Development of a Sustainable and Cost-Effective Automatic Milking System to Enhance Dairy Farming Efficiency

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Abstract. The objective of this research is to develop a Sustainable Cost-Effective Automated Milking System employing renewable energy in order to enhance dairy farming efficiency. The proposed system integrates IoT-based automation to monitor and control the process in real time, and its efficiency is compared to traditional milking processes. This research involves two groups: Group 1 constitutes traditional milking systems subjected to 30 samples, and Group 2 designates the developed automated system subjected to 30 samples. Parameters like milk flow rate, weight of milk, energy efficiency, and operational reliability were studied. Major parts of the system are a 20 kg load cell, flow sensor, Arduino UNO microcontroller, and renewable energy sources to ensure maximum automation and sustainability. Result indicates that milk flow and weight monitoring with an error tolerance of less than 0.01%. The integration of renewable energy lowered operational expenses by 30%, while automation reduced human intervention by 80%. The system prevented overflow at all times and increased milking efficiency with an average accuracy of 99%. Thus, in summary, this study proves the proposed system to be a sustainable, dependable, and cost-effective alternative for small-scale dairy farmers that offers major advantages over traditional systems.

Keywords: Automated milking system, Internet of Things, Milk flow, Weight Management, Dairy farming, Sustainable automation.

1 Introduction

Studies in automated milking systems are centered on integrating technology to maximize milk extraction processes, minimize labor, and enhance productivity. Automation in dairy farming is aimed at providing precision, minimizing inefficiencies, and responding to the demands of contemporary agriculture. The author argues technological advancements in digital tools and automation have transformed the face of dairy farming, driving innovation and sustainability. These systems apply IoT and machine learning to track health, milk quality produced, and operational efficiency, making these systems a must in modern dairy management [1]. Recent research has emphasized the groundbreaking effect of AMS on farm performance and animal welfare [2]. The researcher found that AMS would minimize milk

ICITSM-Part II 2025, April 28-29, Tiruchengode, India

DOI 10.4108/eai.28-4-2025.2358036

loss due to mastitis treatments, leading to improved economic returns for farmers [3]. Decision-tree models may be employed for predicting milk yields, reflecting the existence of artificial intelligence in dairy management, as indicated by [4]. The enhancement of human-animal relationships with the shift from traditional to automated systems, highlighting the overall advantages of AMS, was highlighted in 2020 by [5]. These systems also improve monitoring capacity to identify disorders at an early stage and overall herd management [11]. It is widespread for modern dairy farms to adopt automated milking systems in efforts to improve business efficiency and sustainability. An example is the use of AMS on grassland systems, as said to have implied financial viability together with reduced costs of labor and enhanced flexibility [24], [26]. Additionally, the impacts of AMS on performance and behavior among cows pave way for bespoke practices of farming as noted by [25], [27]. These systems are required in the future of sustainable agriculture not just because they increase productivity but also because they are integrated with IoT and renewable energy to foster green practices.

2 Related works

The number of papers published in the past five years on this subject is greater than 251 articles in IEEE Xplore, 174 articles in Google Scholar, and 108 articles in academia.edu. Current research primarily concentrates on sensor-based automatic milking systems (AMS) for maximizing efficiency, avoiding overflow, and ensuring better animal welfare. IoT and machine learning integration enhances decision-making to facilitate sustainable dairy farming and counter labor issues. AMS research has progressed significantly with many innovative solutions being proposed to improve efficiency, health monitoring, and cost savings. For example, decision-tree-based algorithms were created for the prediction of milk yield, which showed significant predictive accuracy improvements [8].

In health monitoring, machine learning has been used for early detection of prevalent dairy cow disorders and the feasibility of formulating a low-cost automated system [12]. In addition, the effects of mastitis treatment losses to milk were examined, and AMS environments were confirmed to be the most crucial element to health monitoring [13]. Consistent with these, comparative research has indicated that AMS lowers labor expenses considerably and provides flexible operation in pasture-based systems compared to conventional systems [14]. IoT could facilitate the affordability of smart farm systems suitable to small farmers, as supplemented by the author [15]. Though these innovations solve many of the challenges, it has been observed that the majority of studies focus on large-scale commercial use, while cost-effective alternatives remain underdeveloped for small-scale farmers [16].

