



Smart Multi-Species Milk Bank System (SM²BS) Integrating Cold Chain Management, Digital Traceability, and Nutritional Profiling of Cow, Goat, Sheep, Mare, and Buffalo Milk

Nicholas Renaldo ^{a*}, Azridjal Aziz ^b, Achmad Tavip Junaedi ^a, Suhardjo Suhardjo ^a, M. Dalil ^b, Erpiani Siregar ^c, Marice Br Hutahuruk ^d, Muhammad Pringgo Prayetno ^a, Arih Dwi Prihastomo ^a, Affilla Fetty Anggraheni ^d

^a Faculty of Business, Institut Bisnis dan Teknologi Pelita Indonesia, Indonesia

^b Faculty of Engineering, Universitas Riau, Indonesia

^c Faculty of Agriculture, Universitas Riau, Indonesia

^d Informatics Management Study Program, AMIK Mahaputra Riau, Indonesia

*Corresponding Author: nicholasrenaldo@lecturer.pelitaindonesia.ac.id

Article History

Received

12 July 2026

Revised

5 August 2026

Accepted

25 September 2026

Published

31 October 2026

ABSTRACT

The Smart Multi-Species Milk Bank System (SM²BS) is proposed as an integrated digital platform to improve milk supply chain management through cold chain management, digital traceability, and nutritional profiling. This study adopts a qualitative approach involving literature review, observation of milk handling processes, and stakeholder discussions to identify operational challenges and develop a conceptual framework for managing cow, goat, sheep, mare, and buffalo milk. Building on the existing Smart Milk Bank System (SMBS) prototype and preliminary goat milk quality testing conducted with CV Cahaya Firdaus, the proposed system integrates batch identification, quality records, storage conditions, and comparative nutritional data. Its disruptive novelty lies in connecting multi-species nutritional intelligence with cold chain monitoring and end-to-end traceability within a unified digital ecosystem. The framework is expected to support improved transparency, quality management, inventory coordination, and informed decision-making across milk supply chains. However, the proposed multi-species functionality and its operational benefits require further implementation and validation. This study provides a conceptual foundation for developing a more integrated, data-driven milk bank system and strengthening dairy supply chain resilience.

Keywords: Smart Multi-Species Milk Bank System; Cold Chain Management; Digital Traceability; Nutritional Profiling; Milk Supply Chain; Dairy Innovation

Field: Agricultural Technology; Food Supply Chain Management; Information Systems; Dairy Science; Food Quality Management; Supply Chain Innovation

DOI: <https://doi.org/10.61230/reflection.v4i2.169>

SDG's: Zero Hunger (2); Industry, Innovation and Infrastructure (9); Responsible Consumption and Production (12)

INTRODUCTION

Milk supply chains face persistent challenges related to quality deterioration, fluctuating supply, limited traceability, and insufficient integration of nutritional data (Al-Khatib et al., 2024). Conventional milk bank systems generally focus on storage and distribution, leaving opportunities to integrate quality monitoring, nutritional comparison, and supply chain intelligence into a unified platform (Junaedi et al., 2025).

The Smart Multi-Species Milk Bank System (SM²BS) introduces a disruptive approach by integrating cold chain management, digital traceability, and nutritional profiling of cow, goat, sheep, mare, and buffalo milk within a single digital ecosystem (Hutahuruk et al., 2026). Unlike conventional systems that manage milk primarily as a storage commodity, SM²BS treats each milk batch as a traceable, quality-monitored, and nutritionally characterized resource. Its proposed innovation includes a comparative nutritional database across five species, enabling users to examine differences in protein, fat, lactose, and total solids, supported by laboratory measurements and standardized data recording.

By connecting milk quality information with storage conditions, batch histories, and nutritional profiles, SM²BS aims to transform milk bank management from a conventional storage-oriented model into an integrated, data-driven supply chain system. This approach has the potential to improve operational transparency, reduce preventable quality losses, strengthen supply stability, and support more informed decisions among farmers, milk bank operators, and dairy processing industries. Its distinctive contribution lies in combining multi-species nutritional intelligence with cold chain monitoring and end-to-end digital traceability in one integrated platform.

