



ADOPTION OF SMART TECHNOLOGIES AND IOT IN DAIRY FARMING: ENTREPRENEURIAL OPPORTUNITIES AND BARRIERS SMART TECHNOLOGIES AND IOT

Rejish M T

Part-time Research Scholar, Government College Kodenchery affiliated to University of Calicut

Dr.(prof) A. Mohandas. Government College Kodenchery

Jobin George

Part-time Research Scholar, Government College Kodenchery affiliated to University of Calicut

ABSTRACT

This research investigates the adoption of Smart Technologies and the Internet of Things (business 5.0) in the dairy industry, with a particular emphasis on the opportunities and challenges that are specifically related to entrepreneurship. The authors did a literature investigation to evaluate the various applications of Industry 5.0 and came up with 37 claims to test the hypothesis of the primary variables driving its adoption. An online survey was utilized to acquire data from 327 persons engaged in the dairy sector, such as farmers, professionals in the area, and academics. Initially, we used Exploratory Factor Analysis (EFA) to identify the primary factors that contributed to adoption, and then, we utilized Multiple Linear Regressions (MLR) to investigate the impact that these variables had on adoption rates. Competitiveness in the market and cooperation, data-driven decision-making and compliance, operational efficiency and productivity, and environmental impact and sustainability are the five main issues that need to be addressed, according to the assessment. The model, which included four components with statistically significant positive benefits, explained 63.8% of the variation in adoption. The findings provide insights that may be used by business owners, policymakers, and other stakeholders in the dairy industry in order to expedite the utilization of intelligent technology and the Internet of Things within the sector.

Keywords: *Smart Technologies, Internet of Things (IoT), Industry 5.0, Dairy Farming , Technology Adoption, Operational Efficiency, Sustainability, Data-Driven Decision Making*

INTRODUCTION

There are many different aspects of the food industry that depend on technology to assist them in addressing concerns about the safety and security of food. In the most recent few decades, the food and dairy sectors have been drastically transformed by the introduction of modern technologies. This shift is

being propelled by two primary concepts in the IT sector: Industry 4.0 (I4.0) and Artificial Intelligence (AI) [1]. The new technological framework known as "Industry 4.0" (I4.0) applies to a wide variety of companies. In the here and now, it uses cognitive computing, big data, and IoT-connected devices to make decisions [2, 3]. With the help of Industry 4.0, businesses may be able to streamline their processes and increase output while decreasing lead times without sacrificing quality. There have been tremendous shifts in the dairy sector as a result of new technology, particularly cyber-physical systems, the IoT, AI, and big data analytics. The dairy industry in India has great potential for technological advancement since it produces around 25% of the world's milk [4]. However, there are still challenges in the business that need considerable investments in order to be modernized. These challenges include limits on the infrastructure of transportation, chilling, processing, and feed management [5]. The development of more advanced feeding technology, the promotion of scientific livestock management, and the empowerment of farm women via extension techniques are all crucial for increasing production [6]. Increasing the use of technology makes it simpler to transition from manual to mechanized and automated operations, which in turn leads to an improvement in the operational efficiency of dairy farming [7,8]. There are millions of people who are employed and get revenue from the dairy industry, making it an essential component of the Indian economy [9].

To satisfy the growing demand for milk and dairy products in India, which is being driven by the country's expanding population [10–12], it is necessary to implement cutting-edge and environmentally friendly technologies. Some examples of these technologies include automated control systems, precision farming, robotics, and management systems that are based on information and communication technology. Through the use of waste-free processing, revolutionary food preservation technologies, pressure-driven membrane systems, and Modified Atmosphere Packaging (MAP), it is possible to enhance quality, cost, and ecological balance [13,14]. While the Gujarat Cooperative Milk Marketing Federation Limited (GCMMFL) is only one of numerous successful instances that demonstrate how information and communication technology have the potential to increase milk production, distribution, and innovation [15], there are also other successful situations. Robots, automation, the IoT, predictive maintenance, and AI are just a few of the many technologies that make up Industry 4.0. Businesses may respond faster to shifting market circumstances, boost productivity, and improve quality with the use of this technology [16–18]. Utilizing technology, precision farming reduces the amount of money spent on labor, ensures that milking schedules are correct, enhances the quality of milk produced, and maximizes the efficiency with which feed and water are managed in the dairy sector [19–22]. A contemporary approach to the management of dairy farms that is driven by technology has arisen as a consequence of these changes. This approach is known as Dairy 4.0.