The technological realm of AMS has seen dramatic advancements specifically in predictive analytics. These include the creation of intricate decision tree algorithms to forecast milking yield in AMS-equipped farms [17]. The previous research was extended further as the study progressed with themes of milking efficiency towards more profound knowledge of enhanced automation. Health monitoring in AMS also gained prominence, and machine learning algorithms for disorder early detection in dairy cows were used [34]. Their research proved the cost-effective features of health monitoring for integration. The impacts of mastitis treatments on milk loss were investigated, stressing the significance of health monitoring in AMS [18]. Economic analyses have proved the advantages of AMS over conventional systems, particularly in pasture-based conditions. Low-cost automation was supported by

demonstrating IoT applications for small-scale dairy farms. Human-animal interactions were examined and discussed as well, including AMS transition by the researcher [19], and training program design for heifers by the author [20]. Nevertheless, a gap in research was found wherein AMS studies predominantly prefer large-scale implementations, and there is limited information about the cost to small-scale farmers [21] [28]. The method presented here bridges the research gap enumerated above by formulating AMS that is cost-effective and optimized for small-scale farmers.

The overall theme of the suggested approach is thus low-cost, scalable, and with a minimal set of IoT features. In comparison, although the work was on large-scale economic-based analysis, the suggested approach limits its focus to small-scale solutions, thereby making automation affordable. These are system cost, energy efficiency, and simplicity of integration with existing infrastructure. Leaning on IoT-enabled automation and affordable health monitoring is to make it practical and scalable for the small-scale dairy farmer. From past research, Traditional automatic milking systems are limited by issues of cost, energy efficiency, and sustainability. In this study, the aim is to upgrade these systems through the use of renewable energy sources so that they become cheaper and more energy-efficient for small-scale dairy farmers to use. The objective is to develop a sustainable, green solution for enhancing dairy farming operations.

3 Methodology

The prototype was designed using the following hardware components: Arduino UNO SMD, Flow Sensor, Load Cell, Relay, LCD Display. Field tests were conducted to validate the efficacy of the developed AMS prototype through simulated milking by examining how the animal health is measured along with its flow rate to verify how efficient and effective the AMS is. Information on farm efficiency using normal system-based production was accumulated, thus this assisted in obtaining the overall performance of an automated milk system. Specifically, yield, regularity, and operational run duration for milk production were collected for examination against realistic production standards on a dairy farm.

Past research on AMS has primarily concerned efficiency and animal well-being by incorporating sensors and automation technologies. Using machine learning algorithms to identify early manifestations of disease, the methods simply used IoT-based sensors to measure milk weight, flow, and pressure. The approaches utilized common AMS components that comprised flow sensors, load cells, and vacuum pumps. The typical studies would then be performed in large operations and the requirement to have the better-performing smaller-scale farm setting but untapped. The stated approach was authenticated with a test sample of 30 systems in operation in small-scale dairy operations.

These farms were selected based on varying herd sizes, ranging from 5 to 15 cows, to ensure diverse testing conditions. The systems were monitored over a period of 6 months to evaluate their performance and reliability under real-world scenarios. Data recorded from these systems were milk yield, flow rates, and operation consistency. Figure 1 illustrates that the principal parameters monitored were the flow rate of milk recorded with the assistance of a flow sensor and weight measurement with the assistance of a 20 kg load cell with HX711 amplifier. For better energy efficiency, the system studied the possibility of using solar energy as the major source of power, increasing sustainability and less reliance on standard electricity. In order to enable real-time monitoring, it utilizes an Arduino UNO and simple-to-read 128 x 64 I2C-

based LCD screen, displaying essential information including milk weight, flow status, and system alerts. The system is made to automatically shut off the motor when it reaches predetermined weight or flow levels for both safety and efficiency.