LITERATURE REVIEW

Milk Supply Chain Management and Milk Bank Systems

Milk supply chain management plays an important role in maintaining milk quality, ensuring product safety, and stabilizing the availability of raw milk for dairy processing industries (Yang et al., 2023). Milk is a perishable agricultural product whose quality can deteriorate due to improper handling, temperature fluctuations, delayed cooling, and inadequate storage conditions (Nyoto et al., 2026). Therefore, an effective milk bank system should integrate milk collection, quality assessment, cooling, storage, inventory management, and distribution into a coordinated operational framework.

Traditional milk collection and storage systems primarily emphasize the physical handling and preservation of milk (Renaldo et al., 2026). However, the increasing demand for transparency, efficiency, and reliable quality information creates opportunities to develop digitally integrated milk bank systems. Renaldo et al. (2026), in *Beyond Cold Storage and Smart Milk Bank as a Disruptive Supply Chain Innovation for Strengthening National Dairy Industry Resilience*, highlight the potential of smart milk bank systems as a supply chain innovation to strengthen the resilience of the dairy industry (Prihastomo et al., 2026).

Building on this concept, the Smart Multi-Species Milk Bank System (SM²BS) extends the milk bank approach beyond conventional storage management by integrating cold chain management, digital traceability, and nutritional profiling for multiple milk species. This integration is intended to provide a more comprehensive framework for managing milk quality and supply chain information.

Cold Chain Management and Milk Quality Preservation

Cold chain management is a fundamental component of dairy supply chains because temperature and storage duration influence the stability and microbiological quality of milk (Iyer & Robb, 2025). Effective cooling, controlled storage, and appropriate transportation procedures are essential for reducing quality deterioration before milk reaches processing facilities.

For a smart milk bank, cold chain management should not be limited to refrigeration equipment. It should also include temperature recording, storage history, batch identification, and procedures for responding to temperature deviations. Integrating these functions into a digital platform can provide operators with more reliable information for inventory rotation and product handling.

The existing SMBS prototype described in the 2026 research progress report incorporates a workflow covering milk reception, rapid cooling, quality standardization, food-grade tank storage, storage-condition monitoring, and verified distribution. The report identifies integration of sensor data, batch recording, and operational validation as important next steps.

This development direction is consistent with the broader digitalization of dairy supply chains, where traceability and process monitoring are increasingly recognized as mechanisms for improving transparency, quality assurance, and operational coordination.

Digital Traceability in Dairy Supply Chains

Digital traceability refers to the systematic recording and retrieval of information about a product as it moves through the supply chain (Cromwell et al., 2025). In dairy operations, traceability can connect the milk producer, collection time, batch identity, quality measurements, storage conditions, processing activities, and distribution records.

A review published in *Future Foods* identifies traceability as an important mechanism for improving transparency, quality management, safety, and coordination across dairy supply chains. Digital traceability can also support the investigation of quality deviations by allowing operators to identify the relevant batch and examine its handling history.

For SM²BS, traceability can be extended to multiple milk species through a shared digital architecture. Each batch would be assigned a unique identifier and linked to its species, supplier, collection date, laboratory results, temperature history, and destination. Species-specific records would remain distinguishable even when the system uses a common platform.

The disruptive potential lies in combining traceability with quality and nutritional information. Instead of recording only where milk has travelled, SM²BS would also connect each batch to its measured composition and handling history. This would create a more information-rich foundation for inventory management, supplier evaluation, and industry decision-making.

Nutritional Composition of Milk from Different Species

Milk from different mammalian species varies in its concentrations of protein, fat, lactose, minerals, and total solids (Kelly, 2007). These differences are influenced not only by species but also by breed, feed, lactation stage, milking interval, and environmental conditions. Therefore, nutritional comparisons require careful consideration of sampling conditions and analytical methods.

Research reviews have documented substantial compositional differences between cow, goat, sheep, mare, and buffalo milk. Sheep and buffalo milk can have relatively high concentrations of fat and protein, while mare's milk generally has lower fat and protein concentrations and relatively high lactose. However, the actual values vary across studies and production conditions.

These differences make nutritional profiling a valuable component of a multi-species milk bank. A comparative database could organize the principal parameters as follows:

Parameter	Relevance to SM ² BS
Fat	Nutritional composition and processing suitability
Protein	Protein content and product formulation
Lactose	Carbohydrate composition
Total solids	Overall solids content
Solids-not-fat (SNF)	Non-fat milk solids
Density	Physicochemical quality assessment
Minerals or ash	Mineral composition, where measured
Energy	Nutritional comparison, where measured or validly calculated

The proposed database should distinguish between reference values from published literature and actual laboratory results from Riau. Literature values can establish an initial comparison framework, but they should not be presented as measurements of locally collected milk.

