reduces the cost of disease to the farm, animal sufferings and increases the length of animals' lives. Minimize the use of medication through preventive health measures (Schulze *et al.*, 2007).
- **Supplements observation activities of farm personnels**: Precision dairy farming technologies supplement the observations of farm personnels, which is especially critical as more cows are managed by fewer skilled workers. As dairy operations continue to expand, Precision Dairy Farming technologies are becoming more achievable due to the increased dependence on less skilled labour and the ability to take advantage of the large economies associated with technology adoption.
- **Timely Decision making:** Precision Dairy Farming technology enables dairy farmers to make more timely and informed decisions, leading to increased productivity and profitability (Van Asseldonk *et al.*, 1999).

➢ *Components of Pdf System*

PDF system is consist of the following components: a sensor which generates data, the resulting data can be sent to the cloud, a model that provides data interpretation by using Internet of Things, a management decision making process and ultimately the implementation of the decision (Figure:01) (Chao-Hsi *et al.,* 2015). Integrated computer-based information systems are essential to interpreting the massive amounts of data obtained from Precision Dairy Farming technologies.

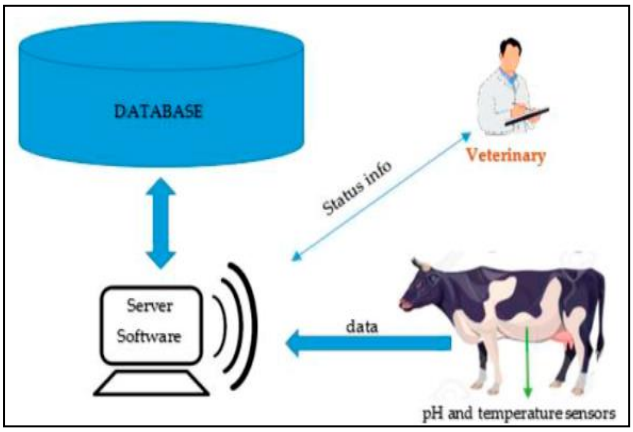

Fig 1: Decision implementation process

➢ *Sensor*

A sensor can generate and collect the data for interpretation by a human or a machine. Advancements in sensing technologies made it possible to increase the availability of sensors in dairy farming. Systems that monitor the behaviour of each animal, such as rumination, estrus, location, or rumen pH, also become available (Zehner *et al.*, 2017). There are numerous optical and movement sensors available for assessing the fat and protein content of milk as well as the reproductive health of cows. These gadgets can convey movements like a cow walking, drinking, eating, or lying down with accuracy. Prior to becoming serious, health issues like mastitis or lameness may be identified. These sensors can identify unwell animals, enabling farmers to treat them right away and stop the spread of disease.

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➢ *Location of various sensors for data collection in a dairy animal (Figure: 02):*

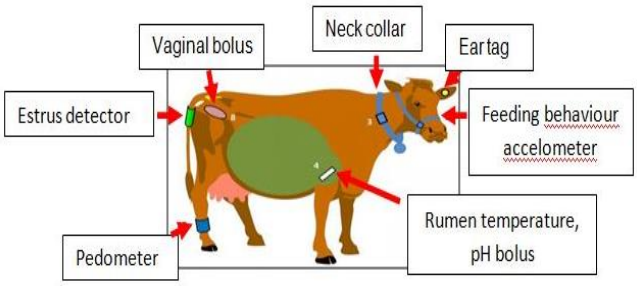

Figure 02 : Location of various sensors for data collection

III. PRECISION DAIRY FARMING TECHNOLOGIES

Modern dairy farming is continually looking for new ideas. The most recent developments in dairy farming can increase milk yields, improve milk quality, and lower production costs. There are certain aspects of farm management that, when managed technologically, can lower expenses and improve productivity. Some dairy farmers across the world use some incredible tools to run lucrative operations. Dairy management and control activities can sometimes be automated (Delorenzo and Thomas, 1996). There are so many important precision dairy farming technologies available globally, which are routinely useful for large and commercial dairy farm.