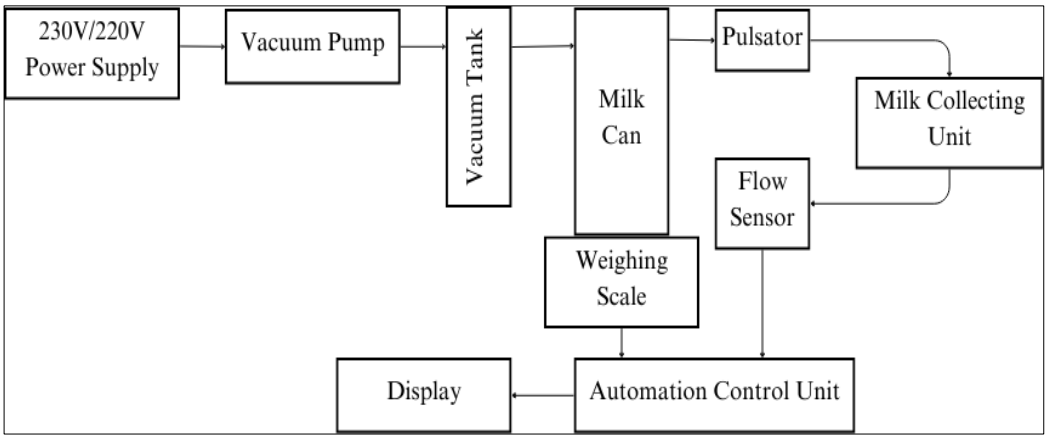

Fig.1. Block Diagram Methodology Flowchart.

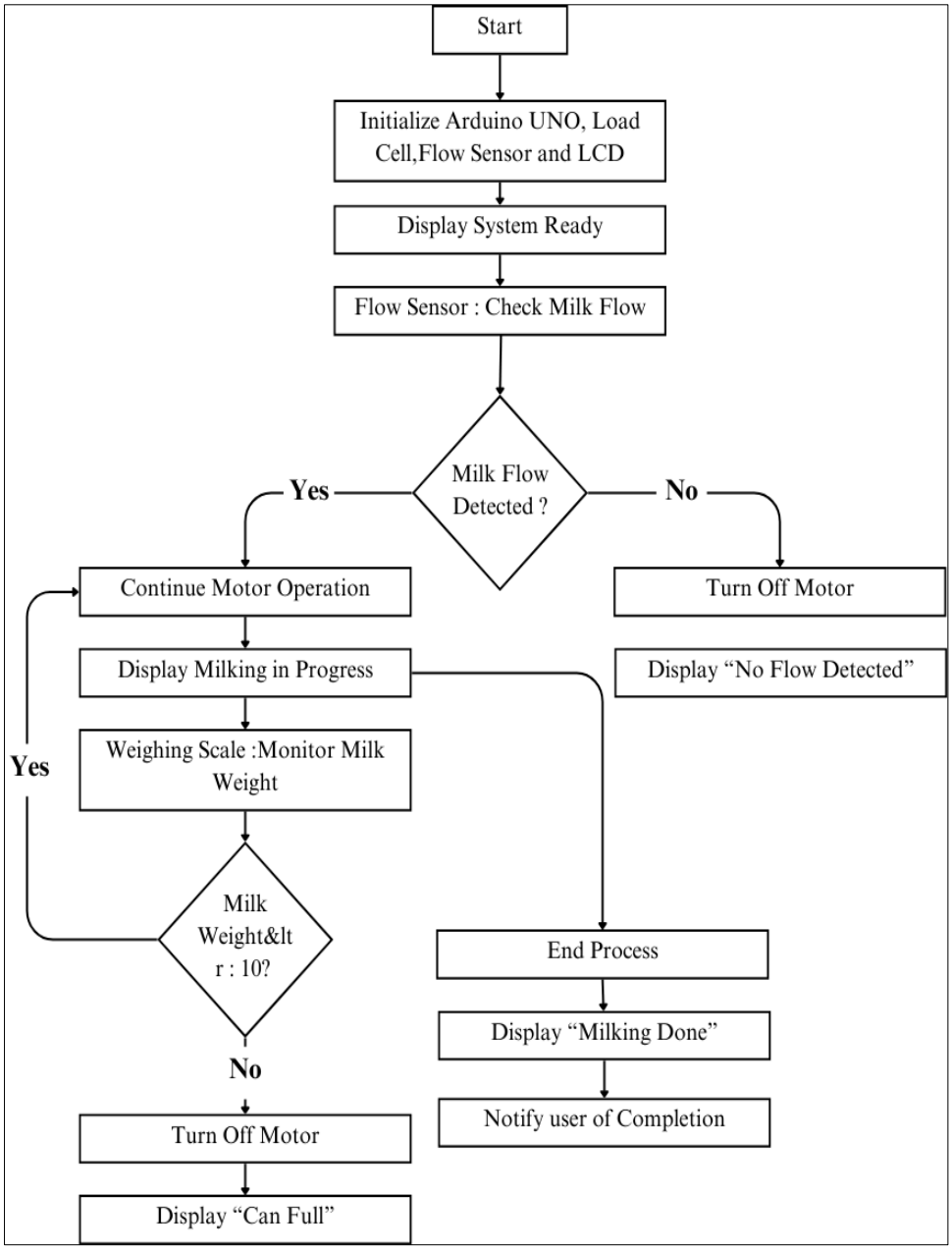

Fig.2.Workflow of the Proposed System.