Milk Quality Measurement and Nutritional Data Integration

Reliable nutritional comparison depends on appropriate sampling, analytical methods, and quality control (Danet & Badea, 2004). Instruments such as milk analyzers can provide measurements of fat, protein, lactose, SNF, density, and total solids. However, measurement accuracy and suitability should be verified for each species and milk matrix before the results are compared or used for operational decisions.

The 2026 SMBS progress report documents initial goat milk measurements using a Lactoscan Milk Analyzer LITE. Recorded parameters included fat, protein, SNF, lactose, density, and total solids. These results provide a baseline for developing digital quality records, but the report emphasizes the need for repeated sampling and further validation before drawing conclusions about milk quality.

For SM²BS, the measurement framework should therefore include standardized sample identification, instrument calibration and verification, replicate measurements where appropriate, and documentation of analytical methods. Additional laboratory testing may be required for nutritional components that cannot be reliably measured by the available instrument.

The integration of these records into a shared database would allow the system to compare milk composition across species while retaining information about the source, sampling conditions, and reliability of each measurement.

Research Gap and Disruptive Novelty of SM²BS

Existing research provides a strong foundation for understanding milk preservation, digital traceability, and interspecies nutritional differences (Becchi et al., 2025). However, these topics are often examined

separately: cold chain systems focus on preservation, traceability research emphasizes product movement and transparency, and nutritional studies investigate milk composition.

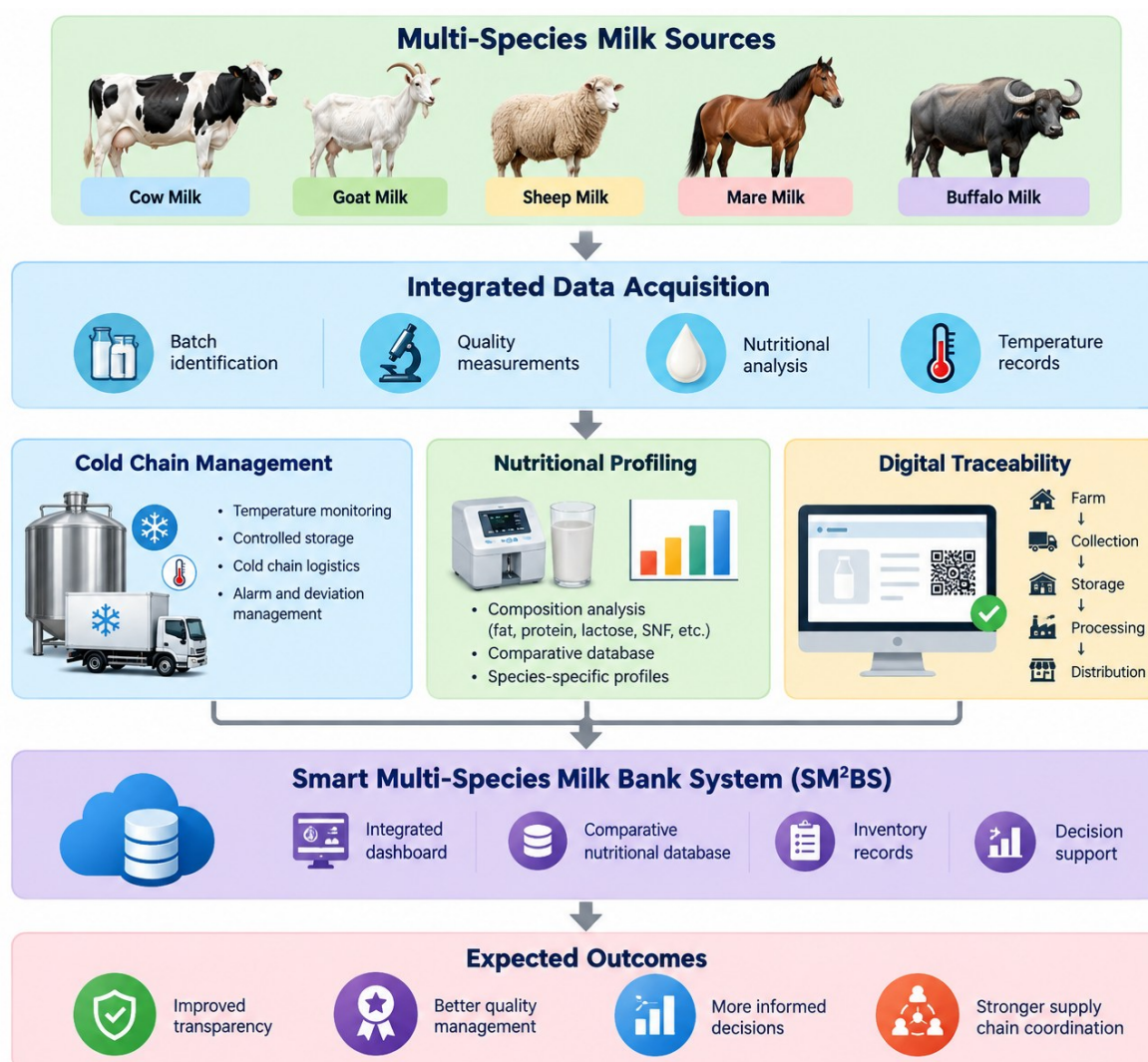
SM²BS proposes to connect these functions within one digital platform. Its main innovation is not simply the inclusion of five milk species, but the integration of three complementary information layers:

