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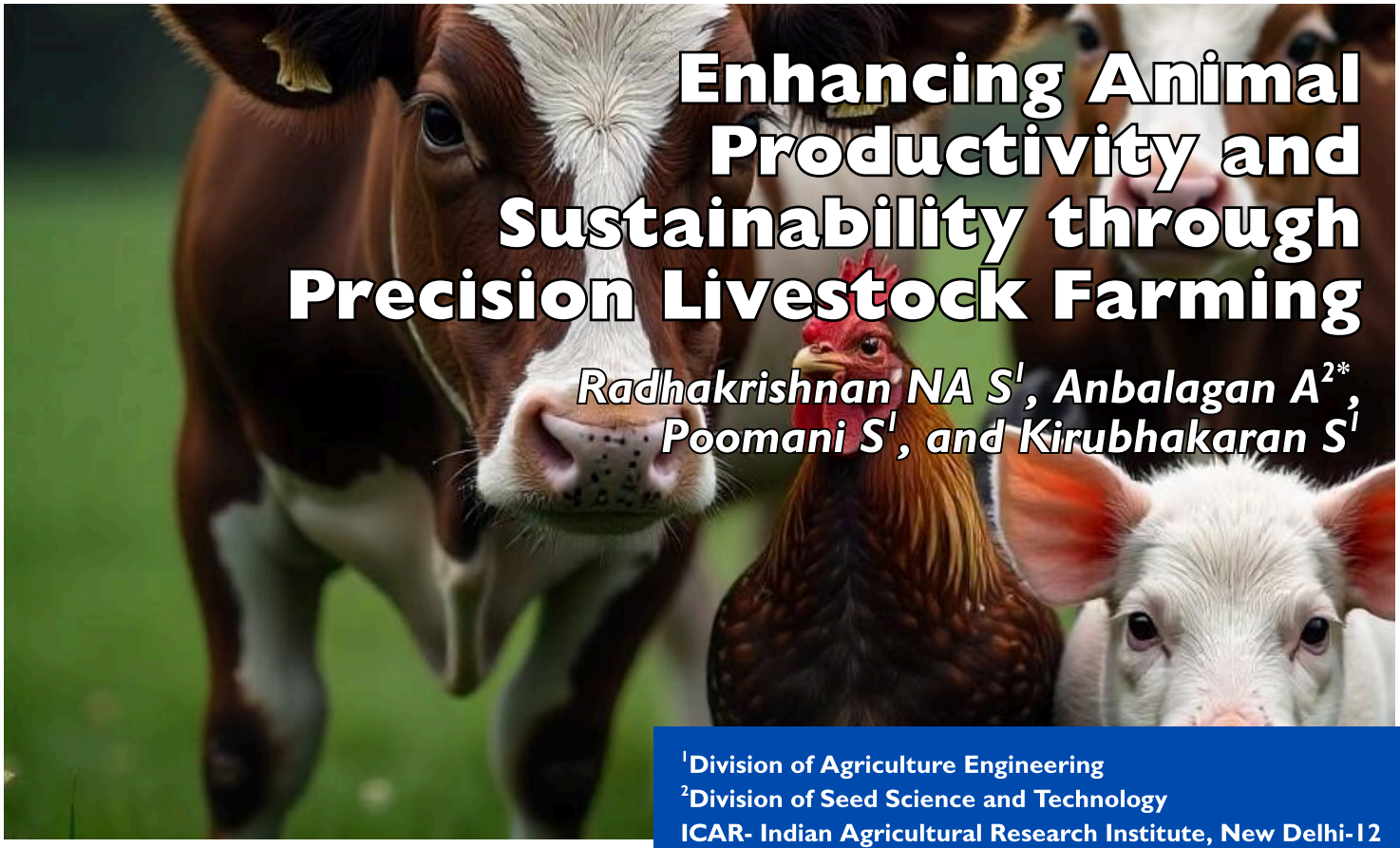

Enhancing Animal Productivity and Sustainability through Precision Livestock Farming