Using robotics, big data, AI, blockchain, and the internet of things, Dairy 4.0 aims to raise the bar on sustainability, breeding, herd management, and production [23,24]. Even while technological developments have had a beneficial influence, the industry must continue to place a strong emphasis on investing in infrastructure and the development of talent if it wishes to experience the full benefits of these breakthroughs and stay up with the ever-changing demands of the market.

There have been four distinct periods in the history of dairy farming in India:

- **Dairy 1.0:** Back to the basics: agrarian lifestyle with little machinery and basic medical treatment.

- **Dairy 2.0:** The implementation of fundamental machinery, blended feeding, regulated breeding, and paper-based documentation.
- **Dairy 3.0:** Significant financial outlay for equipment, IVF, computerized record-keeping, and ecological compliance.
- **Dairy 4.0:** Incorporating cutting-edge innovation, solutions built on the internet of things, precision farming, and eco-friendly methods to maximize efficiency and minimize impact on the environment [25].

This study is predicated on the hypothesis that Dairy 4.0, which makes use of intelligent technology and the Internet of Things, offers a substantial potential for business owners by resolving issues pertaining to operations, sustainability, and economic concerns.

OBJECTIVES

1. To determine the main elements impacting dairy farming's adoption of IoT (Industry 5.0) and smart technologies.
2. To examine the impact of these factors on adoption levels and explore entrepreneurial opportunities and barriers in the dairy sector

METHODS

The authors searched the literature for dairy sector 5.0 applications. They then supported their statements with actual research. We used EFA to identify the primary elements influencing the dairy industry's adoption of I5.0 technologies, and we employed MLR to quantify the extent to which those elements were influential. They employed EFA with great care, as per the advice of Hair et al. (2006) [26], and the Bartlett test of sphericity confirmed the findings. The findings were corroborated using the Kaiser-Meyer-Olkin (KMO) values. All assessed statements must have commonality values greater than 0.5 to fulfill EFA thresholds. If the value is below the threshold, the statement will be eliminated and the data reanalyzed [27]. The statistical significance of the regression model in the ANOVA table shows that independent variables explain a lot of I5.0 technology adoption variance.

Sampling and data collection

A literature research informed the writers' questionnaire, which intended to highlight I5.0's most significant dairy sector elements. The authors made 37 statements about I5.0's key applications and four assertions about stakeholders' adoption levels to identify the main motivators. Information was collected using computerized survey forms and communication. In the 37-statement questionnaire examined by academic and business specialists, four statements were utilized to assess stakeholders' views on I5.0 adoption in the dairy industry. In order to gauge reader sentiment, the authors used a 5-point Likert scale, where 1 indicates strong disagreement and 5 indicates strong agreement. Out of 410 people that were surveyed, 327 were involved in the dairy industry.

Exploratory factor analysis

To prioritize, the authors employed factor analysis. The EFA is helpful for studying variables and their reliability. EFA was done using IBM SPSS v23. In EFA, data is cleaned, coded, loaded into SPSS, and analyzed. The authors utilized PCA with Varimax rotation for factor analysis. The research's major goal was to reduce data by considering response dimensions, hence principal component analysis (PCA) was selected above other common factor extraction methods including exploratory factor analysis' main axis. Statistical significance was determined using PCA for five components with eigenvalues larger than 1 and total variance explanations higher than 70%. Statements having a commonality below 0.5 were often omitted from the research. The absence of such a declaration is due to the fact that all of the study data fell within permissible boundaries.

Regression analysis using multiple linear

To determine how important factors affected adoption, researchers used multiple linear regression. Degree of adoption was the dependent variable, whereas recognized components were independent. A licensed version of XLStat integrated MLR. First, we averaged the answers to the dependent variable "level of adoption" for MLR, then we selected five independent factors, and last we generated the composite score for the dependent variable. We then checked all our assumptions.

DATA ANALYSIS

Reliability analysis

The authors used Cronbach alpha to verify response data. Maintaining consistent and reliable measurement instruments is the objective. Total data dependability was 0.962, indicating measurement error caused considerable fluctuation. This number indicates that all claims that meet the thresholds are very reliable.