1. Cold chain intelligence: Recording and monitoring milk storage conditions throughout the supply chain (Yar et al., 2025).
2. Multi-species nutritional intelligence: Organizing comparable nutritional and physicochemical data for cow, goat, sheep, mare, and buffalo milk.
3. End-to-end digital traceability: Connecting each batch to its supplier, quality results, storage history, and distribution destination.

This integration could enable a shift from conventional milk storage management toward data-driven milk bank operations. It could also support more informed supplier selection, batch allocation, quality assessment, and product development.

Nevertheless, the novelty claim should be treated as a proposed contribution until validated through a systematic literature search and comparison with existing commercial systems and patents. The effectiveness of SM²BS must also be evaluated through multi-species sampling, system testing, and operational validation.

Conceptual Framework



METHODOLOGY

This study adopts a qualitative research approach to develop the Smart Multi-Species Milk Bank System (SM²BS), integrating cold chain management, digital traceability, and nutritional profiling of cow, goat,

sheep, mare, and buffalo milk. The research focuses on understanding existing milk supply chain practices, identifying operational challenges, and designing an integrated digital system to support milk quality management and supply stability.

Data are collected through literature reviews, observations of milk handling and storage processes, and discussions with relevant stakeholders, including farmers, milk bank operators, and dairy processing industries. The system design builds on the existing Smart Milk Bank System (SMBS) prototype and its initial goat milk quality testing activities conducted with CV Cahaya Firdaus. The collected information is analyzed thematically to identify system requirements, workflow improvements, and opportunities for innovation.

The proposed system integrates three main components: (1) cold chain management to support temperature monitoring and storage control; (2) digital traceability to record milk batches, suppliers, quality measurements, and distribution histories; and (3) nutritional profiling to organize and compare milk composition data across the five species. Nutritional comparisons are developed using relevant scientific literature and, where available, validated laboratory measurements. The qualitative evaluation examines system functionality, operational relevance, data integration, and potential benefits for stakeholders. The resulting framework is intended to provide a foundation for further prototype development, industry validation, and future implementation in the Riau milk supply chain.

RESULTS AND DISCUSSION

Development of the Smart Multi-Species Milk Bank System

The study proposes the Smart Multi-Species Milk Bank System (SM²BS) as an integrated digital platform for managing cow, goat, sheep, mare, and buffalo milk. The system extends the existing Smart Milk Bank System (SMBS), which was developed to address milk supply instability, quality inconsistencies, limited traceability, and challenges in cold chain management.

The existing SMBS prototype has established an initial foundation through website development, cold chain workflow design, and preliminary goat milk quality testing with CV Cahaya Firdaus. The proposed SM²BS builds on this foundation by extending the system architecture to accommodate multiple milk species and incorporating comparative nutritional profiling. However, the multi-species functionality remains a proposed development that requires further implementation and validation.