A. Electronic (Radio Frequency) Identification Systems

Animal identification is very necessary to analyze the activities of animals that directly predict an animal's health status and progress of any animal production unit. Previously intuitive processes for managing individual animals have been improved by the use of electronic identification (EID) systems. In recent years, radio frequency identification (RFID) has become one of the most advanced and efficient identification technologies and has been widely adopted by the dairy industries (Singh *et al.*, 2014). National Livestock Identification Scheme (NLIS) RFID tags were introduced in 2000. These tags contain a microchip that can be read electronically by producers who have a suitable RFID reader in a fraction of a second.

In addition to accurate animal identification, management events, electronic milk meters, computer controlled feeding, automatic sorting and weighing, and records of animal events like heat detection, treatments, calving interval, sire selection, etc., the system enables the automation of the farm management system with reduced labour costs. By enabling improved management of an individual animal's performance through the analysis of the gathered data, this can lead to an improvement in production and profitability.

B. Automatic Lameness Detection

Following mastitis and reproductive issues as the leading causes of financial losses on dairy farms, lameness comes in third. Lameness is typically detected when the illness is already advanced and requires rapid, frequently costly treatment. An alert system to predict incidence of lameness early is essential.

Early identification could prevent lameness situations from worsening, hastening rehabilitation, boosting output, and enhancing welfare (Daros *et al.*, 2020). There are some Precision dairy farming techniques for early detection of lameness-

➢ *Image Processing Techniques*

Image processing methods examine the animal's posture as it passes through an alley or heads to a milking parlous. The use of 2D or 3D video camera solutions in lameness monitoring systems is possible with this method. The back posture is typically assessed to gauge the severity of lameness in the 2D and 3D image systems and values are automatically retrieved from the cows' top views (Van Hertem *et al.*, 2014). The variance in each cow's back position indicates lameness for one cow but a regular gait for another.

➢ *Activity-Based Techniques*

Accelerometers (2D and 3D) are frequently used in activity-based procedures to record the animal's movement patterns. The everyday behaviors of the cow, such as walking and lying down, are then constructed using the data. The development of automatic lameness detection systems using accelerometers has advanced steadily in recent years (O'Leary *et al.*, 2020).

C. Automatic Mastitis Detection

Mastitis, which has a detrimental effect on both animal welfare and product quality, is the most expensive disease afflicting the dairy cattle industry. Mastitis alone costs the dairy sector about 6% of its total revenue and as the need for higher milk output per cow rises, this cost is anticipated to increase (Shim *et al.*, 2004). Therefore, it is crucial to identify a disease outbreak as soon as possible so that treatment may be started and the milk can be separated.

Automated mastitis detection offers a fantastic opportunity to implement early treatment plans and avoid overusing antibiotics, protecting the health and welfare of cows, minimising discomfort and anguish, increasing the recovery rate, and ensuring the financial viability of farms (Stevens *et al.*, 2016).

Numerous changes in the cow and in the milk are linked to mastitis, and it has been found that using multiple indicators together is helpful (Hogeveen *et al.*, 2010). The somatic cell score (SCS) has historically been the most widely used mastitis indication, but new markers have recently been developed, including lactate dehydrogenase (LDH) and electrical conductivity (EC).

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➢ *Somatic Cell Count*

The most common indicator for determining the state of a dairy cow's udder is somatic cell count (SCC). Fully automated online analytical equipment is provided in automatic milking systems (AMS) to analyse SCC at the farm after every milking. The SCC can be used to monitor intra-mammary infections, and novel sensors specifically made for monitoring udder health are now being developed by the industry. These could be used in AMS's automatic detection systems to manage udder health (Dalen *et al.*, 2019).

➢ *Electrical Conductivity (EC) and Enzymatic Concentrations of Lactate Dehydrogenase (LDH)*

It has been used as indicators to detect mastitis (Khatun *et al.*, 2019). This type of equipment allows producers to increase milking frequency, milk production per cow and reduce labor costs. The AMS has in-line sensors that measure EC and look for mastitis. Throughout the milk collecting procedure, these sensors continuously check the milk ion concentration.

➢ *Infrared Thermography (IRT)*

It is a non-invasive technology with numerous applications in animal science that enables precise temperature measuring at a distance (Cook, 2021). In dairy production, IRT has been successfully used for early mastitis detection. Zaninelli *et al.* (2018) used software that located the pixel with the highest temperature in udder thermograms to distinguish between cows with normal and elevated SCC.