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Abstract

The major constraint in livestock farming is the continuous monitoring of animals for better production. Poor environmental conditions, inadequate nutrient supplements, and improper disease management may lead to major losses. Precision livestock farming integrates continuous monitoring of animals and their behavioral changes to environmental conditions and their productivity through the use of instruments, sensors, data analytics, machine vision, and so on. Livestock farming requires monitoring and management in all aspects of the identification of individual cattle, their physiological movements, disease prediction, feed intake, and environmental conditions. Identification techniques such as RFID tagging, biometric identification, and GPS has enabling accurate management and tracking of animals. Precision feeding improves livestock health through proper nutrient intake and reducing feed waste. Environmental monitoring systems regulate the favorable climate conditions whereas physiological data collection using wearable sensors and advanced techniques aids in better health assessment and early detection of diseases. Precision livestock farming can maximize the farmers' profit and improve overall productivity by reducing the costs of production as well as environmental impacts.

Key words: Precision Livestock Farming, Sensors, Environment, Animal Husbandry

Introduction

Livestock is an important source of income, particularly for small and landless farmers. Across the world, around 1.3 billion people are involved in livestock farming. In India, a livestock census is taken every five years. According to the 20th census, the total livestock population is 535.78 million (Government of India, 2019), being first in milk production with 239.30 million tonnes in the year 2023-2024 (Department of Animal Husbandry and Dairying, 2024).However, the major constraints in livestock farming are related to the inability to continuously monitor and notice animals resulting in inadequate distribution of feed and nutrient

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supplements, lack of disease control and eradication, and improper environmental maintenance ultimately resulting in increased cost of production or decrease in the yield. Hence continuous monitoring is required. Traditional livestock farming the decision making is based on the experience. Precision livestock farming (PLF) utilize advanced technologies to continuously monitor and manage livestock in real-time. (Berckmans et al., 2014) This can improve individual animal health, welfare, productivity and the environmental impact of animal husbandry, contributing to the economic, social and environmental sustainability of livestock farming (FAO, 2021). Our Indian Government has also taken several initiatives like National Digital Livestock Mission for creating a digital ecosystem using artificial intelligence (Department of Animal Husbandry and Dairying, 2022), Internet of things and data analytics, Rastria Gokul Mission (RGM) promotes the digital use of Pashu Aadhar and automated milking systems (Department of Animal Husbandry and Dairying, 2023), e- Gopala App by National Animal Disease Control Programme (NACDP) provides information at farm level based on data-driven decisions (National Dairy Development Board, 2020). Research institutions such as National Dairy Research Institute (NDRI) and Indian Veterinary Research Institute (IVRI) are also focusing on PLF technologies. These initiatives highlight the government's efforts towards the livestock sector for sustainability in animal husbandry

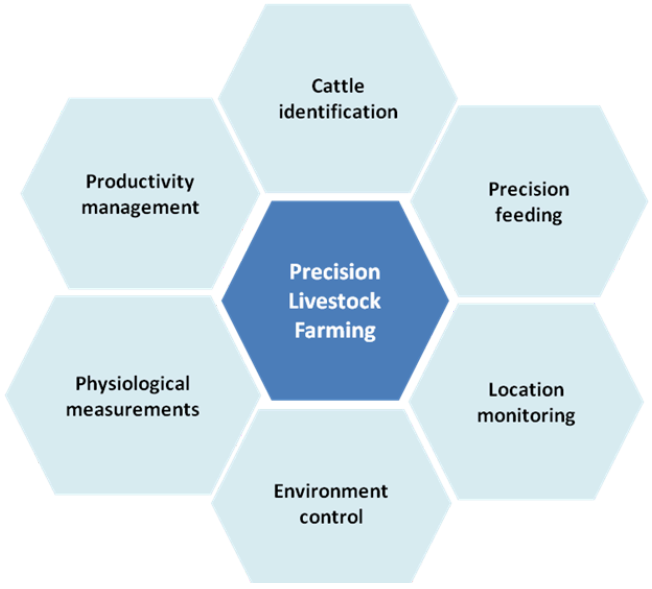

Fig. 1. Components of Precision Livestock Farming

Livestock identification systems

Cattle identification systems include animal recognition, identification of missing cattle, reallocation of livestock, and eradication of false insurance claims.

