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Article

Supply Chain Integration and Quality-Based Management in Dairy Processing Enterprises: Evidence from Uzbekistan

Mukhayyo Tillaeva[*1]

1. Researcher, Andijan Institute of Agriculture and Agrotechnologies, Uzbekistan

Abstract: Dairy processing enterprises play a strategic role in food security, rural income generation and value-added development in agri-food systems. However, their efficiency depends not only on production capacity, but also on the stability of raw milk supply, hygienic control, cold-chain logistics, traceability and market-oriented management decisions. The purpose of this study is to develop an integrated management mechanism for dairy processing enterprises by combining supply chain coordination, quality and safety control, digital monitoring and performance-based decision-making. The study uses systematic literature analysis, comparative analysis, indicator-based assessment and management modelling. The empirical context is Uzbekistan, where the dairy sector has a considerable raw milk base: in January-December 2024, all categories of farms produced 12,443.8 thousand tons of milk, equal to 104.0% compared with the same period of 2023. The proposed model consists of five interrelated blocks: raw milk supply coordination, quality and safety control, cold-chain and logistics management, digital monitoring and market-oriented performance evaluation. The scientific contribution of the article is that it shifts the focus from fragmented production management to an integrated management mechanism suitable for dairy processing enterprises in emerging agri-food markets.

Keywords: Dairy Processing Enterprises, Management Mechanism, Quality Control, Supply Chain Integration, Cold-Chain Logistics, Digital Monitoring.

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1. Introduction

Dairy processing enterprises are a key component of modern agri-food systems because they transform raw milk into higher-value products, support food security, create employment and connect agricultural producers with consumer markets. Unlike many other agricultural raw materials, milk is highly perishable and requires rapid collection, hygienic handling, cooling, processing and distribution. Therefore, the management of dairy processing enterprises must be understood not only as internal production management, but also as the coordination of the whole chain from raw milk supply to final consumer delivery. Codex Alimentarius states that the Code of Hygienic Practice for Milk and Milk Products provides guidance to ensure the safety and suitability of milk and milk products and emphasizes proper hygienic control throughout the food chain [1], [2].

The global dairy sector is expected to continue growing in the coming decade. The OECD-FAO Agricultural Outlook 2025-2034 projects that world milk production will increase by 1.8% per year and reach 1,146 million tonnes by 2034. This growth creates new opportunities for dairy processing enterprises, but it also increases the importance of quality assurance, logistics, traceability and efficient management systems [3].

Uzbekistan is a relevant case for studying dairy processing management because milk production has been increasing and the domestic dairy market has significant development potential. According to the Statistics Agency under the President of the

Republic of Uzbekistan, in January-December 2024 all categories of farms produced 12,443.8 thousand tons of milk, and this figure amounted to 104.0% compared with the corresponding period of 2023. This confirms that the country has a considerable raw milk base for dairy processing, but the existence of raw material alone does not automatically lead to high processing efficiency [4].

The management problem becomes more complex because dairy processing enterprises depend on several interrelated factors. First, raw milk quality is strongly affected by farm-level practices, animal health, milking hygiene, collection time and storage temperature. Second, processing efficiency depends on timely delivery of raw milk and stable technological discipline inside the enterprise. Third, consumer trust depends on product safety, labelling, certification and consistency of quality. Fourth, modern markets require digital tools for monitoring inventory, tracing product batches, analysing demand and reducing losses. Therefore, a fragmented approach to management is insufficient for dairy processing enterprises [5].

Traceability is particularly important in food supply chains because it connects safety, quality and consumer confidence. Aung and Chang (2014) argue that traceability is applied as a tool to support food safety and quality assurance and to achieve consumer confidence in food supply chains. In dairy processing, traceability can support the monitoring of raw milk origin, collection time, processing batch, storage conditions and product distribution [6].

The aim of this article is to develop an integrated management mechanism for dairy processing enterprises based on supply chain integration, quality and safety control, digital monitoring and market-oriented performance evaluation. The article addresses the following research questions: What are the main management challenges faced by dairy processing enterprises in the context of raw milk supply, quality control and logistics? Which functional blocks should be included in an integrated management mechanism for dairy processing enterprises? How can digital monitoring and traceability strengthen quality-based management in dairy processing enterprises? How can the proposed management mechanism be applied to the development of dairy processing enterprises in Uzbekistan [7]?

The scientific novelty of this study lies in proposing an integrated management mechanism that combines five functional blocks: raw milk supply coordination, quality and safety control, cold-chain and logistics management, digital monitoring and market-oriented performance evaluation. This approach differs from traditional production-centred management because it evaluates dairy processing enterprises as part of a wider agri-food value chain [8].