Exploratory factor analysis

The authors followed the protocol of Hair et al. (2006) by using EFA consecutively. The research was confirmed by using the Bartlett test of sphericity. According to the Kaiser-Meyer-Olkin (KMO) values, the data was suitable. The Bartlett test of sphericity KMO result in SPSS v23 is shown in Table 1.

Table 1. KMO and Bartlett's test values

Adequacy of the Kaiser-Meyer-Olkin sampling method		0.951
Bartlett's sphericity test	Approx. chi-square	8735.739
	df	561
	Sig	0.000

By classifying relevant assumptions, the study found the I5.0 drivers for the dairy business. Since the KMO value is 0.951, which is far higher than the permissible limit of 0.6, the analysis may be considered credible. According to Bartlett's test of sphericity, the association between population characteristics is supported by the statistical significance ($P < 0.000$). A total of five factors were identified through factor analysis, all of which had eigenvalues greater than 1. These elements were operational efficiency and productivity, animal health and product quality, sustainability and environmental effect, data-driven decision-making and compliance, and market competitiveness and cooperation. It is encouraging that all 33 claims had similarities greater than 0.5. According to Table 2, the analysis was confirmed since all 33 claims had commonality values larger than 0.5. The claims were categorized into five sets, with each set explaining 70.586% of the total variation. Since 47.534% of the variation is explained by Factor 1, bias technique concerns are uncommon.

Table 2. Factors identified

Factor (F)	Factor Name	Statements	Commonality	Factor Loading	Reliability (Cronbach's α)
F1	Productivity and operational efficiency	The productivity of dairy farms is greatly increased by Industry 5.0 technology.	0.794	0.812	0.959
		Labor expenses are decreased by automation using Industry 5.0 technology.	0.763	0.803	
		Industry 5.0 technology increase production by optimizing milking schedules.	0.740	0.785	
		Robotics increases operational efficiency in dairy production.	0.779	0.785	
		Dairy processing procedures are	0.707	0.775	

		streamlined using Industry 5.0 technology.			
		Industry 5.0-enabled predictive maintenance lowers equipment downtime.	0.692	0.754	
		Using Industry 5.0 technology increases the overall effectiveness of farm management.	0.728	0.754	
		Industry 5.0's real-time data analytics enhances decision-making.	0.736	0.750	
		Dairy farmers' strategic planning is improved by predictive analytics in Industry 5.0.	0.723	0.748	
		Industry 5.0 technologies provide insightful information on how to allocate resources.	0.680	0.694	
		Innovation in the creation of dairy products is fueled by Industry 5.0 adoption. Industry 5.0 technologies allow for the early identification of	0.620	0.563	

		problems with animal health.			
F2	Product quality and animal welfare	Animal welfare is enhanced by Industry 5.0's real-time health monitoring.	0.713	0.779	0.922
		Automated feeding systems provide animals reliable, stress-free habits.	0.721	0.769	
		Technologies from Industry 5.0 improve the quality of milk produced.	0.748	0.759	
		Industry 5.0's ongoing oversight guarantees strict milk safety regulations.	0.685	0.752	
		Improvements in dairy product traceability are made possible by Industry 5.0 technology.	0.644	0.743	
		The nutritious value of dairy products is enhanced by the use of Industry 5.0 technology.	0.671	0.735	
		Dairy farming may attain sustainability objectives with the	0.711	0.710	

		use of Industry 5.0 technology.			
F3	Environmental effect and sustainability	Industry 5.0 technologies optimize waste management on dairy farms while reducing water and feed usage via precise resource management.	0.728	0.710	0.911
		The environmental impact of dairy operations is reduced by the use of Industry 5.0 technology.	0.767	0.682	
		Dairy production can better comply with environmental regulations thanks to Industry 5.0 technology.	0.653	0.667	
		Industry 5.0-enabled energy-efficient technologies lower total farm energy use.	0.733	0.636	
		Using Industry 5.0 technology makes it easier to comply with food safety laws.	0.765	0.584	
		Industry 5.0's ongoing oversight guarantees	0.597	0.518	

		adherence to animal welfare regulations.			
F4	Compliance and data-driven decision-making	Industry 5.0 technologies assist in achieving industry standards and certifications.	0.725	0.829	0.856
		Blockchain-powered industry traceability 5.0 boosts customer confidence	0.740	0.818	
		Industry 5.0-enabled secure supply chain transactions reduce fraud.	0.638	0.796	
		Industry 5.0 technology enable customers to purchase customized dairy products.	0.629	0.723	
		Collaboration with technology suppliers is facilitated by Industry 5.0 technologies.	0.585	0.720	
F5	Competition in the market and cooperation	Open and honest business practices via industry 5.0 strengthen supply chain collaborations	0.733	0.804	0.859