The conceptual framework integrates three main components: cold chain management, nutritional profiling, and digital traceability. These components are designed to work together within a unified platform, enabling milk bank operators to access storage records, quality measurements, batch information, and nutritional data in a structured manner.

Integration of Cold Chain Management

Cold chain management is a central component of SM²BS because milk quality can deteriorate when handling, cooling, and storage conditions are inadequate. The proposed system includes milk reception, rapid cooling, controlled storage, temperature monitoring, and distribution records.

Integrating temperature records with batch identification can improve operational visibility and help operators identify potential storage deviations (Edo et al., 2026). Rather than managing refrigeration and inventory as separate activities, the proposed system connects storage conditions with the history of each milk batch.

The existing SMBS prototype already presents a cold chain workflow, including reception, rapid cooling, standardization, cold storage, and distribution. The next development stage is to integrate continuous sensor data and evaluate system performance under actual operating conditions.

The potential contribution of SM²BS lies in extending this workflow to five milk species. Nevertheless, species-specific storage protocols and acceptable temperature limits must be established using relevant food safety standards and validated operating procedures.

Digital Traceability and Data Integration

Digital traceability is intended to connect milk suppliers, collection records, quality measurements, storage conditions, and distribution activities (Malik et al., 2024). Each batch can be assigned a unique identifier linked to its source and handling history.

This approach offers several potential advantages. First, it supports more systematic retrieval of milk quality information. Second, it helps operators identify the origin of a batch when quality deviations occur.

Third, it provides a structured basis for inventory management and coordination between farmers, milk bank operators, and dairy processors.

The disruptive element of SM²BS is the integration of traceability with nutritional profiling and cold chain information. Conventional recordkeeping may document where milk originates or where it is delivered, whereas the proposed platform aims to connect this information with measured composition and storage history.

However, the effectiveness of this integration will depend on data completeness, measurement reliability, and the consistent recording of operational activities. These benefits should therefore be evaluated during subsequent prototype testing rather than treated as confirmed outcomes.

Comparative Nutritional Profiling of Five Milk Species

An important proposed feature of SM²BS is a comparative nutritional database covering cow, goat, sheep, mare, and buffalo milk. The database is intended to organize nutritional and physicochemical parameters in a standardized format.

The following table presents the proposed comparison framework. It identifies the parameters to be examined rather than reporting experimental results from the five species.

Nutritional Parameter	Human Breast Milk	Cow	Goat	Sheep	Mare (Horse)	Buffalo
Total solids (%)	11.3	11.8–13.0	11.9–16.3	18.1–20.0	9.3–11.6	15.7–17.2
Protein (%)	0.8–0.9	3.0–3.9	3.0–5.2	4.5–7.0	1.4–3.2	2.7–4.7
Fat (%)	3.0–5.0	3.3–5.4	3.0–7.2	5.0–9.0	0.3–4.2	5.3–9.0
Lactose (%)	6.9–7.2	4.4–5.6	3.2–5.0	4.1–5.9	5.6–7.2	3.2–4.9
Ash / mineral residue (%)	0.2	0.7–0.8	0.7–0.9	0.8–1.0	0.3–0.5	0.8–0.9

Milk Species	Energy (kcal/100 g)
Human Breast Milk	67
Cow	62
Goat	66
Sheep	100
Mare (Horse)	48
Buffalo	99

The table presents a comparison of the nutritional composition of human, cow, goat, sheep, horse, and buffalo milk based on five key parameters: total solids, protein, fat, lactose, and ash (mineral residue). The data indicate that milk composition varies by species, reflecting differences in biological characteristics and nutritional requirements.

In general, sheep milk has the highest total solids content (18.1–20.0%), followed by buffalo milk (15.7–17.2%). A high total solids content indicates a relatively large proportion of non-water components. Regarding protein, sheep milk also exhibits the highest content range (4.5–7.0%), whereas goat milk contains approximately 3.0–5.2% protein. In terms of fat, sheep milk contains 5.0–9.0%, while goat milk ranges from 3.0–7.2%. This suggests that sheep and goat milk have the potential to serve as raw materials for dairy products with nutritional characteristics distinct from those of cow milk.