There are various types of cattle recognition techniques

Permanent identification techniques involve ear tips, tattoos, and freeze branding. Semi-permanent method includes ear tagging and ID collars. Temporary methods include sketching and methods like Radio Frequency identification (RFID) and detection. (Dogan et al., 2023).

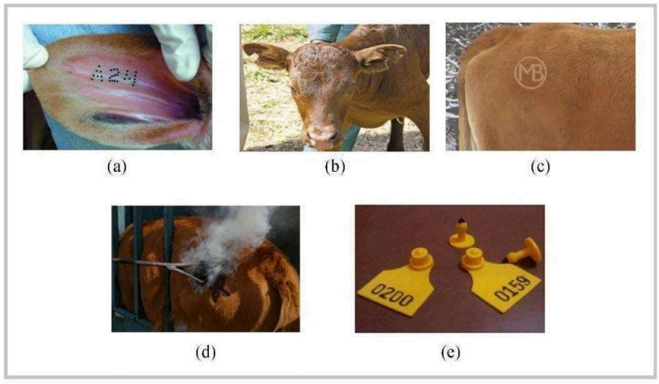

Fig. 2. Traditional animal identification methods. (a) Tattooing, (b) Ear notch, (c) Cold stamping, (d) Hot stamping, (e) Ear Tag (Dogan et al., 2023)

Further, the advanced identification techniques identify the individual cattle using animal biometrics such as muzzle patterns, Facial images, and Iris patterns. (Kumar and Singh et al., 2020)

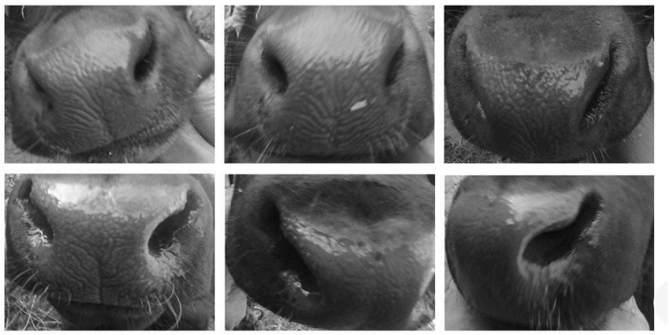

Fig. 3. A sample of the collected muzzle print images database. The images, from two living animals, show different deteriorating factors: image orientation, blurred images, low resolution images, and partial images (Awad et al., 2016). This type of cattle identification includes two phases viz., training and testing phase. The training phase includes collecting

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features like muzzle patterns, facial images, or iris patterns. The next step involves extracting the features, representing each image by one feature vector, and applying a dimensionality reduction to reduce the number of features in the vector and storing them in the database. The testing phase includes collecting the muzzle point image of a particular animal, extracting the features, and applying the machine learning algorithms in classifying the test features and match them with the database.

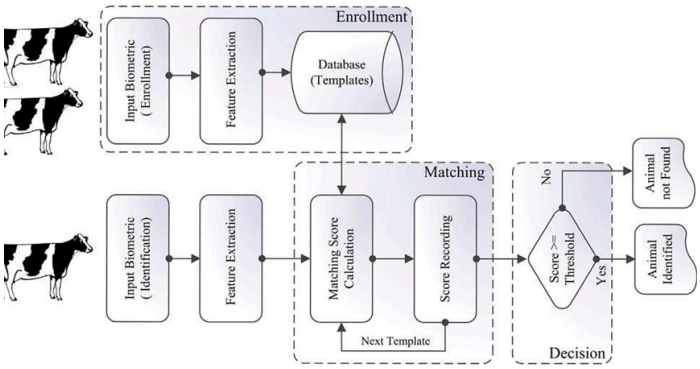


Fig. 4. A block diagram of a complete biometric-based animal identification system (Awad et al., 2016)