D. Body Condition Score

Monitoring the body condition score of cows is one technique to observe their physiological state (BCS). The BCS (on a scale of 1-5 or 1-10) measures the fat reserves of the cows and might therefore suggest the need for adjustments to the management of feeding or reproduction. To keep track of the health state of both the individual cows and the herds, advisors advise conducting routine BCS scoring. (Song *et al.*, 2019).

Visual BCS scoring is time-consuming and requires expert training. Researchers therefore want to automate the scoring process. Two-dimensional (2-D), three-dimensional (3-D), and thermal imaging have all been employed by machine vision to automatically extract BCS, albeit these methods take into account fewer body regions than are scored during direct observation BCS scoring (Bercovich *et al.*, 2013).

Song *et al.* (2019) evaluated top-view images from two cameras that recorded various body regions of the cow and were able to correctly classify BCS from a wider range of body regions using the closest neighbor classification algorithm. Using pearson correlation for cattle body condition scores (scale 1 to 5, low to high), Mullins *et al.* (2019) compared continuous and categorical automated camera scoring to manual scoring averages to assess the validity of a commercial automated body condition scoring system on a commercial dairy farm (MAN). Ferguson *et al.* (2006) evaluated the feasibility of BCS assignment to a dairy cow from digital images. It has been shown to be possible to perform automated body condition scoring (BCS) by extracting data from digital photographs, and commercial methods are now being developed.

E. Automatic recording devices for rumen health

To identify the incidence of health issues such sub-acute rumen acidosis and bloat, it can be extremely important to measure the ruminal pH, temperature, and rumination in animals (Singh *et al.*, 2014).

➢ *Rumen temperature*

The development of technology will enable continuous monitoring of intra-ruminal conditions including pH and temperature. According to Al-Zahal et al. (2008), the correlation between rumen temperature and rumen pH may serve as a diagnostic marker for SARA (Sub Acute Rumen Acidosis). A bolus containing a mote (temperature sensor, processor and radio) can be permitted to rumen either fistulation or orally in animal to monitor body temperature (Ipema *et al.*, 2008). Rumen temperature was measured every minute and stored in the internal buffer of the mote. Smaxtec® (Figure: 03) is an example of a device available on the market for this purpose.

➢ *Rumen pressure*

Rumen pressure changes can be used to measure rumen motility. Therefore it is possible to determine bloat through rumen pressure. For dairy animals, there is not a lot of information on rumen pressure. The boluses would therefore be a very helpful tool for determining how rumen pressures and bloat in dairy animals relate to one another.

➢ *Rumen pH*

The measurement of rumen pH can be a tool for ensuring the health and productivity of dairy animals. In order to maintain the ideal physiological circumstances for fermentation, the pH value in the reticulo-rumen should be kept between 6.3 and 6.7. A permanent device in the rumen is needed to continually monitor rumen pH from a distance without interfering with the animal's natural behaviour in order to monitor ruminal fluid pH. Wireless telemetry makes it possible to continuously monitor ruminal pH and can reliably identify sub-acute ruminal acidosis (Phillips *et al.*, 2010).

Fig 3: Automatic recording devices for rumen health

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➢ *Chewing Activity*

For automated, non-invasive assessment of chewing activity in ruminants, a number of techniques have been developed. These techniques involve the detection of jaw movements using strain or pressure sensors attached to a halter (Zehner *et al.*, 2017). Pereira *et al*. (2019) studied feeding behaviors from Rumi-Watch (Figure: 04) compared to direct visual observations in crossbred dairy cattle and got significant correlations between these.

