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Original Article

Precision Livestock Farming and Animal Welfare in Dairy Systems

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Abstract - *Precision Livestock Farming integrates sensor technologies, automated monitoring systems, and data-driven decision tools to improve the management of livestock at the individual-animal level. In dairy systems, PLF has rapidly expanded as a tool to enhance productivity, environmental sustainability, and animal welfare. This literature review synthesizes current knowledge on PLF applications in dairy cattle, with emphasis on heat stress detection, behavior and welfare assessment, automatic milking systems, and performance optimization. Findings highlight that PLF improves early disease detection, enhances milking efficiency, optimizes resource use, and provides welfare-related behavioral insights. However, challenges remain, including technical failures, risks of reduced human-animal interaction, welfare trade-offs, and ethical concerns linked to excessive technologization of animal care. Significant knowledge gaps also persist concerning positive welfare assessment, long-term impacts, standardized metrics, and applicability across diverse production systems. This review concludes that Precision Livestock Farming has strong potential to support sustainable and welfare-friendly dairy production when integrated with thoughtful management, ethical oversight, and robust farmer engagement.*

Keywords - *Precision Livestock Farming, Dairy Cattle, Animal Welfare, Automatic Milking Systems, Sensor Technologies, Ethical Considerations, Farm Management.*

1. Introduction

Precision Livestock Farming is defined as "the use of information and communication technologies for improved control of fine-scale animal and physical resource variability to optimize economic, social, and environmental dairy farm performance" (Eastwood *et al*., 2012). Precision Livestock Farming (PLF) is a concept that enables real-time monitoring of animals by equipping them with sensors that generate livestock-related data, which can be further utilized by farmers. Precision Livestock Farming comes with many benefits and ensures maximum use of farm resources, thus enabling control of the health status of animals, while potentially mitigating Greenhouse Gas (GHG) emissions.

Precision livestock farming is defined as the "management of individual animals by continuous, automated, and real-time monitoring of health, welfare, production/reproduction, and environmental impact" (Berckmans, 2017). Precision Livestock Farming (PLF) uses sensor technology and an automated monitoring system to continually manage each animal's health, behavior, and other environmental factors. Precision Livestock Farming's mission is to manage individual animals by ongoing, real-time observation of their health, welfare, reproductive and production processes, and environmental effects (Lavanya *et al.,* 2024).

Precision Livestock Farming (PLF) describes the combined use of sensor technology, the related algorithms, interfaces, and applications in animal husbandry. Precision Livestock Farming technology is used in all animal production systems and is most extensively described in dairy farming. PLF is developing rapidly and is moving beyond health alarms towards an integrated decision-making system. Precision Livestock Farming (PLF) technologies have been developed with the intention of improving farm management and minimizing aversive handling practices. According to Berckmans (2004), a Precision Livestock Farming system is a support tool that includes cameras, microphones and other sensors for tracking livestock, as well as computer software, and could improve the production efficiency through the adoption of electronic data collection, processing and application, but does not intend to replace the farmer; is an animal-centric tool the animal is the main part of the process and needs ideal conditions for the monitoring and control processes. For example, Precision Livestock Farming systems have revolutionized the milking process through the introduction of automatic milking robots, leading to an improved quality and increased quantity of milk, while welfare status is maintained at high levels (*John et al.,*2016), since each individual animal can choose their preferred time of being milked. Precision Livestock Farming is a real-time monitoring technology with the core purpose to 'manage even the slight EST manageable production unit's temporal variability (i.e., per animal approach)' (Halachmi *et al*., 2018). They are frequently integrated with other new technologies to improve human–livestock interactions, productivity, and economic sustainability in modern farms (Vaintrub *et al*., 2021). Animal welfare is an ethical concept and is subject to societal input. Animal welfare refers to the physical and emotional state that is impacted by the environment in which the animal lives and works, human attitudes and practices, and resources available to it. Welfare is an ever-changing state in which all of these factors can and will cause welfare to fluctuate between good, bad, and somewhere in between on a near-constant basis. Animal welfare refers to an animal's physical and mental state in relation to the conditions in which it lives and dies. This literature review examines recent advances, benefits, challenges, and knowledge gaps in Precision Livestock Farming as they relate to dairy cattle welfare and behavior.

1.1. Objectives

The purpose of this literature review is to:

- To examine advancements in precision livestock farming technologies relevant to dairy systems, including monitoring of heat stress, behavior, health, and productivity.
- To assess the benefits of precision livestock farming for animal welfare, resource efficiency, and farm management.
- To identify challenges and risks, including technical limitations, welfare trade-offs, and ethical concerns.