Precision feeding

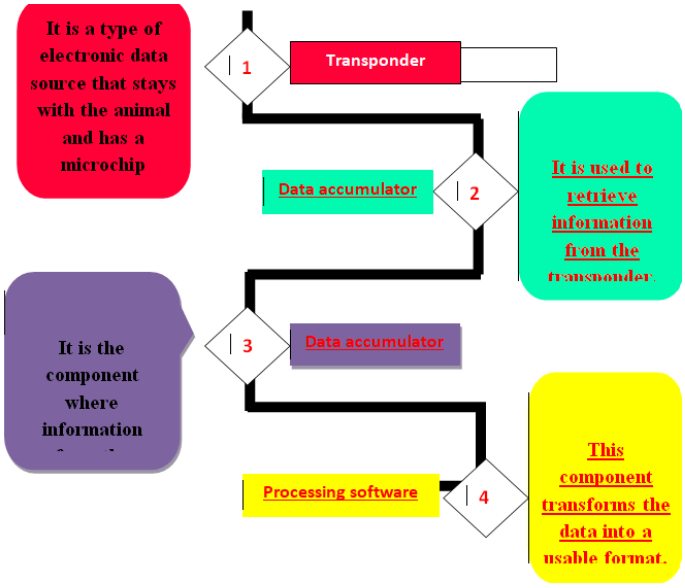
Precision feeding techniques are important for tracking and optimizing the feed intake of an individual animal. Feeding less than the preferred quantity may result in a lack of nutrient requirements. On the other hand, overfeeding should also be avoided as it reduces profit, increases feed costs, and may result in metabolic disorders. Precision feeding enables feeding at the right time, right composition, and right amount, resulting in improved nutrient utilization.

The tools of precision feeding include precise estimation of nutrient requirements, precise nutrient analysis (use of feed additives and supplements, feed processing techniques, proper weighing and mixing of nutrients), and ration formulation on a nutrient availability basis.

The feeding management practices include phase feeding and split-sex feeding. Precision feeding is determined by animal factors such as genotype, sex, age, body weight, etc., and external factors such as health status, environment, stress, water intake, etc., and also the availability of nutrients vitamins, and mineral contents.

Location monitoring

Traceability of animals for safer food, supply, and control of diseases is very important. Global positioning systems (GPS) with RFID wifi networks enable easy monitoring of the animals. Research has proven that RFID-based tracking is more promising. RFID tracking includes active and passive modes. The four basic components of RFID tracking are given below



GPS is an important solution for cattle localization and management. Various Low Power Wide Area Networks are also available for the tracking of animals.

Environment control

Climate is the main factor in reducing the efficiency of the animals. Environmental control involves improved air and water quality, utilization to minimize waste, and so on. An increasing population puts increasing demand on livestock production. There is a need for continuous real-time monitoring of the physical environment of the animal.

An effective precision environment requires continuous sensing at the appropriate frequency, room temperature, humidity, air speed across the animal, solar radiation, and air circulation. Based on the complexity of the system, some behavioral and physical responses are noted.

For example, the dry –bulb temperature can be measured using thermocouple, resistance

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temperature detector or thermistor, the dew point temperature measured by chilled mirror hygrometer, the relative humidity can be measured b capacitance hygrometer, absolute humidity can be measured be thermal conductivity sensor, Solar radiation can be measured using Pyranometer or black globe radiation, air speed can be measured by propeller anemometer, pitot tube and orifice plates, or hot wire anemometer. (Fournel et al., 2017)

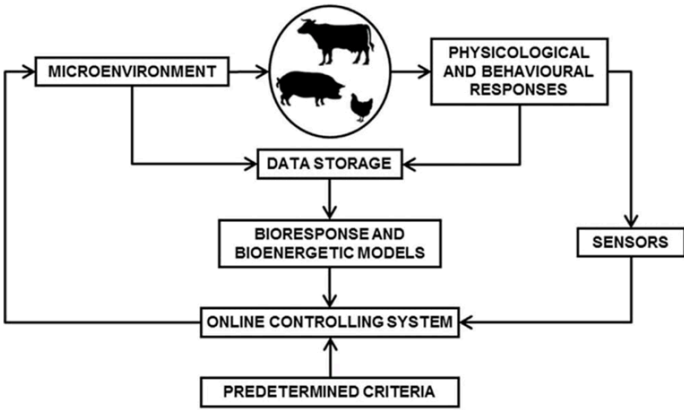

Fig. 5. Schematic overview of the key components of environment control through precision livestock farming. (Fournel et al., 2017)

The data are then stored and the interpretations of the measurements are done using response simulations such as animal comfort indices or bio-energetic models. These will enable the online controlling systems.The environmental control of livestock buildings includes analysis of heat and moisture production rates using models, thermal stress through multifactor animal comfort indices, and animal behavioral response to the changing environment.