		The use of industry 5.0 technologies greatly increase our edge over competitors.	0.730	0.699	
		The productivity of dairy farms is greatly increased by Industry 5.0 technology.	0.700	0.585	
		Labor expenses are decreased by automation using Industry 5.0 technology.			

Multiple regression analysis

The goodness-of-fit statistics and MLR results are in Table 3. The training dataset's R² score was 0.638, indicating that the five factors explained 63.8% of I5.0 technology uptake. This model fits the training dataset well, as evidenced by the R² value, and these five criteria impact adoption. R² reveals that 36.2% of variation was unexplained despite high model fit. It is likely since current research restrictions prevented the empirical model from include survey length, time, etc. during study design. However, the authors value these traits and believe they may illuminate the remaining variance. Among these factors were market competitiveness and collaboration, data-driven decision-making and compliance, sustainability and environmental impact, animal health and product quality, and operational efficiency and productivity. Root mean squared error of 0.514 indicates comparable satisfaction. Overall, MLR analysis shows the model fits the data well.

Table 3. Statistics on the goodness of fit

Statistic	Training set	Validation set
Observations	196	131
Sum of weights	196	131
DF	190	125
R ²	0.638	0.561

Adjusted R2	0.628	
MSE	0.264	0.245
RMSE	0.514	0.495
MAPE	12.531	10.921
DW	2.089	
Cp	6.000	
AIC	-254.852	
AICC	-254.408	
SBC	-235.184	
PC	0.385	

Independence, normalcy, etc. were confirmed by residual analysis. There are no residual autocorrelations if the Durbin-Watson value is 2.089. According to the model, the highlighted factors have an effect on the heterogeneity of I5.0 technology adoption. The constant error metrics and goodness-of-fit statistics suggest that the model predicts well on both training and validation sets. The dairy business must adopt business 5.0 with efficiency, animal well-being, product quality, sustainability, environmental impact, market competitiveness, and cooperation. Table 4 shows variance analysis findings.

Table 4. Variance analysis

Source	DF	Sum of squares	Mean squares	F	Pr > F	p-value significance codes
Model	5.000	88.472	17.694	66.930	<0.0001	***
Error	190.000	50.231	0.264			
Corrected total	195.000	138.703				

The p-value suggests a highly significant model since chance has minimal effect on the F-statistic. Significant variance in adoption may be explained by independent variables, or factors. A total of 138.703 variance points are explained by the model's sum of squares (88.472), while 50.231 are explained by the

error. A high F-value (66.930) suggests good dependent variable variation accounting. This suggests that the listed primary drivers impact adoption levels. Table 5 shows p-value, confidence intervals, and standardized coefficients.

Table 5. Coefficients of regression and significance

Factor	Coefficient	p-value	Significance	95% CI
(F1): Productivity and operational efficiency	0.174	0.012	*	[0.038, 0.301]
(F2): Product quality and animal welfare	0.046	0.429	ns (not significant)	[-0.069, 0.162]
(F3): Sustainability and environmental impact	0.283	<0.001	***	[0.146, 0.421]
(F4): Data-driven decision-making and compliance	0.114	0.012	*	[0.025, 0.203]
(F5): Competitiveness and cooperation in the market	0.233	<0.001	***	[0.113, 0.353]

You can see the model's equation for the adoption levels in the equation below.

$$LOA = 0.344 + 0.174 \times F1 + 0.046 \times F2 + 0.283 \times F3 + 0.114 \times F4 + 0.233 \times F5$$

Increased operational efficiency and productivity affect I5.0 technology adoption, according to the "F1: operational efficiency and productivity" coefficient. Operational efficiency is proven by positive coefficient values, and adoption increases with productivity. "F3: Sustainability and environmental impact," "F4: Data-driven decision-making and compliance," and "F5: Market competitiveness and collaboration" further show that these factors will affect I5.0 system deployment. "F2: Animal health and product quality" was the only factor without statistically significant impacts; although it emphasizes animal health and product quality, therefore adoption levels of I5.0 had no felt influence. It is a baseline compliance dimension, not an influence.

