Assessment of the Efficiency of the Dairy Supply Chain in Micro-Processing Centers in Arusha City, Tanzania.

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Abstract

The dairy sector is globally significant, yet inefficiencies and underutilized capacities challenge Tanzania's industry, particularly in Arusha City. This study investigated factors influencing dairy supply chain efficiency in micro-processing centres. Using a mixed methods approach with purposive and random sampling, data were collected through structured interviews and questionnaires from 105 respondents, analysed using thematic analysis, descriptive statistics and multiple regression analysis. Results highlight that raw milk availability, technological adoption, and technical expertise are critical for efficiency, while operational practices like skilled personnel, value added activities inventory and quality management can affect efficiency in operations, rate of defects and wastage. External challenges, including infrastructure limitations, regulatory barriers, and restricted market access, hinder optimal performance. The study recommends targeted interventions such as infrastructure improvement, technology investment, regulatory streamlining, and enhanced market access, emphasizing stakeholder collaboration and smart climate practices for sustainability.

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1. Introduction

The dairy sector plays a pivotal role in global economic growth by contributing to food security, poverty alleviation, and employment opportunities. Industrialized nations leverage modern technologies within supply chains to enhance food quality, ensure safety, and minimize labor dependency, achieving competitive advantages and cost-effective delivery (Christopher, 2016; Christopher & Towill, 2022; Lammers & Huffman, 2023). In Sub-Saharan Africa, including Tanzania, the dairy sector is equally significant, serving as a source of nutrition, rural income, and employment. It also supports livelihoods through dairy production and the creation of value-added products (Muthoni, Mwaura, & Mutisya, 2021; Hassan & Msangi, 2024).

In Tanzania, the government and stakeholders have implemented initiatives to address inefficiencies in the dairy value chain. These include the Tanzania Dairy Industry Board's programs, such as the School Milk Drinking Program and the annual Dairy Consumption Week, which aim to increase dairy consumption and processing capacity (Tanzania Dairy Board, 2024; Dessalegn & Ulega, 2023). However, despite these efforts, the sector's contribution to the national GDP remains at a mere 2%, indicating significant underperformance compared to its potential (Kolumbia, 2023). Over the past four years, milk production in Tanzania has grown by 20%, reaching 3.9 billion liters annually. Yet, only 2% of this output—approximately 81.8 million liters—is processed. The country still relies heavily on imports, importing up to 11.7 million liters annually at a cost of TZS 22.766 billion (Kolumbia, 2023; Kamugisha, Kibirige, & Nchimbi, 2021).

This disparity highlights persistent inefficiencies across the Tanzanian dairy supply chain. Studies show that micro-processing centers, particularly in Arusha City—a major dairy-producing region—operate below optimal capacity, with utilization rates ranging between 40% and 60% (Lunogelo, Makene, & Gray, 2021; Kimaro, Mpagalile, & Mgonja, 2021). Arusha benefits from favorable climatic conditions and accessible markets, yet challenges such as inconsistent raw milk supply, inadequate technology adoption, and limited skilled personnel hinder growth (Chasama & Maasawe, 2022; Ignas, 2013).

Several studies have examined the Tanzanian dairy value chain, addressing issues such as smallholder farmer contributions, processing technologies, and financial constraints (Sumuni et al., 2023; Katjiuongua & Nelgen, 2021). However, gaps remain in understanding the roles of marketing, logistics, distribution, raw milk availability, and waste management in shaping supply chain efficiency (Chasama & Maasawe, 2022; Smith, Mlinga, & Mwita, 2022). Furthermore, existing research often focuses on broader national trends or regions other than Arusha, offering limited insights into the unique dynamics of micro-processing centers within this region (Mwangi, Karani, & Mureithi, 2023; Kolumbia, 2023).

The lean supply chain model, as advocated by Davenport & Short (2021) and Javadi, Hassanpour, & Modares (2024), provides a strategic framework for addressing these inefficiencies. By emphasizing waste reduction, resource optimization, and demand-driven operations, the lean approach offers practical solutions for improving processing capacity and overall supply chain performance. In addition, global insights suggest that integrating advanced logistics, such as collaborative and simulation-based planning, can significantly enhance operational efficiency (Salas-Navarro et al., 2024; Michael & Kivuyo, 2022).

This study aims to bridge these research gaps by applying the lean supply chain model to analyze the efficiency of dairy supply chains in Arusha's micro-processing centers. The focus is on identifying key inefficiencies, such as raw milk availability, operational practices, and external factors, and proposing targeted interventions. Enhancing the supply chain's performance will not only increase processing capacity and reduce dependency on imports but also contribute to economic growth and food security in Tanzania (Hassan & Msangi, 2024; Akyoo, Nyamoga, & Madulu, 2021). By modernizing supply chain systems and promoting nationwide dairy consumption, Tanzania can build a resilient and sustainable dairy sector that capitalizes on its existing potential (Lunogelo, Songora, & Lasway, 2021; Addis, 2019). This research is especially relevant in the context of Tanzania's commitment to agricultural transformation, aligning with broader national and regional development goals. It provides actionable insights for policymakers, industry stakeholders, and international partners seeking to support sustainable dairy industry growth (Kitole & Utouh, 2023; Utouh & Kitole, 2024).