Literature Review.

The development of dairy processing enterprises is closely linked with the transformation of agri-food supply chains, food safety requirements and quality-oriented management systems. In the dairy sector, management decisions cannot be limited to production volume because milk is a highly perishable raw material and requires hygienic handling, timely collection, cooling, traceability and safe processing. Codex Alimentarius provides principles and guidelines for the production, processing and handling of milk and milk products throughout the food chain.

Food hygiene and safety management are also based on general preventive principles. The Codex General Principles of Food Hygiene include good hygiene practices and the Hazard Analysis and Critical Control Point system. These principles provide a systematic basis for identifying and controlling food safety hazards. For dairy processing enterprises, this means that quality and safety must be controlled not only at the final product stage, but also during raw milk reception, storage, processing, packaging and distribution [9].

International management standards provide an additional methodological basis for dairy enterprises. ISO 9001 is a globally recognized quality management standard that helps organizations improve performance, meet customer expectations and maintain a quality management system. In the context of dairy processing, this standard is relevant for process discipline, documentation, customer orientation and continuous improvement [10].

Food safety management requires a more specialized approach. ISO 22000:2018 specifies the requirements for a food safety management system and integrates the principles of the Hazard Analysis and Critical Control Point system developed by the Codex Alimentarius Commission. This makes the standard particularly relevant for dairy processing enterprises, where biological, chemical and physical risks must be systematically controlled.

Traceability is another important element of quality-based management in food supply chains. Aung and Chang (2014) describe traceability as a tool that supports food safety and quality assurance and helps build consumer confidence. In dairy processing, traceability allows enterprises to monitor the origin of raw milk, collection time, processing batch, storage conditions and product movement. This is especially important because quality losses in dairy products may occur at any stage of the chain if temperature, hygiene or documentation requirements are not properly maintained [11].

The global context also supports the relevance of improving dairy processing management. The OECD-FAO Agricultural Outlook 2025-2034 projects that world milk production will grow by 1.8% annually and reach 1,146 million tonnes by 2034. This expected growth increases the need for stronger processing capacity, better quality control, improved cold-chain logistics and market-oriented management mechanisms.

For Uzbekistan, the issue is highly relevant because the country has a significant raw milk base. According to official statistics, 12,443.8 thousand tons of milk were produced in January-December 2024, which amounted to 104.0% compared with the same period of 2023. However, the availability of raw milk does not automatically guarantee the efficiency of dairy processing enterprises. The sector needs management mechanisms that connect raw milk supply, processing technology, product safety, logistics and market demand [12].

Based on the reviewed literature, the main research gap can be formulated as follows: existing approaches often examine quality control, supply chain management, traceability or logistics separately, while dairy processing enterprises require an integrated management mechanism that combines these elements into one functional system.

2. Research Methodology

This study applies a mixed methodological approach based on qualitative and quantitative analysis. The qualitative part includes systematic literature analysis, comparative analysis of international standards and conceptual modelling. The quantitative part is based on indicator-based assessment of dairy processing management efficiency [13].

The research design is aimed at developing an integrated management mechanism for dairy processing enterprises. The logic of the study is based on the following sequence: problem diagnosis -> literature and standards analysis -> identification of management blocks -> indicator selection -> model development -> interpretation of expected management effects.

The article uses four groups of sources: (1) international food safety and quality standards, including Codex Alimentarius, HACCP principles, ISO 9001 and ISO 22000; (2) scientific literature on traceability, food supply chain safety and quality management; (3) official statistical sources from the Statistics Agency of Uzbekistan on milk production; and

(4) comparative and analytical sources, particularly the OECD-FAO Agricultural Outlook and international dairy market reviews.

Systematic literature analysis is used to identify the main scientific approaches to dairy processing management, food safety, traceability, quality control and supply chain integration.

Comparative analysis is applied to compare traditional production-centred management with integrated supply-chain-based management. The comparison shows that traditional management focuses mainly on production volume, while integrated management includes raw milk quality, supplier coordination, cold-chain logistics, digital monitoring and consumer-oriented performance indicators [14].

Indicator-based assessment is used to evaluate management efficiency in dairy processing enterprises through measurable indicators. Management mechanism modelling is used to develop an integrated management mechanism that combines five functional blocks.

Table 1. Proposed indicator system.