Key Findings

IoT and smart technologies are growing in the dairy business for five reasons:

1. Sustainability, environmental effect, data-driven decision-making, market competitiveness, cooperation, animal welfare, and product quality

2. Main motivations for adoption: streamlined procedures and enhanced output Compliance and data-driven decision-making

- Collaboration and market competitiveness
- Reduced environmental impact

3. Non-significant factor: Animal welfare and product quality had little impact on adoption.

4. Since the model explains 63.8% of adoption variance, it matches well.

5. Business prospects exist in improving efficiency, sustainability, compliance, and market competitiveness with smart technology and the Internet of Things.

CONCLUSION

According to the findings of the study, the dairy industry stands to benefit significantly from the advances in operational efficiency, sustainability, data-driven decision-making, and competitiveness that are made available by sector 5.0 technologies, which include smart technologies and the Internet of Things. Animal welfare and product quality are issues that should be taken into consideration, but it does not seem that they have much of an effect on adoption decisions. The primary factors that promote adoption are compliance, efficiency, sustainability, and collaboration among team members. In order to develop solutions that are both technically feasible and commercially successful, stakeholders and entrepreneurs should focus their attention on three essential drivers. It is conceivable for the dairy sector to become more digitally connected, productive, and sustainable if policymakers support adoption by addressing constraints such as the readiness of the infrastructure, the cost, and the understanding of stakeholders.

REFERENCES

1. Dopico, M., Gómez, A., De la Fuente, D., García, N., Rosillo, R. and Puche, J. (2016). A Vision of Industry 4.0 from an Artificial Intelligence Point of View. In Proceedings on the International Conference on Artificial Intelligence (ICAI). 407.
2. Khan, M., Wu, X., Xu, X. and Dou, W. (2017, May). Big data challenges and opportunities in the hype of Industry 4.0. In 2017 IEEE International Conference on Communications (ICC). pp.1-6.
3. Malik, M., Gahlawat, V.K., Mor, R.S. and Hosseinian-Far, A. (2024). Towards white revolution 2.0: Challenges and opportunities for the industry 4.0 technologies in Indian dairy industry. Operations Management Research. pp.1-22.
4. Janssen, E. and Swinnen, J. (2019). Technology adoption and value chains in developing countries: Evidence from dairy in India. Food Policy. 83: 327-336.
5. Leitch, H., Ahuja, V. and Jabbar, M. (2014). India's livestock sector: Demand growth, food security and public investment- issues and options. Prepared for the World Bank, Washington DC, USA.