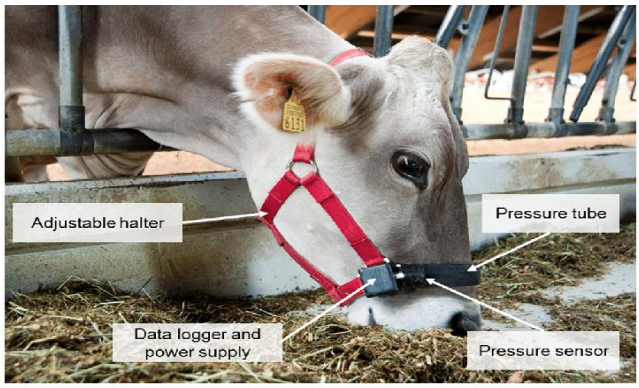

Fig 4: Rumi-Watch

F. Reproductive Management

Profitability and dairy animal reproduction effectiveness are closely related. Long calving intervals were a sign of poor reproductive health, which could lead to lower milk output, fewer calves per animal during its lifetime and higher replacement expenses (Sewalem *et al.*, 2008). It is necessary to adapt the monitoring and detection of signals, which will be markers of the timing of insemination employed by a cow, in order to carry out good reproductive management.

➢ *Estrus Detection System*

Estrus can no longer be detected just by visual observation; additional techniques are now necessary. To increase the reproductive indexes of dairy cattle, automated estrus detection methods and computerised record systems can be used (Giordano *et al.*, 2011).

Large-scale dairy production already makes use of automated detection systems including activity monitors that use accelerometers and acoustic sensors (pedometers, necklaces, earrings, pressure, and friction detectors). The drawback of wearable technology is that environmental or physiological disturbances can interfere with movement and temperature detection.

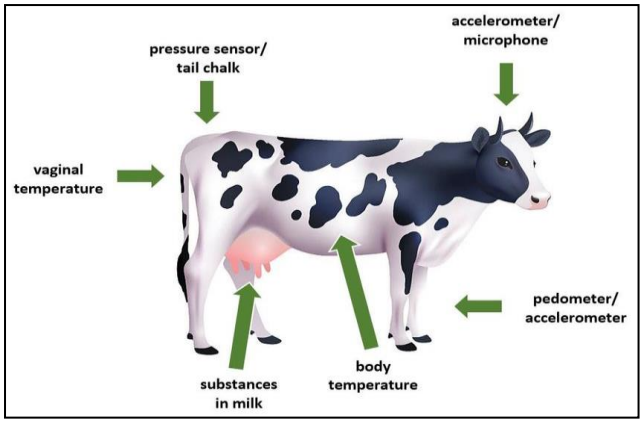

Fig 5: Sensor for estrus detection

Pedometers are the devices that track the number of steps taken per unit of time are fastened to the cow legs (Maatje *et al.*, 1997). This number serves as a measure of walking activity, which significantly rises during dairy cows' proestrus and estrus. Eg. IceTag® (Ice Robotics Ltd., Edinburgh, UK).

Accelerometers are tags that can be placed on a collar around the animal's neck. The motions of the head and neck during walking and mounting are used to determine the cow's activity, which is then converted into an index that indicates the weighted standard deviation of each basal activity of the cow itself. e.g. HeaTime® (SCR Engineers Ltd., Netanya, Israel).

Radiotelemetry (Figure: 06)- Additionally, mounting activity is detected commercially using methods that use pressure detection. The HeatWatch (HeatWatch® DDx, Inc., Denver, CO, USA) is attached to the cow's tail hair in the sacral area and comprises of a tiny radionic transmitter connected to a pressure sensor in a rigid plastic box enclosed in a nylon wrapper (Walker et al., 1996). The mounting animal's weight activates the device for at least two seconds before the transmitter transmits the breeding acceptance signal along with the animal's identification to the system.