Physiological measurements

The collection of body temperature data, movement patterns, and behavioral data helps in the early prediction of diseases. The dairy cattle-focused platform element comprises a neck count sensor network with neck neck-mountedcollar electronic unit. The collar electronic unit is mounted on the neck of animals with 3 a 3-axis accelerometer to monitor the rumination and feeding details. The energy spent will help in the identification of the physical condition of the cow.

Monitoring the feed intake helps in establishing the overall welfare of the animal. If the animal spends less time eating or ruminating, there are chances of illness. Research implies that a healthy cow ruminates 500 – 600 times per day. Jaw movements are bigger during eating than during rumination.

The other measurements such as dry bulb temperature, dew point temperature, etc., are measured using specified equipment. The internal body temperature can be measured by using the gastrointestinal device, implanted data logger, or implanted radio transmitter.

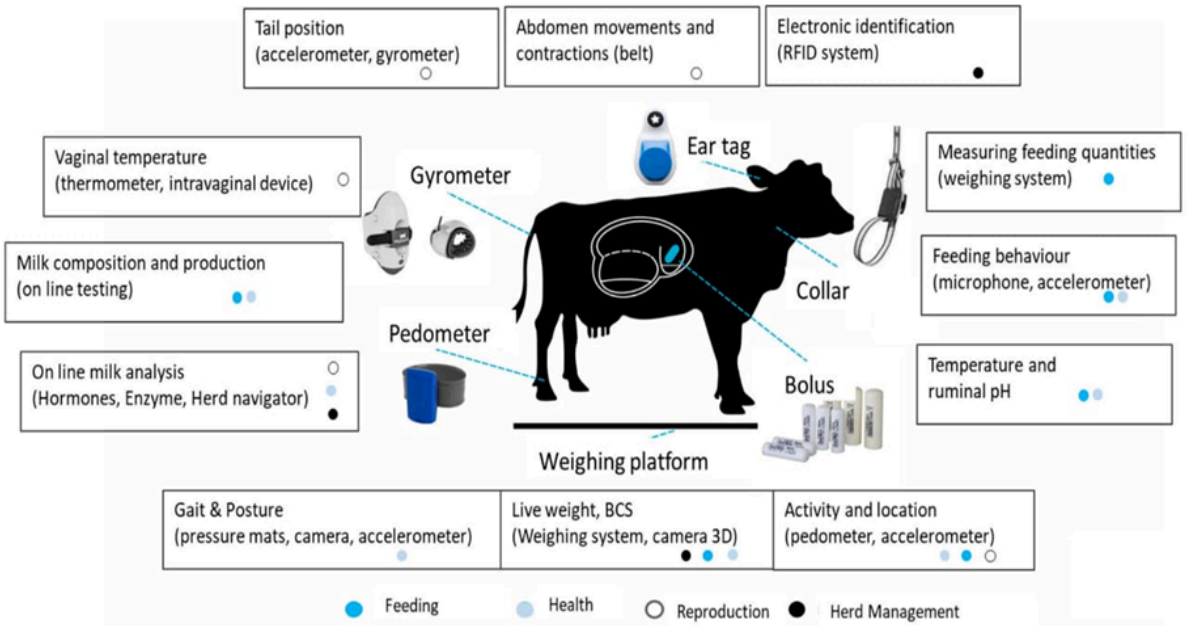

Fig. 6. Overview of currently used devices for measuring physiological measurement of animals

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The respiration rate can be monitored by automated cattle respiration rate or automated dairy cow respiration rate. The heart rate variability can be recorded by a Holter recorder, Polar recorder, or implantable telemetric transmitter. (Fournel et al., 2017)

The body weight can be measured with a scale plate (platform with strain gauge load) or machine vision system (image or video capture from which the weight can be calculated based on the superior area, perimeter, side of abdomen, wide of capture of the animal)

Production management

The key components of production management include all the above-mentioned automated monitoring systems, data-driven decision-making, environmental control, individualized animal care, etc., For example, a dairy cow should be monitored based on the milk production as well as estrus cycle.