Functional block	Main indicators	Management meaning
Raw milk supply coordination	Volume of collected raw milk; supplier stability; share of contracted suppliers	Shows the reliability of the raw milk base
Quality and safety control	Laboratory control frequency; rejected raw milk share; HACCP/ISO compliance	Shows product safety and quality discipline
Cold-chain and logistics management	Delivery time; temperature control; storage losses	Shows logistics and preservation efficiency
Digital monitoring	Electronic records; batch traceability; inventory accuracy	Shows the level of digital control
Market-oriented performance	Sales growth; product return rate; customer complaints; profitability	Shows market responsiveness and economic efficiency

Integrated dairy management index

To make the proposed mechanism measurable, the study introduces an Integrated Dairy Management Index (IDMI):

$$\mathbf{IDMI = (RSC + QSC + CLM + DMI + MPE) / 5}$$

Where IDMI is the Integrated Dairy Management Index; RSC is Raw Supply Coordination; QSC is Quality and Safety Control; CLM is Cold-chain and Logistics Management; DMI is Digital Monitoring and Information; and MPE is Market-oriented Performance Evaluation.

Score	Interpretation
0	System does not exist
1	Very weak and irregular
2	Partially functioning
3	Moderate level
4	Well-organized
5	Fully integrated and digitally monitored

Additional indicators. Product Return Rate (PRR) is calculated as:

PRR = Returned products / Total products delivered x 100

Raw Milk Utilization Efficiency (RMUE) is calculated as:

RMUE = Marketable dairy output / Raw milk input x 100

Cold-chain Compliance (CCC) is calculated as:

CCC = Temperature-compliant stages / Total monitored stages x 100

These indicators allow the proposed mechanism to be used not only as a theoretical model, but also as a practical diagnostic instrument for dissertation research.

3. Results

The analysis of standards, scientific literature and Uzbekistan's dairy sector context shows that dairy processing enterprises require a management mechanism that is broader than traditional production control. Milk is a highly perishable raw material; therefore, the efficiency of a dairy processing enterprise depends on the ability to coordinate raw milk supply, preserve quality, control safety risks, maintain cold-chain conditions and respond to market demand.

The main management problem can therefore be summarized as follows: raw milk production growth does not automatically lead to high processing efficiency unless the enterprise has an integrated mechanism for supply coordination, quality assurance, cold-chain logistics, digital monitoring and market-oriented performance evaluation.

Proposed integrated management mechanism**.** The article proposes a five-block integrated management mechanism for dairy processing enterprises:

Raw milk supply coordination -> Quality and safety control -> Cold-chain and logistics management -> Digital monitoring -> Market-oriented performance evaluation -> Sustainable enterprise development

Each block affects the next one. If raw milk supply is unstable or quality is low, the processing enterprise cannot ensure stable product quality. If quality and safety control are weak, consumer trust and market competitiveness decrease. If cold-chain logistics are not properly organized, product losses and return rates increase. If digital monitoring is absent, management decisions are based on incomplete or delayed information. Finally, if market-oriented indicators are not evaluated, the enterprise cannot adapt production and assortment to real demand.

Functional blocks of the proposed model. The first block is raw milk supply coordination. Dairy processing enterprises depend on daily and stable raw milk inflow. This block includes supplier selection, contract-based procurement, quality requirements for raw milk, collection schedules and incentives for suppliers.

The second block is quality and safety control. In dairy processing, quality control begins before processing and continues during reception, storage, pasteurization, fermentation, packaging and distribution. ISO 9001 provides a framework for quality management systems, while ISO 22000 provides a food safety management framework applicable to organizations across the food chain.

The third block is cold-chain and logistics management. Milk and dairy products require temperature control from collection to final delivery. Failure of cold-chain logistics may cause quality losses, product returns and consumer complaints.

The fourth block is digital monitoring and traceability. Traceability can connect the origin of raw milk, laboratory results, processing batch, packaging date, storage conditions and distribution route into one information chain. This converts operational data into management information.

The fifth block is market-oriented performance evaluation. Dairy processing enterprises should evaluate not only production volume, but also market results, including

sales growth, product return rate, customer complaint rate, profitability, assortment turnover and repeat purchase rate.

Table 2. Example of IDMI calculation.

Block	Score
Raw milk supply coordination	3
Quality and safety control	4
Cold-chain and logistics management	2
Digital monitoring	1
Market-oriented performance evaluation	2

$$IDMI = (3 + 4 + 2 + 1 + 2) / 5 = 2.4$$

This means that the enterprise has a partially functioning but weakly integrated management system. The weakest block is digital monitoring, and therefore, digitalization should become a priority for improvement.