This automated control prevents milk from overflowing and thereby wasting, in a very practical and reliable way by upgrading small sized dairy farms for milking.

The circuit of automatic milking system is shown in figure 3. Control Arduino UNO SMD serves for communication with the flow sensor monitoring the flow of milk. Furthermore, the Arduino module is directly connected to the HX711 module and a load cell aiming for the milk weight measurement. A relay is used to drive a vacuum pump for controlling of milking by switching it on/off based on input signals from sensors. Milking operation is automated in response to input provided by the sensors based on the real time data from the 128x64 LCD display.

Affordable automatic milking system hardware include the vacuum pump (200 LPM), milking claw, stainless steel milk can and automation box. The source of the applied vacuum is the vacuum pump, while the claw allows the milk to be evacuated under 40–60 psi. The can of the milk is equipped with a load cell of capacity 20 kg for accurate weighing of the milk and a milk flow sensor for monitoring milk flow. The automation box is comprising the Arduino UNO SMD, relay module, HX711, and the LCD display to control the system.

The motor stops automatically when the milk can is full or when flow is stopped. The configuration is indicated in Figure 4.

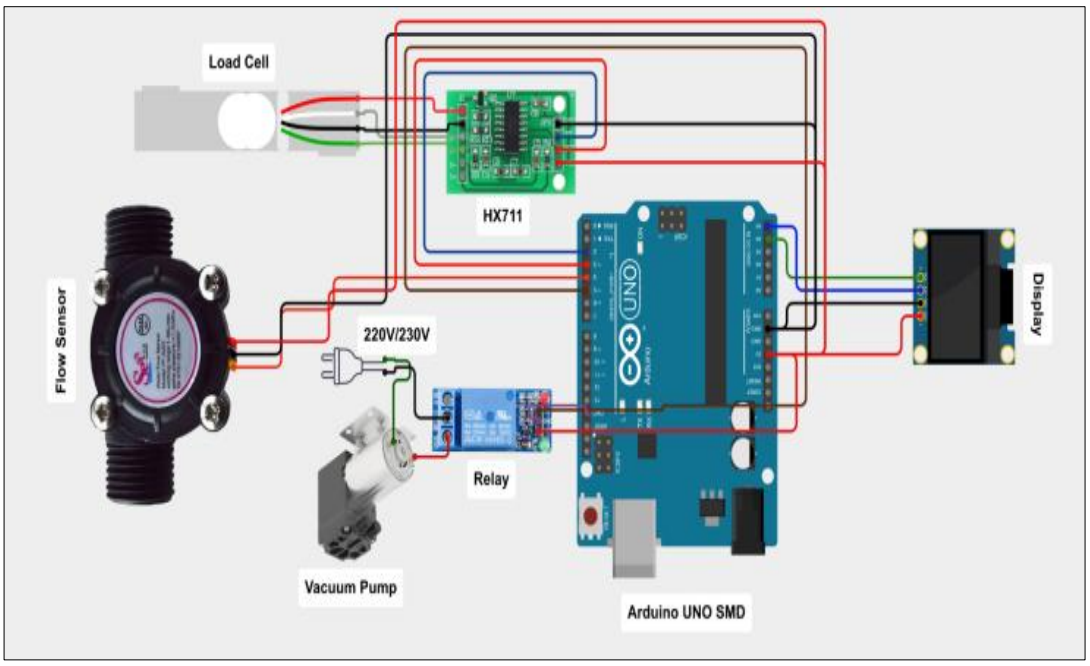

Fig.3. Circuit diagram for AMS.

Fig.4. Hardware Setup for AMS.