6. Bollido, M.E., Polbos, T.B. and Bejar, F.R. (2020). Intensifying forage legume strata system technology through dairy cattle production. *ASEAN Journal of Community Engagement*. Pp 1-24.
7. Kaushik, H., Rajwanshi, R. and Bhadauria, A. (2023). Modeling the challenges of technology adoption in dairy farming. *Journal of Science and Technology Policy Management*. <https://doi.org/10.1108/JSTPM-09-2022-0163>
8. Zambon, I., Cecchini, M., Egidi, G., Saporito, M., Colantoni, A. (2019). Revolution 4.0: Industry vs. agriculture in a future development for SMEs. *Processes*. 7(1): 36. <https://doi.org/10.3390/pr7010036>.
9. Sarkar, A., Gupta, H. and Dutta, A. (2024). Sustainable dairy sector of an emerging economy: An empirical quest based on India. *Agricultural Systems*. 218: 103970. doi: 10.1016/j.agsy.2024.103970.
10. Kozina, A. and Semkiv, L. (2020). Sustainable development of dairy farming through the use of digital technologies. *IOP Conf. Series: Earth and Environmental Science*. pp.1-5.
11. Meena, L.R., Kochewad, S.A., Kumar, D., Malik, S., Meena, S.R. and Anjali. (2024). Development of sustainable integrated farming systems for small and marginal farmers and ecosystem services-A comprehensive review. *Agricultural Science Digest*. 44(3): 391-397. doi: 10.18805/ag.D-5961.
12. Sharma, A., Devadas, V., Sharma, H., Kartha, B.D., Pandey, H., Soni, G., Kumari, N. (2022). Advancement of agricultural technology in farming of India. *Bhartiya Krishi Anusandhan Patrika*. 36(4): 313-319. doi: 10.18805/BKAP390.
13. Dalisova, N., Martinova, T. and Rozhkov, S.E. (2022). Sustainable development strategy of the dairy agro-industrial complex through the use of waste-free technologies. *IOP Conference Series: Earth and Environmental Science*. pp 1-5.
14. Asgar, S. and Chauhan, M. (2023). Scope of technological intervention in the sector of traditional indian milk products industry for sustainable rural development. *Journal of Scientific and Industrial Research*. 82: 1-10.
15. Desai, P.D. (2016). The ICT Adoption in AMUL: An Easy, Innovative, Self-Sustainable Approach for Rural Regions. In: *Rural Entrepreneurship and Innovation in the Digital Era*. [Desai, P.D. (Ed.)], 16.
16. Ashima, R., Haleem, A., Bahl, S., Javaid, M., Mahla, S.K. and Singh, S. (2021). Automation and manufacturing of smart materials in additive manufacturing technologies using internet of things towards the adoption of industry 4.0. *Materials Today: Proceedings*. 45: 5081-5088.
17. Nascimento, D.L.M., Alencastro, V., Quelhas, O.L.G., Caiado, R.G.G., Garza-Reyes, J.A., Rocha-Lona, L. and Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular

- economy practices in a manufacturing context: A business model proposal. *Journal of Manufacturing Technology Management*. 30: 607-627.
18. Mohamed, M. (2018). Challenges and benefits of industry 4.0: An overview. *International Journal of Supply and Operations Management*. 5: 256-265.
 19. Fedotova, G.V., Ilyasov, R.H., Buletova, N.E., Yakushkina, T.A. and Kurbanov, T.K. (2020). AI as a Breakthrough Technology of Agriculture Development. In: *Artificial Intelligence: Anthropogenic Nature vs. Social Origin*. [Scientific, A.G. (Ed.)], pp. 384-393.
 20. Hogenboom, J.A., Pellegrino, L., Sandrucci, A., Rosi, V. and D’Incecco, P. (2019). Invited review: Hygienic quality, composition and technological performance of raw milk obtained by robotic milking of cows. *Journal of Dairy Science*. 102: 7640-7654.
 21. Neethirajan, S. (2020). The role of sensors, big data and machine learning in modern animal farming. *Sensing and Bio-Sensing Research*. 29: 100367. <https://doi.org/10.1016/j.sbsr.2020.100367>.
 22. Neethirajan, S. and Kemp, B. (2021). Digital livestock farming. *Sensing and Bio-Sensing Research*. 32: 100408. <https://doi.org/10.1016/j.sbsr.2021.100408>.
 23. Gehlot, A., Malik, P.K., Singh, R., Akram, S.V. and Alsuwian, T. (2022). Dairy 4.0: Intelligent communication ecosystem for the cattle animal welfare with blockchain and IoT enabled technologies. *Applied Sciences*. 12: 7316. <https://doi.org/10.3390/app12147316>.
 24. Karavolias, N.G. (2023). Applications of Gene Editing for Improving Climate Change Resilience in Agriculture. University of California, Berkeley.
 25. Abed, N., Murugan, R. and Manalil, S. (2024). Optimizing synergistic combinations of adaptive iot based animal repellent systems for sustainable agriculture in Rajasthan, India. *Agricultural Science Digest*. 44(3): 580-587. doi: 10.18805/ag.D-5887.
 26. J. F. Hair, W. C. Black, B. J. Babin, R. E. Anderson and R. L. Tatham, *Multivariate Data Analysis*, Pearson Prentice Hall, 2006, vol.
 27. R. S. Mor, A. Bhardwaj, S. Singh and V. K. Arora, Exploring the factors affecting supply chain performance in dairy industry using exploratory factor analysis technique, *Int. J. Ind. Syst. Eng.*, 2020, 36(2), 248–265, DOI:[10.1504/IJISE.2020.10031380](https://doi.org/10.1504/IJISE.2020.10031380).