2. Literature Review

2.1. Benefits of Precision Livestock Farming and Housing or Management Innovations

2.1.1. Heat Stress and Thermal Comfort

Exposure to elevated ambient temperatures and humidity primarily induces heat stress in livestock, hindering their ability to dissipate heat to their surroundings, whether on the farm or during transportation. The consequences of heat stress typically manifest as reduced productivity and compromised animal welfare, although severe or prolonged conditions can lead to fatalities. The susceptibility to heat stress varies among animals depending on factors such as species, breed, life stage, genetic makeup, nutritional status, size, insulation level (including hide thickness or feather distribution), and previous exposure. Metabolically, heat stress induces physiological responses, including heightened respiratory and sweating rates, coupled with reduced feed intake, leading to diminished growth rates and decreased milk or egg production (Polsky *et al.,* 2017). Studies in dairy cattle have shown that prenatal heat stress reduces milk yield in the first lactation (Papatsiros et al., 2022) and alters nutrient allocation and carcass composition (Johnson *et al*., 2015). High-energy-demand individuals and breeds, such as high-yielding dairy cows, are particularly vulnerable to heat stress compared to beef cattle (Rashamol *et al*., 2019). Furthermore, heat stress exacerbates metabolic disorders such as lameness stemming from ruminal acidosis or bicarbonate output, weight loss, ketosis, and liver lipidosis (Lacetera, 2018)

2.1.2. Behavior, Social Stress, Welfare Indicators

In dairy cattle farming, animals face several stressors related to housing technology and arising from the husbandry itself. These can include overcrowding, heat stress, and pain caused by inflammation or diseases related to internal origins, as well as severe lameness, the presence of the farmer, and inappropriate human–cattle relationships, or milking, which are among the most common short-term stressors in dairy cattle housing systems. Animals react to these stressors with behavioral responses, such as prolonged standing, reduced lying times, abnormal gait, decreased activity and rumination, or avoidance of humans. In the following, stress-inducing factors and the changes in the behavior of dairy cattle are discussed. Besides stall comfort, social factors such as stocking density and regrouping also significantly impact the behavior of dairy cattle (Chebel *et al.,* 2016). Higher density leads to shorter lying times, and animals spend more time outside the stalls. There are increasing displacements, and the animals try to rest earlier after milking (Fregonesi *et al.,* 2007). A higher stocking density increases the number of aggressive non-nutritive behaviors at the feeding bunk and displacements, and decreases feeding bouts.

2.1.3. Automatic Milking Systems and Modeling of Sensor Data

Automatic Milking Systems (AMSs) are revolutionizing dairy farming worldwide. Not only do they control the milking process, but they also bring changes to the whole farm system management. Automatic Milking Systems (AMS) have played a pioneering role in the advancement of Precision Livestock Farming, revolutionizing the dairy farming industry on a global scale. Automatic milking is based on cows' voluntary visits to the robot, so that cows are no longer brought to the milking parlor two or three times daily by human handlers. Animals are free to go to milking at any time on a daily basis, as well as to dynamically adjust the intervals between milking throughout the lactation period (Vijayakumar *et al*., 2017). The AMS process is entirely mechanized, reducing the labor burden on farmers in relation to milking operations. This has the potential to enhance the quality of their work and improve their overall lifestyle. AMS has the potential to increase milk production in cows as they can be milked up to three times a day on average, compared to twice-daily milking in conventional systems. Studies have shown an increase in milk production ranging from 3% to 25% with the use of Automatic milking systems (Tse *et al*., 2018).

Modeling tools have been widely used in predicting mastitis based on data from Automatic milking systems, proving useful in addressing the economic losses and welfare concerns associated with this disease in the dairy industry. Mastitis is a highly concerning condition that results in decreased milk production, reduced milk quality, and compromised cow welfare (Melchior *et al*., 2006). Models that utilize milk parameters to detect the presence of mastitis-causing pathogens can provide valuable information for managing the disease. After consulting the mastitis alert lists, farmers must be aware of the causal pathogen to initiate an effective antimicrobial treatment (Kamphuis *et al*., 2011).

2.1.4. Performance, Productivity, and Sustainability Impacts

These technological systems function in unison to provide favorable living conditions, extended lifespan, and decreased death rates for animals in agricultural facilities (Laylani *et al*., 2024). Productivity gains through Precision Livestock Farming occur because farmers can optimize feeding operations, breeding schedules, and general farm management practices (Mohamad *et al*., 2025). A combination of automated feeding systems regulates the precise delivery of feed to animals so farmers achieve better productivity along with lower waste rates (Saadoon *et al*., 2025). Through advanced reproductive monitoring, farmers obtain better knowledge about breeding times, allowing them to optimize reproductive management and achieve higher livestock yield (Abed *et al*., 2024). The use of real-time health monitoring prevents productivity decreases because animals recover faster and continue performing when diseases receive prompt diagnosis and treatment (Laylani, 2024). Various challenging obstacles prevent the large-scale implementation of Precision Livestock Farming technology. Starting up with expensive advanced technology poses a major financial barrier for small agricultural producers because the required capital outlay is challenging to obtain. Specialized knowledge and training become necessary for handling the complicated process of integrating and making sense of the extensive data retrieved from Precision Livestock Farming systems (Al-Aameli *et al*., 2019).