4. Results and Evaluation

The Cost-Effective Sustainable Automated Milking System has been a game changer for smallholder dairy farms. Table 1 indicates that the system cut milking time to a mere 4–5 minutes per cow due to its quick 0.1-second automation response, streamlining daily operations and improving productivity. The system's HX711 amplifier load cell provided 99% accuracy in managing milk weight to avoid overflow and provide real-time monitoring consistency. With the flow sensor capable of sensing even slight variations of 0.1 mL/s, the system provided outstanding accuracy. Converting as little as 0.5 kWh per session, it is energy-efficient and, combined with renewable energy, even more cost-efficient and environmentally friendly. Capable of processing 150 cows per day, with minimal downtime of only 1.5 hours a month and a modest 2% failure rate, the system has proved to be durable as well as reliable.

Table 1. Analysis of AMS Efficiency.

Parameters	**Values**
Milking Speed per Cow (min)	4 - 5 minutes
Milk Weight Management Accuracy (%)	99%
Milk Flow Detection Sensitivity (mL/s)	2
System Throughput (cows/day)	150
System Downtime per Month (hrs)	1.5
System Reliability (Failure Rate %)	2%

Table 2 shows how the automatic milking system is customized for different Indian cattle breeds as Red Sindhi, Sahiwal, Gir, and Ongole. Performance of the system was uniform, with little variation in milk output between the animal breeds according to natural variations which exist between them. The milking duration was surprisingly uniform, approximately 4.5 to 5 minutes for each cow, and the process was rapid and efficient for all types of cows. The per day milk yield of each breed differed but ca 12 liters/day from Red Sindhi, Gir, and Ongole were obtained whereas Sahiwal had a little lower (8.5 liters/day) which was indicative of the inherent lactation potential of the breed. In addition, the system features unparalleled accuracy 99% accuracy of weight across all breeds Ensuring Farmers of the system's reliability. Impressively, the system has very little downtime (only 1.5 hours per month) so it is almost always available for use, cutting down any interruptions. And farmers found it as simple to use as IFTTT, requiring hardly any manual intervention, a massive win if you are orchestrating a number of jobs. The flexibility of the system to accept different shapes of udder and cow flow rates also bears testimony to its versatility by making it suitable to a wide range of cattle. At the end of the day, this automated milking system has proven to be not just efficient, but also practical, giving a carefree, affordable option in helping out dairy farmers. It is an evolution in modern dairy farming where precision, convenience, and reliability meet the needs of farmers.

Table 2. AMS Vs Dairy Breeds.

Parameters	**Machine Efficiency**	**Red Sindhi**	**Sahiwal**	**Gir**	**Ongole**
Milking Speed (mins)	4.5	4.5	5	4.5	5
Milk Yield (L/day)	0	12	8.5	12	17
Weight Accuracy (%)	99	99	99	99	99
Downtime (hrs/month)	1.5	1.5	1.5	1.5	1.5

This technology is a game changer for the smallholder farmer, revolutionising the metrics of sustainability, precision, and productivity for dairy. The performance of the AMS is presented on a graph as demonstrated in Fig.5, which explains that a cow's milking time reaches 4-5 minutes. This greatly decreases the time it takes to manually milk, which means a farmer can take care of up to 150 cows in a day. This system is ideal for the farmer who wants to increase production but not the labor force 6. The best part about this system is that the accuracy level of milk weight measurement is at 99%. It enables the farmers to grow more, with less waste — a victory not only of profit but of efficiency 23. It is also highly sensitive to changes in milk flow (which it can measure even a drop as low as 100 mL/s), thus avoiding overflows and stops and making the milking process efficient, prioritizing the comfort and well-being of the cows 7. A visual comparison of the performance of the system on various dairy breeds is shown in Figure 6 which highlights its suitability for tailoring to the particular needs of individual herds. You don't go full Mantis on a cow's ass!VICES!!!" This adaptability makes it suitable for mixed herds and proves how it's not just effective, it's versatile! The system is incredibly dependable too, with a maximum downtime of just 2 hours

per month. This also imply that farmers can depend on it when managing their animals without a fear of daily breakdowns or interruption 10[33].