Regarding lactose, human milk has the highest content (6.9–7.2%), while goat and buffalo milk show relatively lower ranges (3.2–5.0% and 3.2–4.9%, respectively). Meanwhile, the ash or mineral residue content in the animal milks listed in the table falls within the 0.3–1.0% range, with sheep milk showing the highest values (0.8–1.0%).

Thus, the table demonstrates that milk from each species possesses a unique nutritional profile. Sheep and buffalo milk tend to have higher solids content, while goat milk offers compositional characteristics that warrant consideration in the development of dairy-based food products. However, the values in the table represent general ranges and can be influenced by other factors, such as feed, breed, stage of lactation, and husbandry conditions.

The next table presents a comparison of milk energy content in kilocalories per 100 grams (kcal/100 g). Based on the data, sheep milk has the highest energy content at 100 kcal/100 g, followed by buffalo milk at 99 kcal/100 g. Human milk has an energy content of 67 kcal/100 g, goat milk 66 kcal/100 g, cow milk 62 kcal/100 g, and horse milk 48 kcal/100 g.

The high energy content of sheep and buffalo milk aligns with the high total solids and fat content shown in the first table. Fat is a major contributor to the energy content of milk—alongside protein and carbohydrates (particularly lactose). Conversely, horse milk has the lowest energy content in the table, consistent with its relatively low-fat content.

Goat milk, with an energy content of 66 kcal/100 g, shows a value close to that of human milk and slightly higher than that of cow milk, based on the presented data. This information can be a consideration in the development of goat milk products, including pasteurized milk, yogurt, cheese, and other processed items. However, energy content alone is insufficient to determine nutritional quality or suitability for specific consumer groups, as factors such as amino acid and fatty acid profiles, minerals, vitamins, and food safety must also be taken into account.

Both tables demonstrate that the nutritional composition and energy content of milk vary across species. Sheep and buffalo milk stand out in terms of total solids and energy content, whereas goat milk has an energy content relatively similar to that of human and cow milk. These differences are important to consider when selecting raw materials, formulating products, and developing milk processing technologies.

Disruptive Novelty and Potential Impact

The proposed novelty of SM²BS lies in integrating three functions that are often managed separately: cold chain management, digital traceability, and comparative nutritional profiling across multiple milk species.

1. Cold chain intelligence. Links storage conditions and temperature records to individual milk batches.
2. Multi-species nutritional intelligence. Organizes comparative nutritional data for five species in a common digital database.
3. End-to-end digital traceability. Connects supplier information, quality measurements, storage history, and distribution records.

Together, these components could transform milk bank management from a predominantly storage-oriented process into a more integrated, information-driven supply chain model. The platform may support improved transparency, more systematic quality management, and better-informed decisions regarding inventory and processing.

Its broader contribution is the possibility of developing a shared digital infrastructure for different milk-producing sectors. In the context of Riau, this could provide a framework for connecting existing dairy activities with other potential milk sources as their production and supply feasibility are established.

However, the proposed novelty should be understood as a system-level innovation concept. Its distinctiveness relative to existing commercial platforms and patented technologies must be assessed through further literature and intellectual property searches.

Overall Discussion

The proposed SM²BS framework builds on the existing SMBS prototype by integrating cold chain management, digital traceability, and nutritional profiling across five milk species. Its principal contribution is the conceptual integration of operational and nutritional information within a unified platform.

The framework offers a potential pathway toward more transparent and data-driven milk supply chain management. Nevertheless, the present findings primarily establish the system concept and its development direction. Demonstrating improvements in milk quality, supply stability, operational efficiency, or nutritional decision-making will require further empirical testing and validation.

Thus, SM²BS represents a proposed advancement from a goat milk-focused bank system toward a multi-species digital milk bank. Its practical and scientific contributions will ultimately depend on successful implementation, validated nutritional data, and demonstrated benefits in real operating environments.

CONCLUSION

Conclusion

The Smart Multi-Species Milk Bank System (SM²BS) proposes an integrated approach to milk supply chain management by combining cold chain management, digital traceability, and nutritional profiling for cow, goat, sheep, mare, and buffalo milk. Building on the existing Smart Milk Bank System (SMBS) prototype, the proposed framework extends the concept of milk bank management beyond conventional storage and distribution toward a more comprehensive, data-driven system. Its principal innovation lies in connecting milk quality measurements, storage records, batch identification, and comparative nutritional information within a

unified digital platform. Although the current empirical foundation focuses primarily on goat milk, the proposed multi-species framework provides a basis for further development, operational testing, and validation in the Riau dairy supply chain.