2.2. Challenges, Risks, and Ethical Considerations

2.2.1. Technical and Practical Limitations

Precision Livestock Farming can directly harm animals due to technical failures, the harmful effects of exposure, adaptation, or wear of hardware components, inaccurate predictions and decisions resulting from poor external validation, and a lack of uptake of the most meaningful indicators for animal welfare. Precision Livestock Farming may create indirect effects on animal welfare if the farmer or stockperson becomes under- or over-reliant on Precision Livestock Farming technology, spends less (quality) time with the animals, and loses animal-oriented husbandry skills.

Precision Livestock Farming may also compromise the interests of the animals by creating transformations in animal farming so that the housing and management are adapted to optimize Precision Livestock Farming performance or become more industrialized. Finally, Precision Livestock Farming may affect the moral status of farm animals in society by leading to increased speciesism.

2.2.2. Welfare Indicators and Ethical Concerns

The variability in production systems in terms of species, genetic variability, and rearing environments, as well as individual variability in behaviors such as feeding or drinking. For this reason, devices that are not 'wearer-driven' or repurposed for different species may not always be suitable; hence, there is a potential that devices could cause physical injuries or have an impact on animal behavior, e.g., social behavior, especially if a single animal is wearing multiple devices. There are also concerns that the implementation of Precision Livestock Farming could change farm management to fit the use of technology rather than to improve welfare. For example, cameras may need longer and brighter light hours to work efficiently, or rearing environments may be made more barren to reduce obstacles or background noises for cameras.

3. Gaps in Current Knowledge

Current research in Precision Livestock Farming (PLF) reveals several notable gaps that limit a comprehensive understanding of its long-term and system-wide impacts. Studies rarely address positive welfare, leaving limited evidence on how Precision Livestock Farming can support positive affective states, social interaction, and enrichment-based outcomes. Research also tends to rely on short-term or cross-sectional designs, resulting in insufficient knowledge about the long-term behavioral and welfare implications of Precision Livestock Farming technologies. Standardization challenges persist, as studies employ diverse behavioral and physiological indicators, which complicates the comparison and synthesis of findings. Additionally, the geographical and production-system focus of current research is narrow, with most studies conducted in temperate, intensive dairy systems and far fewer in tropical, semi-arid, or smallholder contexts where constraints and opportunities differ markedly. Finally, limited attention has been given to how Precision Livestock Farming alters human–animal interactions, including stockperson observational skills, bonding, and routine management practices.

4. Conclusion

Precision Livestock Farming holds significant promise for transforming dairy production by enabling individualized monitoring of health, behavior, and environmental conditions. When effectively implemented, Precision Livestock Farming can enhance early disease detection, reduce labor demands, improve productivity, and support more sustainable resource use. However, welfare outcomes depend on more than technological capability. Ethical deployment requires robust system validation, ongoing human oversight, and attention to the holistic needs of dairy cattle, including psychological well-being, comfort, social behavior, and environmental enrichment. Future efforts should address existing knowledge gaps—particularly in positive welfare assessment, long-term impacts, and system standardization—to ensure that PLF evolves as a tool that genuinely supports the welfare of dairy animals while strengthening the sustainability and resilience of dairy farming systems.

Recommendations

To ensure that Precision Livestock Farming technologies meaningfully enhance dairy cattle welfare, several key recommendations emerge from the literature. First, Precision Livestock Farming systems should be designed with welfare as a primary objective by incorporating indicators of comfort, positive affect, social behavior, and environmental quality. Second, sensors and predictive models should undergo rigorous validation and calibration across diverse farming environments, breeds, and management systems to ensure reliability. Third, farmers must receive adequate training to interpret PLF-generated data, maintain animal-focused skills, and intervene appropriately. Fourth, management strategies such as improved housing design, shading and cooling systems, and pasture access should accompany technological tools to create welfare-supportive environments. Finally, continuous monitoring for unintended consequences, such as device-induced stress, behavioral disruption, or reduced human–animal interaction, is essential to prevent welfare trade-offs and ensure the ethical use of Precision Livestock Farming.