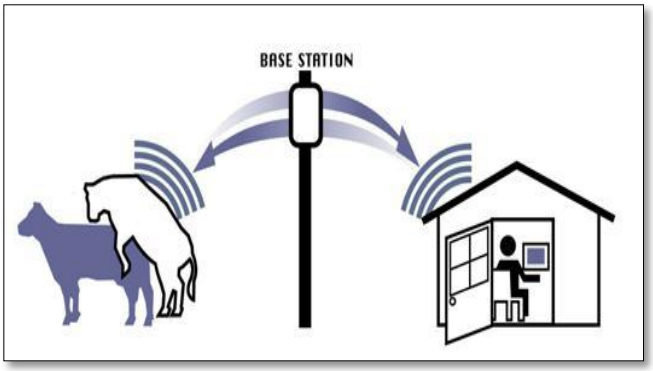

Fig 6: Radiotelemetry

➢ *Dystocia and Calving Detection Systems*

The number of live calf births has an impact on dairy farming profitability as well. Dystocia is characterized by difficult calving, which necessitates extended labor and calf extraction with human assistance. Dystocia is more likely to occur in cows that calve slowly (more than 70 minutes from the development of the amniotic sac outside the vulva), but if delivery aid is given on schedule, this danger and the stress it causes can be minimized (Palombi *et al.*, 2013). Cows that are about to give birth exhibit lower body temperatures, relaxed pelvic ligaments, altered feeding and rumination patterns, more lying down and frequent head movements toward the flank (2 h before delivery).

Automated calving prediction solutions have been developed, the majority of which are based on wearable sensors such temperature sensors, rumination activity microphones, accelerometers, and tags for electromyography (Borchers *et al.*, 2017). Zehner *et al.* (2017) analyzed the digestive changes of cows near parturition through a muzzle sensor (RumiWatch®). These authors observed that the sensitivity and specificity of the model were adequate for detecting pregnancies an hour before they began, but that it's positive predictive value was poor and its false positive rate was significant. The technical benefits of utilizing this type of calving detection equipment are to utilise a tool that is already in use for calving detection and for monitoring the health of cows (Borchers *et al.*, 2017).

An intravaginal childbirth detection device called VelPhone® is based on the difference in temperature between the vaginal temperature just before calving and the vaginal temperature when the device is ejected from the vagina just before parturition. This technique provided up to 100% positive value predictions (Horvath *et al.*, 2021).

G. Automatic milking system

Automated Milking Systems (AMS) are the outcome of the implementation of state of the art technology related to robotics to boost milk yield through increased automation and efficiency (Britt *et al.*, 2018). The 1990s saw the introduction of automatic milking systems (AMS), sometimes known as robotic milking systems, on dairy farms. This method is based on the voluntary milking of dairy cattle in a fully automated process that relies on computer management, with a significant average increase in milking frequency.

When compared to conventional milking, AMS significantly modifies herd management, having a considerable impact on the physiology, health, and welfare of animals as well as on the economic, technical and social facets of farming. In comparison to conventional milking systems (CMS) in a parlous, AMS enhanced the quality of labour and lifestyle of farmers at dairy farms, which is largely responsible for its success.

The automatic milking unit comprises a milking machine, a teat position sensor, a robotic arm for automatic teat-cup application and removal, and a gate system for controlling cow traffic. Robotic arms are the main working element of an automatic milking system designed in the image of a human hand (Figure: 07). Cows are individually milked in a box where they enter voluntarily as attracted by feed supplements (Jacobs and Siegford, 2012). When the cow elects to enter the milking unit, a cow ID sensor reads an identification tag on the cow and passes the cow ID to the control system. The robot arm can move in three dimensions and can attach milking clusters to the teats and, in some versions, clean the teats after milking to prepare the udder for milking. The automatic gate mechanism will send the cow outside if it has been milked too recently. Automatic teat cleaning, milking, milking cup application, and teats praying occur if the cow can be milked.

Quarter-based in-line milk meters as well as sensors for milk composition monitoring and early mastitis detection have been implemented. They are needed to establish the correct time for automatic cup detachment and automatically separate abnormal milk, and produce health alerts. Milk is automatically collected in a commercial milk container and if the milk is not fit for human consumption, it is diverted to a separate container.

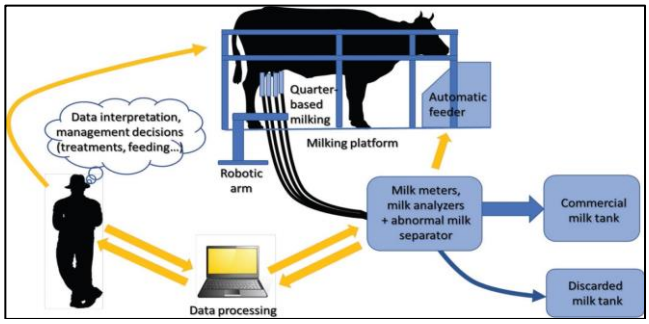

Fig 7: Automatic milking system

H. Management of Heat stress

In the past, lactating buffaloes have benefited from physical modifications to the habitat that lower the ambient temperature or increase heat dissipation from the animal body, such as shading and fans (Ahmad *et al.*, 2019), and in dairy cows using mixed-flow fans. However, one of the most effective methods found is spraying water over animals using sprinkler systems (Tresoldi *et al.*, 2019). An automated system based on an individual cow assessment combined with environmental factors obtained from an automatic meteorological station (AME).