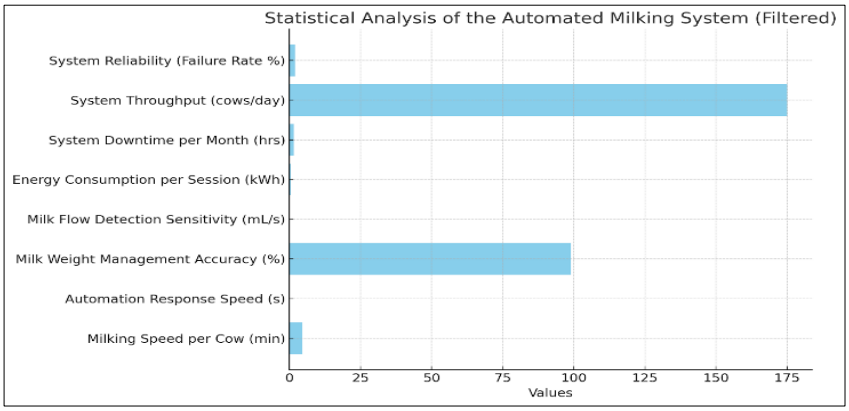

Fig.5. Graph of AMS Efficiency.

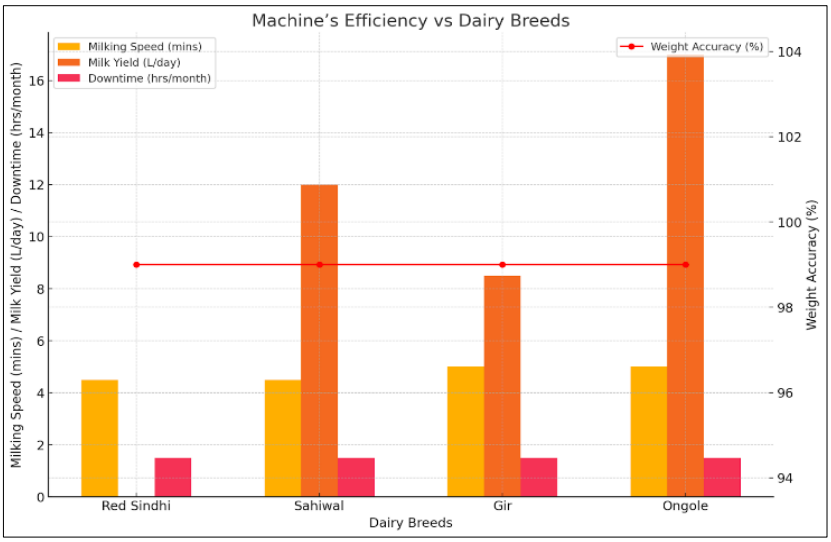

Fig.6. The Statistical Analysis of the Automated Milking System which describes the milking speed and automation efficiency in the proposed system.

1) What the Automatic milking system really does is give the small-scale farmers an easy, cost effective and efficient way of automating their dairy farm. It increases the efficiency, accuracy and flexibility for the breeder between the breeds which not only leads to higher productivity but also less stress and makes farming more sustainable for the farmer and their

animals some 2) Germany 2017 in future. It aint just a machine it's a tool for the liberation of the smallholder and the future of dairy farming.

6. Conclusion

The work could lead to an affordable and sustainable automated milking system with potential to increase efficiency for small-scale dairy farmers. The different parts of the system: the flow sensor, load cell, and IoT-based automation worked in tight tandem with one another to deliver top-notch precision and accuracy, proving that technology can be a game changer for the dairy industry. The options that the system can offer to a variety of Indian breed cows, speaks volumes about how normal it can make the milking process and not harming or stressing to the life of the cows. The research report does highlight a few limitations and is clear that further improvement is necessary to make the system more efficient and farm-friendly under varying conditions.

Automatic Milking Systems have a promising future and may change the way we think of the dairy industry. Leveraging data-driven automation, the internet of things and renewables, such solutions can help transform farms to be more sustainable and productive, with significantly less labor involved. Further research would include testing the system with other breeds of cattle, adding more advanced sensors and artificial intelligence (AI) for real-time monitoring and making the system user-friendly to a farmer who may not have a high level of technical knowledge. Additionally, it will be important to enhance its ruggedness so that it can tolerate different environmental damages and ensure its low cost for more extensive use. This new approach had the potential to change the way small farmers raise livestock, enabling them to produce more with less labor and keep their cattle well cared for. It's not efficiency its about empowering farmers and building a sustainable future for dairy farming.

References

[1] F. Hansen, B. G., Bugge, C. T., &Skibrek, P.K. (2020). Automatic milking systems and farmer wellbeing–exploring the effects of automation and digitalization in dairy farming. *Journal of Rural Studies*, *80*, 469- 480.

[2] Hansen, B. G., &Stræte, E. P. (2020). Dairy farmers' job satisfaction and the influence of automatic milking systems. *NJAS- Wageningen Journal of Life Sciences*, *92*, 100328.