Table 3. Expected effects of the proposed mechanism.

Management direction	Expected effect
Supplier coordination	More stable raw milk supply
Quality and safety control	Lower rejection and complaint rates
Cold-chain logistics	Reduced product losses and returns
Digital monitoring	Faster and more accurate decisions
Market evaluation	Better alignment of production with demand
Integrated management	Higher competitiveness and sustainability

The most important result is that the enterprise moves from reactive management to preventive and data-based management. Instead of solving problems after product returns or complaints occur, the enterprise can identify weak points earlier through indicators and monitoring.

4. Discussion

The findings of this study show that dairy processing enterprises should be analysed as part of a wider agri-food value chain. This approach is consistent with Codex Alimentarius, which treats milk and milk products through a food-chain perspective and highlights the need for hygienic control from production to consumption. In the context of Uzbekistan, where official data show significant milk production volume, the main managerial challenge is to convert the raw milk base into processed dairy products with stable quality, safety and market value.

The proposed mechanism confirms the relevance of international quality and safety standards. ISO 9001 is useful for organizing quality management processes, documentation and continuous improvement, while ISO 22000 provides a food safety management framework applicable to organizations across the food chain. Together, these standards can serve as methodological support for improving dairy processing enterprises in Uzbekistan.

A key contribution of this study is the integration of traceability into the management mechanism. Traceability is not only a technical function; it is also a management tool. It helps identify which supplier provided raw milk, which batch was processed, where the product was stored, when it was delivered and whether complaints or returns are linked with a specific batch. This is especially important for dairy products because their quality and safety depend on time, temperature and hygiene discipline.

From the dissertation point of view, the proposed model can be used in three ways. First, it provides a theoretical basis for explaining the specific features of dairy processing

enterprises in Chapter 1. Second, it can be applied as an assessment framework in Chapter 2 to evaluate the current state of dairy processing enterprises in Uzbekistan and Andijan region. Third, it can support the recommendations in Chapter 3 by showing which functional blocks need improvement.

The practical value of the proposed mechanism is that it can be implemented gradually. Small and medium dairy enterprises do not need to introduce a full digital system immediately. They can begin with daily production and return records, supplier evaluation forms, simple laboratory logs and QR-code-based batch identification. Later, these tools can be integrated into enterprise resource planning systems, digital dashboards and full traceability platforms.

However, the study has limitations. The current article proposes a conceptual and methodological model rather than testing it on a large sample of enterprises. Future research should apply the IDMI index to several dairy processing enterprises, compare regions, and analyse the relationship between management integration and economic indicators such as profitability, product return rate and processing capacity utilization [15].

5. Conclusion

This study developed an integrated management mechanism for dairy processing enterprises based on supply chain coordination, quality and safety control, cold-chain logistics, digital monitoring and market-oriented performance evaluation. The findings show that dairy processing enterprises cannot be effectively managed only through traditional production-centred approaches. Since milk is highly perishable, the management system must cover the entire chain from raw milk supply to product delivery and consumer feedback.

The study confirms that quality and safety management are central to dairy processing. Codex Alimentarius emphasizes the need for hygienic control throughout the milk and dairy product chain, while ISO 9001 and ISO 22000 provide internationally recognized frameworks for quality management and food safety management. Therefore, dairy processing enterprises should combine process discipline, documentation, laboratory control, HACCP-based risk monitoring and continuous improvement within one management system.

The main scientific contribution of the article is the proposed five-block integrated management mechanism: raw milk supply coordination -> quality and safety control -> cold-chain and logistics management -> digital monitoring -> market-oriented performance evaluation. In addition, the article introduced the Integrated Dairy Management Index (IDMI), which allows the management level of dairy processing enterprises to be evaluated through measurable indicators. This makes the proposed model applicable not only as a theoretical framework, but also as a practical diagnostic tool.

The proposed mechanism can be used in dissertation research in three directions. First, it explains the specific management characteristics of dairy processing enterprises in the theoretical chapter. Second, it can be used as an analytical framework for evaluating dairy processing enterprises in Uzbekistan and Andijan region. Third, it provides a methodological basis for developing practical recommendations aimed at improving quality control, digital monitoring, supplier coordination, cold-chain logistics and market responsiveness.

Future research should test the proposed IDMI model on several dairy processing enterprises, compare regional differences, and analyse the relationship between management integration and economic indicators such as profitability, processing capacity utilization, product return rate, customer complaints and raw milk utilization efficiency.

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