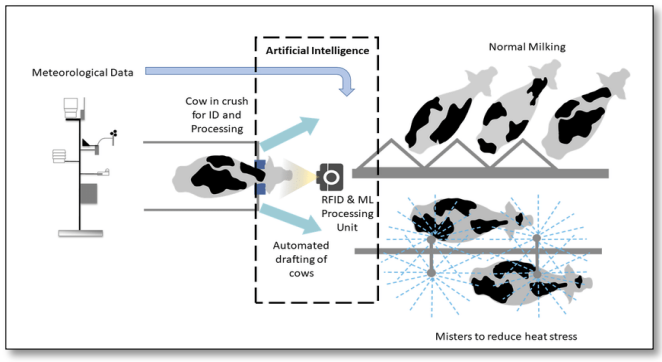

Fig 8: Management of heat stress

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A processing device (microprocessor or Smartphone app) that can read the RFID and ML Processing Unit from cows that will be milked can be readily connected to the AME. The system can then use gates to automatically route certain cows to typical milking sections, a cooling system with water sprays to help the cows cope with the heat, or both. The heat-stressed cows will be reevaluated the next day, if they continue to be heat stressed, they will go to the sprinkler system and get milked to avoid mastitis. (Figure: 08)

I. Automatic calf feeding

Automatic calf feeder system is designed to replace the human work in several areas. Automated systems for feeding calves controlled by computer allow the farmer an economy of labor, thus providing considerable economic benefits them an exceptional start.

This system consists of a standalone unit that heat water and dispenses a preset powder milk quantity and mix it, then transfer in a glass cylinder from which the calf can be fed from feeding station via the teat (Fujiwara *et al.*, 2014). When a calf enters in the feeding station, RFID tag placed on the ear is recognized by receiver antenna placed on side of feeding station and start preparing adequate recipe to calf's age as well adding vitamins or antibiotics according to state of sickness. In the first 7 to 10 days, calves will be fed with bottle teat in order to familiarize with automatic feeding systems. Calves can still enjoy their natural rhythm and can drink whenever they want, in a controlled manner while working to minimize staff.

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, low maintenance. Weaning calves is made simpler by automatic feeding systems since the amount of milk consumed is steadily decreased. This lessens the strain on the calf, which lowers the risk of pneumonia and post-weaning illnesses.

J. Automatic feeding system

Precision dairy farming is embracing the idea of individual animal management, where success depends on careful individual monitoring. One of the most important and labor-intensive aspects of dairying is feeding management, which requires automation to give specialized care. Complete automation of the feeding processes would increase labour efficiency by lowering labour requirements and labour expenses while also freeing up more time for other farm tasks. Automation improves production and boosts feed efficiency. Overall automation in dairy farm feeding operations may enhance the welfare and health of dairy cows.

Different varieties of AFS have recently been developed by research institutions and manufacturers, and they often rely either on already-existing technology for automated distribution of specific feedstuffs like concentrates, silages, and forages, or on entirely fresh ideas like total mixed ration or partial mixed ration. It is anticipated that feeding fully or partially mixed rations to both the feeding apparatuses and the automatic milking system will lower the need for farm labour (Tamaki, 2002).

IV. CURRENT STATUS OF PDF

The status of PDF in India is still in a juvenile stage as it has large number of cattle population which are scattered in wide range of geographical rural areas.