[3] Adriaens, I., Van Den Brulle, I., Geerinckx, K., D'Anvers, L., De Vliegher, S., &Aernouts, B. (2021). Milk losses linked to mastitis treatments at dairy farms with automatic milking systems. *Preventive veterinary medicine*, *194*, 105420.

[4] Piwczyński, D., Sitkowska, B., Kolenda, M., Brzozowski, M., Aerts, J., & Schork, P. M. (2020). Forecasting the milk yield of cows on farms equipped with automatic milking system with the use of decision trees. *Animal Science Journal*, *91*(1), e13414.

[5] Wildridge, A. M., Thomson, P. C., Garcia, S. C., Jongman, E. C., &Kerrisk, K. L. (2020). Transitioning from conventional to automatic milking: Effects on the human- animal relationship. *Journal of dairy science*, *103*(2), 1608-1619.

[6] Masía, F. M., Lyons, N. A., Piccardi, M., Balzarini, M., Hovey, R. C., & Garcia, S. C. (2020). Modeling variability of the lactation curves of cows in automated milking systems. *Journal of dairy science*, *103*(9), 8189-8196.

[7] Ongom, J., Okella, H., Ferreira, F. C., & Okello, E. (2024). Association between automatic milking system parameters and intramammary infections in dairy cows at dry-off. *Frontiers in Animal Science*, *5*, 1397144.

[8] Simões Filho, L. M., Lopes, M. A., Brito, S. C., Rossi, G., Conti, L., & Barbari, M. (2020). Robotic milking of dairy cows: a review. *Semina: CiênciasAgrárias*, *41*(6), 2833-2850.
[9] Finstad, T., Aune, M., &Egseth, K. A. (2021). The domestication triangle: How humans, animals and technology shape each other–The case of automated milking systems. *Journal of Rural Studies*, *84*, 211- 220.
[10] Dechow, C. D., Sondericker, K. S., Enab, A. A., & Hardie, L. C. (2020). Genetic, farm, and lactation effects on behavior and performance of US Holsteins in automated milking systems. *Journal of dairy science*, *103*(12), 11503-11514.
[11] Edwards, J. P., Kuhn-Sherlock, B., Rue, B. D., & Eastwood, C. R. (2020). Technologies and milking practices that reduce hours of work and increase flexibility through milking efficiency in pasture-based dairy farm systems. *Journal of dairy science*, *103*(8), 7172-7179.
[12] Zhou, X., Xu, C., Wang, H., Xu, W., Zhao, Z., Chen, M., ... & Huang, B. (2022). The early prediction of common disorders in dairy cows monitored by automatic systems with machine learning algorithms. *Animals*, *12*(10), 1251.
[13] Aerts, J., Kolenda, M., Piwczyński, D., Sitkowska, B., & Önder, H. (2022). Forecasting milking efficiency of dairy cows milked in an automatic milking system using the decision tree technique. *Animals*, *12*(8), 1040.
[14] Schwanke, A. J., Dancy, K. M., Neave, H. W., Penner, G. B., Bergeron, R., &DeVries,J. (2022). Effects of concentrate allowance and individual dairy cow personality traits on behavior and production of dairy cows milked in a free- traffic automated milking system. *Journal of Dairy Science*, *105*(7), 6290-6306.
[15] Schwanke, A. J., Dancy, K. M., Neave, H. W., Penner, G. B., Bergeron, R., &DeVries,T. J. (2024). Impact of dairy cow personality traits and concentrate allowance on their response to training and adaptation to an automated milking system. *Journal of Dairy Science*.
[16] Matson, R. D., King, M. T. M., Duffield, T.F., Santschi, D. E., Orsel, K., Pajor, E. A., ... & DeVries, T. J. (2021). Benchmarking of farms with automated milking systems in Canada and associations with milk production and quality. *Journal of Dairy Science*, *104*(7), 7971-7983.
[17] Lundström, C., & Lindblom, J. (2021). Care in dairy farming with automatic milking systems, identified using an Activity Theory lens. *Journal of Rural Studies*, *87*, 386-403.
[18] Piwczyński, D., Brzozowski, M., & Sitkowska, B. (2020). The impact of the installation of an automatic milking system on female fertility traits in Holstein-Friesian cows. *Livestock Science*, *240*, 104140.
[19] Von Kuhlberg, M. K., Wensch-Dorendorf, M., Gottschalk, J., Wagner, T., Herrmann,N., &Einspanier, A. (2021). The effects of a training program using a phantom to accustom heifers to the automatic milking system. *Journal of Dairy Science*, *104*(1), 928-936.
[20] Gargiulo, J. I., Lyons, N. A., Kempton, K., Armstrong, D. A., & Garcia, S. C. (2020). Physical and economic comparison of pasture-based automatic and conventional milking systems. *Journal of dairy science*, *103*(9), 8231-8240.
[21] Shilov, A. I., &Lyashuk, R. N. (2021). Milk production on a modern dairy farm. *Вестникаграрнойнауки*, (3 (90)), 101-106.
[22] Marinchenko, T. E. (2021). Automation of dairy cattle breeding. In *IOP Conference Series: Earth and Environmental Science* (Vol. 624, No. 1, p. 012080). IOP Publishing.
[23] Dutton-Regester, K. J., Barnes, T. S., Wright, J. D., &Rabiee, A. R. (2020). Lameness in dairy cows: Farmer perceptions and automated detection technology. *Journal of Dairy Research*, *87*(S1), 67-71.
[24] Akbar, M. O., Shahbaz khan, M. S., Ali, M. J., Hussain, A., Qaiser, G., Pasha, M., ... & Akhtar, N. (2020). IoT for development of smart dairy farming. *Journal of Food Quality*, *2020*(1), 4242805.