Implications

The proposed SM²BS framework has several practical and technological implications. For farmers and milk suppliers, digital traceability may improve the transparency of milk collection and handling processes. For milk bank operators, integrating temperature records, quality measurements, and inventory information may support more systematic monitoring and decision-making. For dairy processing industries, comparative nutritional profiling could provide useful information for raw material selection and product formulation. At the institutional level, SM²BS offers a potential digital infrastructure for connecting different milk-producing sectors and strengthening coordination among farmers, milk banks, laboratories, and processing industries. These implications represent anticipated benefits that require validation through practical implementation.

Limitations

This study has several limitations. First, the existing SMBS prototype and preliminary quality measurements primarily concern goat milk, while comparable empirical data for cow, sheep, mare, and buffalo milk have not yet been established. Second, the proposed integration of cold chain monitoring, digital traceability, and nutritional profiling requires further technical development and operational validation. Third, nutritional composition can vary according to breed, feed, lactation stage, and production conditions, making standardized sampling and analytical procedures essential. Fourth, the availability of consistent milk supplies from all five species in Riau requires further verification. Consequently, the present study establishes a proposed system framework rather than demonstrating validated performance across all five species.

Recommendations

Future implementation should prioritize the development and validation of the core SM²BS platform, beginning with milk species for which reliable suppliers and sufficient samples are available. Standardized procedures should be established for milk collection, quality testing, temperature monitoring, batch identification, and nutritional data recording. Laboratory measurements should be used to construct a comparative nutritional database, with clear distinctions between published reference values and locally measured results. In addition, sensor integration and digital traceability should be tested under actual operating conditions. Collaboration with farmers, laboratories, milk bank operators, and dairy processing industries will be important for assessing system usability, operational feasibility, and commercial potential.

Future Research

Future research should investigate the implementation and performance of SM²BS through a multi-stage development and validation process. The first stage should establish baseline nutritional and physicochemical profiles for the five milk species using appropriate laboratory methods. The second stage should integrate sensor-based cold chain monitoring and batch-level digital traceability into the existing SMBS platform. The third stage should conduct pilot testing to evaluate data accuracy, system usability, storage-condition compliance, and inventory management performance. Subsequent studies could explore predictive analytics for milk quality deterioration, data-driven shelf-life estimation, and decision-support models for milk distribution and processing. Comparative evaluations between conventional milk bank operations and SM²BS could also determine whether the integrated approach produces measurable improvements in quality management, supply stability, and operational efficiency.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support provided by the Directorate General of Research and Development (*Direktorat Jenderal Riset dan Pengembangan*), Ministry of Higher Education, Science, and Technology of the Republic of Indonesia (Kementerian Pendidikan Tinggi, Sains, dan Teknologi Republik Indonesia), and Institut Bisnis dan Teknologi Pelita Indonesia under Research Grant Contract No. 179/SPK/C.4/PPK.DHK/IV/2026, April, 20th 2026. The authors also sincerely thank CV Cahaya Firdaus for its valuable collaboration, including access to production facilities, operational data, and the pilot implementation environment for this research. The support and cooperation from all participating institutions and individuals are greatly appreciated and have significantly contributed to the successful completion of this study.