References

[1] Suha Maher Abed, Sahar Naji Rashid, and Fatima Mustafa Al-Najar, “Comparative Effects of Nd:YAG And Diode Laser Irradiation on *Escherichia Coli* Clinical Isolates: A Molecular Analysis,” *International Journal of Design & Nature and Ecodynamics*, vol. 19, no. 4, pp. 1121-1128, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[2] Muna Hussain AL-Aameli, Rajaa Ali Moheiseen Al-Taee, and Heba A. Abd-Alsalam Alsalame, “Histological and Physiological Alterations in the Aorta and Heart in Relation with Cholesterol Diet in Male Albino Rat,” *Indian Journal of Forensic Medicine and Toxicology*, vol. 13, pp. 313-318, 2019. [CrossRef]

[3] Heba A. Abd-Alsalam Alsalame, “Study Effects of *Nigella Sativa* Seeds Oil in Some Physiological Parameters in Experimental Heart Failure Induced by Ivabradine in Male Rats,” *Indian Journal of Forensic Medicine & Toxicology*, vol. 14, no. 3, pp. 2069-2613, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[4] Daniel Berckmans, “Automatic On-Line Monitoring of Animals by Precision Livestock Farming,” *Animal Production in Europe: TheWay Forward in a Changing World*, pp. 27-30, 2004. [Google Scholar] [Publisher Link]

[5] D. Berckmans, “General Introduction to Precision Livestock Farming,” *Animal Frontiers*, vol. 7, pp. 6-11, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[6] Ricardo C. Chebel et al., “Social Stressors and Their Effects on Immunity and Health of Periparturient Dairy Cows,” *Journal of Dairy Science*, vol. 99, no. 4, pp. 3217-3228, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[7] J.A. Fregonesi, C.B. Tucker, and D.M. Weary, “Overstocking Reduces Lying Time in Dairy Cows,” *Journal of Dairy Science*, vol. 90, no. 7, pp. 3349-3354, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[8] K. Lavanya et al., “Overview of Precision Livestock Farming,” *Current Trends in Agriculture & Allied Sciences*, vol. 3, pp. 642-649, 2024. [Publisher Link]

[9] C. Kamphuis, H. Mollenhorst, and H. Hogeveen, “Sensor Measurements Revealed: Predicting the Gram-Status of Clinical Mastitis Causal Pathogens,” *Computers and Electronics in Agriculture*, vol. 77, no. 1, pp. 86-94, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[10] Nicola Lacetera, “Impact of Climate Change on Animal Health and Welfare,” *Animal Frontiers*, vol. 9, pp. 26-31, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[11] Layla S. Laylani et al., “The Effect of Carotenoids of *Rhodotorulaglutinis* and Probiotic of *Lactobacillus Acidophilus* on Physiological and Histological Variables of the Kidney in Male Rats Exposed to Ultraviolet Radiation,” *Journal of Animal Health and Production*, vol. 12, no. s1, pp. 326-331, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[12] M.B. Melchior, H. Vaarkamp, and J. Fink-Gremmels, “Biofilms: A Role in Recurrent Mastitis Infections?,” *The Veterinary Journal*, vol. 171, pp. 398-407, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[13] J.S. Johnson et al., “Effects of in Utero Heat Stress on Postnatal Body Composition in Pigs: II. Finishing Phase,” *Journal of Animal Science*, vol. 93, pp. 82-92, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[14] Sadam Mohamad Hassan et al., “Using the Diverse Vegetables as a Filtration Plants in Aquaculture Intensive System,” *Tikrit Journal for Agricultural Sciences*, vol. 25, no. 1, pp. 1-16, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[15] Vasileios G. Papatsiros et al., “Effects of Phenolic Phytogenic Feed Additives on Certain Oxidative Damage Biomarkers and the Performance of Primiparous Sows Exposed to Heat Stress under Field Conditions,” *Antioxidants*, vol. 11, no. 3, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] Liam Polsky, and Marina A.G. von Keyserlingk, “Invited Review: Effects of Heat Stress on Dairy Cattle Welfare,” *Journal of Dairy* Science, vol. 100, no. 11, pp. 8645-8657, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[17] C. Tse et al., “Impact of Automatic Milking Systems on Dairy Cattle Producers’ Reports of Milking Labour Management, Milk Production and Milk Quality,” *Animal*, vol. 12, no. 12, pp. 2649-2656, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[18] Mahmood Saadoon Salih, Ammar Fakhri Khudair, and Ziyad Khlaf Salih, “Effect of Polymers and NPK Fertilizer on the Vegetative and Flowering Characteristics of *Sennasurattensis* under Deficit Irrigation,” *Tikrit Journal for Agricultural Sciences*, vol. 25, no. 1, pp. 31-43, 2025. [CrossRef] [Google Scholar] [Publisher Link]
[19] Mayakrishnan Vijayakumar et al., “The Effect of Lactation Number, Stage, Length, and Milking Frequency on Milk Yield in Korean Holstein Dairy Cows Using Automatic Milking System,” *Asian-Australasian Journal of Animal Sciences*, vol. 30, no. 8, pp. 1093-1098, 2017. [CrossRef] [Google Scholar] [Publisher Link]