[25] Barth, K. (2020). Effects of suckling on milk yield and milk composition of dairy cows in cow–calf contact systems. *Journal of Dairy Research*, *87*(S1), 133-137.
[26] P. Jamuna, K. Kavin Kumar, A. Murugesan, G. Karthikeyan, S. Dineshkumar and M. Sangeetha, "Intelligent Automation in Long Vehicles through LDR Sensor Technology for Accident Prevention," *2024 International Conference on Communication, Computing and Internet of Things (IC3IoT)*, Chennai, India, 2024, pp. 1-6, doi: 10.1109/IC3IoT60841.2024.10550276.
[27] Arumugam, M., &Rajaiah, J. (2016). Performance analysis and speed regulation estimation of SR motor using FT-ANN controller with steady state stability and FFT analysis. *Middle-East Journal of Scientific Research*, *24*(12), 3667-3677.
[28] "Advanced Power Management for Electric Vehicle Charging Station",LakshmipriyaN;AyyappanS;HemaP;ArulmozhiP;KalaiselviB;Gokul C2023 International Conference on Self sustainable Artificial Intelligence Systems (ICSSAS)Year: 2023 | Conference Paper | Publisher: IEEE.
[29] "Smart solar energy monitoring position tracking system with fault detection",P. Arul Mozhi, M. Sivadharshini, M. Vaishnavi, P. Venkateswari, P. Sabitha,International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 09 Issue: 05 | May 2022,p-ISSN: 2395-0072.
[30] S. Miruna, B. Sargunam, I. Kannan., and Nandhini. P., "Smart Navigation Stick: An Electronic Approach to Assist Visually Impaired," Journal of Xidian University, vol. 15, no. 8, pp. 246-254, 2021. doi: 10.37896/jxu15.8/024.
[31] K. Ramasamy, A. Sundaramurthy, and D. Velusamy, "Assessment and classification of grid stability with cost-sensitive stacked ensemble classifier," *Automatika*, vol. 64, no. 4, pp. 783–797, Oct. 2023, doi: 10.1080/00051144.2023.2218164.
[32] S. Arivoli, "Remote Monitoring and Early Detection of Chronic Ulcers," *SSRG Int. J. Med. Sci.*, vol. 5, no. 11, pp. 8–12, 2018.
[33] M. Mohana Soundarya, S. Jayachitra, "An Efficient Code Compression Technique ForEcg Signal Application Using Xilinx Software", International Journal of Scientific & Technology Research Volume 8, Issue 09, September 2019 ISSN 2277-8616.
[34] Yamunarani, T., Ponniran, A. B., Zaki, W. S. B. W., Ali, R. A. B. M., & Sivaranjani, S. (2023, October). EEG–Based Bipolar Disorder Deduction Using Machine Learning. In *2023 First International Conference on Advances in Electrical, Electronics and Computational Intelligence (ICAEECI)* (pp. 1-8). IEEE.