REFERENCES

- Al-Khatib, M., Haji, M., Haouari, M., & Kharbeche, M. (2024). Building resilience in the infant formula milk supply chain. *Food Control*, 165, 110641. <https://doi.org/10.1016/J.FOODCONT.2024.110641>
- Becchi, P. P., Rocchetti, G., & Lucini, L. (2025). Advancing dairy science through integrated analytical approaches based on multi-omics and machine learning. *Current Opinion in Food Science*, 63, 101289. <https://doi.org/10.1016/J.COFS.2025.101289>
- Cromwell, J., Turkson, C., Dora, M., & Yamoah, F. A. (2025). Digital technologies for traceability and transparency in the global fish supply chains: A systematic review and future directions. *Marine Policy*, 178, 106700. <https://doi.org/10.1016/j.marpol.2025.106700>
- Danet, A. F., & Badea, M. (2004). Industrial Applications. *Encyclopedia of Analytical Science: Second Edition*, 89–97. <https://doi.org/10.1016/B0-12-369397-7/00160-6>
- Edo, G. I., Ali, A. B. M., Owheru, J. O., Iwanegbe, I., Orogu, J. O., Yousif, E., Igbuku, U. A., Oghoro, E. E. A., Opiti, R. A., Essaghah, A. E. A., Makia, R. S., Umar, H., Ahmed, D. S., Alamiery, A. A., Aliyu, M. R., & Fuwape, I. A. (2026). The role of cold chain logistics in reducing postharvest losses. *Next Energy*, 12, 100697. <https://doi.org/10.1016/j.nxener.2026.100697>
- Hutahuruk, M. B., Junaedi, A. T., Renaldo, N., Prayetno, M. P., Prihastomo, A. D., Andi, A., Putri, N. Y., Fransisca, L., Faruq, U., & Musa, S. (2026). Educational Strategies for Fortified Goat Milk Development Supported by Digital Financial Ecosystems. *Reflection: Education and Pedagogical Insights*, 3(1), 19–24. <https://doi.org/10.61230/reflection.v3i1.143>
- Iyer, P., & Robb, D. (2025). Cold chain optimisation models: A systematic literature review. *Computers & Industrial Engineering*, 204, 110972. <https://doi.org/10.1016/J.CIE.2025.110972>
- Junaedi, A. T., Panjaitan, H. P., Renaldo, N., Nyoto, N., Jahrizal, J., Dalil, M., Koto, J., Musa, S., Wahid, N., Veronica, K., & Faruq, U. (2025). Smart Processing Machines and Business Efficiency in Goat Milk Agro-Enterprises. *Luxury: Landscape of Business Administration*, 3(2), 88–97. <https://doi.org/10.61230/luxury.v3i2.137>
- Kelly, A. L. (2007). Milk. *Cheese Problems Solved*, 1–10. <https://doi.org/10.1533/9781845693534.1>
- Malik, M., Gahlawat, V. K., Mor, R. S., & Singh, M. K. (2024). Unlocking dairy traceability: Current trends, applications, and future opportunities. *Future Foods*, 10, 100426. <https://doi.org/10.1016/J.FUFO.2024.100426>
- Nyoto, N., Renaldo, N., Jahrizal, J., Aziz, A., Dalil, M., Junaedi, A. T., Yusrizal, Y., Hajjah, A., Musa, S., & Cecilia, C. (2026). Digital Transformation of Goat Milk Supply Chains through an Integrated Smart Cold-Chain Logistics System. *Journal of Applied Business and Technology*, 7(2), 133–143. <https://doi.org/10.35145/re8a7652>
- Prihastomo, A. D., Renaldo, N., Junaedi, A. T., Panjaitan, H. P., Nyoto, N., Hutahuruk, M. B., Faruq, U., Prayetno, M. P., Wati, Y., & Fransisca, L. (2026). Value Co-Creation and Digital Marketplace Strategy in Enhancing Commercialization Performance, An Educational Perspective from Fortified Goat Milk Entrepreneurship. *Reflection: Education and Pedagogical Insights*, 3(1), 32–40. <https://doi.org/10.61230/reflection.v3i1.151>
- Renaldo, N., Junaedi, A. T., Suhardjo, S., Aziz, A., Dalil, M., Siregar, E., Jahrizal, J., Faruq, U., Koto, J., & Veronica, K. (2026). Beyond Cold Storage and Smart Milk Bank as a Disruptive Supply Chain Innovation for Strengthening National Dairy Industry Resilience. *Journal of Applied Business and Technology*, 7(2), 144–154. <https://doi.org/10.35145/b277se34>
- Yang, M., Işık, C., & Yan, J. (2023). Analysis of collaborative control of dairy product supply chain quality based on evolutionary games: Perspectives from government intervention and market failure. *Heliyon*, 9(12), e23024. <https://doi.org/10.1016/J.HELİYON.2023.E23024>

Yar, M. S., Ibeogu, I. H., Regmi, A., Zhang, N., & Li, C. (2025). Advances in intelligent time-temperature indicators for cold chain monitoring: mechanisms, challenges, and applications. *Trends in Food Science & Technology*, 163, 105128. <https://doi.org/10.1016/j.tifs.2025.105128>