In order to start tracking and to guarantee the accuracy of the information related to each animal, some organised farms in the private sector of India have adopted RFID-based animal identification and farm automation management systems, for example, Kopardem farm at Valpoi in Sattari Taluka in North Goa, Sangamner milk union in Maharashtra, Lakshya dairy in Haryana and Chitale dairy in Pune. The Information Network for Animal Productivity and Health (INAPH), created by the National Dairy Development Board (NDDB), is a desktop, netbook, and android tablet-based field IT application that makes it easier to collect accurate real-time data on breeding, nutrition, and health services provided to farmers. When necessary, INAPH is prepared to send communications to farmers offering pertinent advice regarding their livestock. 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. 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. BAIF development research foundation, Pune has developed a method of rapid pregnancy test in which cattle or buffaloes would be diagnosed for pregnancy after 18 to 19 days. Mumbai Veterinary College 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.

- *Indian Start-Ups Providing Digital Solutions*

The management of cattle is one of the main areas where digitization may play a significant role. Using the internet of things (IoT) and advanced analytics, farmers can monitor cow feeding habits and assess their health. This is expected to increase milk production and cattle productivity.

The Indian Institute of Technology (IIT) in Mumbai to design the 'BovSmart' wearable belt. The belt uses AI and IoT for tracking livestock breeding and delivers timely information to farmers.

Similar technology is provided by Stellapps Technologies (Stellapps- mooONTM), which employs a mobile application and a wearable device for cattle to deliver recommendations to enhance herd performance. According to Stellapps, this method can reduce calf health costs by up to 50% while increasing milk production by 20%. Approximately 4.5 lakh animals are now being tracked using stellapps technology.

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Nitara is an Artificial intelligence-led Agri-Tech platform on a mission to make dairy farming highly profitable and create measurable value for all stakeholders, including farmers. Nitara vision is to work closely at the grass root level of rural dairy farming in India. Nitara send timely notifications for all the important upcoming events related to farms and cattle, like timely insemination, pregnancy diagnosis, regular calving, prompt vaccination, and other medications, thereby ensuring improved health of cattle and increased milk productivity. It also provides customized and budget based scientific nutrition plans by seasoned experts to the farmer. Nitara also help to predict the possible diseases, the future milk yield of each cattle and ensuring minimum productivity loss and lowering the mortality rate.

V. LIMITATIONS OF PDF

- Majority of dairy animals belong to small farm or herd size and majority of the farmers are resource poor who cannot afford such costlier technologies. Moreover most of the herds composed of different species, breeds with different production parameters creating difficulty in adopting the technology of PDF in India.
- This technology also demands regular data collection, analysis and interpretation of the available data which may be performed by a skilled human resource.
- Different skills will be required across the farming team to enact and adapt these technologies (Higgins *et al.*, 2017).
- Despite the growing demand, adoption rates of most commercially available PDF technologies are limited.
- Farmers have expressed reluctance to invest in PDF technologies (Steeneveld and Hogeveen, 2015). This can be because there isn't enough knowledge on the extra economic value that these PDF technologies are implemented on farm.
- The information gleaned from precision dairy farming technologies is only useful if it is interpreted and used effectively in decision making.
- Slow adoption rate brought on by unclear return on investment, high fixed costs associated with investment and information gathering, and a lack of evidence that these technologies have any discernible impact on outputs, input use, and environmental performance (Khanna *et al.*, 1999). These technologies are adopted by younger, more educated farmers who also operate larger operations and generate more revenues.
- Device may sometime read errors.
- Equipment failure is possible because it's common for them to be difficult to use, have poor temporal resolution, and necessitate clear subject visibility.
- Data transfer error may be due to an excessive amount of data, and the time-consuming handling of software programme.
- Lack of validated research findings about the expenses, large capital requirements, and application-related effects.
- Applicable to a restricted spatial area

VI. CONCLUSION

A new golden age for the dairy sector is precision dairy farming. On dairy farms, the use of PDF technology offers numerous chances to enhance individual animal management. Better general health in cows can reduce the cost of animal care and/or treatment, increase animal longevity, and increase milk production. Although there are many potential for adoption, precision dairy farming is still in its infancy in many developing nations, including India. As the technology has the potential to increase yields and financial returns, forward-thinking Indian farmers would adopt it on a small scale with help from the public and private sectors. 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. Effective coordination among the public, private sectors and farmers is, therefore, essential for implementing precision dairy farming to achieve fruitful success.

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