Conclusion

By including contemporary technologies like artificial intelligence, machine learning and the internet of things, precision livestock farming is transforming the animal husbandry sector. Some upcoming advancements like AI based disease prediction models, blockchain-based traceability systems may lead livestock farming to achieve greatest advancements. Farmers can utilize these technologies to become successful in their livestock farming sector with more profit and leading to minimize environmental impact and ensuring animal welfare.

References

Awad, A. I. (2016). From classical methods to animal biometrics: A review on cattle identification and tracking. Computers and electronics in agriculture, 123, 423-435. Berckmans, D. (2014).

Berckmans, D. (2014). Precision livestock farming technologies for welfare management in intensive livestock systems. Revista Brasileira de Zootecnia, 43(11), 354–362.

Department of Animal Husbandry and Dairying. (2022). National Digital Livestock Mission (NDLM) Concept Note. Ministry of Fisheries, Animal Husbandry and Dairying, Government of India.

Department of Animal Husbandry and Dairying. (2023). Rashtriya Gokul Mission Guidelines. Ministry of Fisheries, Animal Husbandry and Dairying, Government of India.

Department of Animal Husbandry and Dairying. (2024). Basic Animal Husbandry Statistics 2024. Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. Retrieved from https://dahd.gov.in/sites/default/files/2024-11/BAHS-2024.pdf

Dogan, H. (2023). RFID Applications in Animal Identification and Tracking. New Frontiers in Engineering, 66-93.

FAO. (2021). The role of livestock in sustainable food systems. Food and Agriculture Organization of the United Nations.

Fournel, S., Rousseau, A. N., & Laberge, B. (2017). Rethinking environment control strategy of confined animal housing systems through precision livestock farming. Biosystems Engineering, 155, 96-123.

Government of India. (2019). 20th Livestock Census. Department of Animal Husbandry and Dairying, Ministry of Fisheries, Animal Husbandry & Dairying.

Grooms, D., & Michigan RFID Education Task Force. (2007, January). Radio frequency identification (RFID) technology for cattle (Extension Bulletin E-2970). Michigan State University Extension. https://www.michigananimalid.com

Kleen, J. L., &Guatteo, R. (2023). Precision Livestock Farming: What Does It Contain and What Are the Perspectives? Animals, 13(5), 779.

Kumar, S., & Singh, S. K. (2020). Cattle recognition: A new frontier in visual animal biometrics research. Proceedings of the national academy of sciences, india section A: physical sciences, 90(4), 689-708.

National Dairy Development Board. (2020). e-GOPALA App

Pomar, C., Kyriazakis, I., Emmans, G. C., & Knap, P. W. (2009). Modeling stochasticity in within-litter variation in piglets. Journal of Animal Science, 87(3), 927-936.

Schirmann, K., von Keyserlingk, M. A. G., Weary, D. M., Veira, D. M., &Heuwieser, W. (2009). Validation of a system for monitoring rumination in dairy cows. Journal of Dairy Science, 92(12), 4634-4638.

Smith, R., Jones, B., & Walker, P. (2013). RFID-based animal traceability: Advancements and applications. Animal Science Journal, 84(6), 123-135.

Wathes, C. M., Kristensen, H. H., Aerts, J. M., &Berckmans, D. (2008). Is precision livestock farming an engineer's daydream or nightmare? Animal, 2(4), 586-595.

Wolfert, S., Ge, L., Verdouw, C., &Bogaardt, M. J. (2017). Big Data in smart farming: A review. Agricultural Systems, 153, 69-80.

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