2. Theoretical Framework

The lean supply chain model, developed by Toyota engineer Shigeo Shingo, is rooted in lean manufacturing principles designed to optimize efficiency and minimize waste throughout the supply chain. By eliminating non-value-added activities, organizations can achieve significant cost savings, enhance quality, and improve responsiveness to customer demands. Central to this approach is the implementation of a pull system, which responds to actual demand rather than forecasts, and the adoption of just-in-time (JIT) production to align resources precisely with customer needs, thereby reducing inefficiencies (Christopher, 2016; Davenport & Short, 1990).

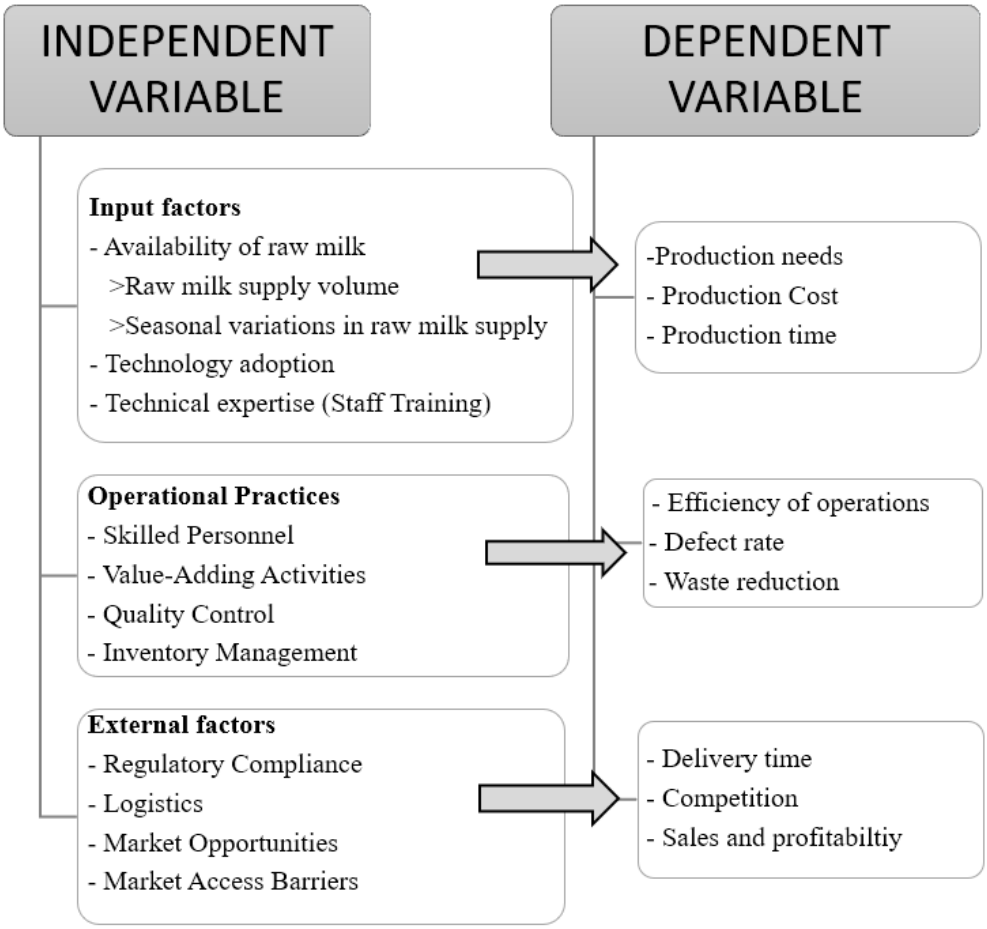
In the context of dairy micro-processing centers, lean strategies are particularly relevant for addressing inefficiencies such as inconsistent raw milk supply, poor inventory management, and external challenges like regulatory constraints and logistical bottlenecks. Lean principles prioritize quality control, waste reduction, and streamlined operations, making them well-suited to improving supply chain efficiency in this sector. By targeting input, operational, and external factors, the lean model aligns with the study's goal of enhancing the performance of micro-processing centers in Arusha City. Through the application of lean practices, such as process optimization and the elimination of redundant steps, the sector can achieve greater capacity utilization, cost reduction, and productivity improvements.

The conceptual framework guiding this study focuses on the relationship between key factors influencing efficiency (independent variables) and the overall efficiency of the dairy supply chain (dependent variable). Input factors such as the seasonality and availability of raw milk, technological infrastructure, and technical expertise directly impact supply chain performance. Operational practices based on the lean supply chain model—such as value stream mapping, quality control, inventory management, and waste reduction—serve as pivotal mechanisms for improving efficiency. Additionally, external factors including regulatory policies, logistical infrastructure, and market access further shape the performance of the dairy supply chain.

By integrating these dimensions, the framework highlights how the optimization of input factors, operational practices, and external conditions can collectively enhance the efficiency of dairy processing centers. This comprehensive approach not only addresses immediate inefficiencies but also contributes to the long-term sustainability and growth of Tanzania's dairy sector. Ultimately,

the application of lean principles in Arusha's micro-processing centers can serve as a transformative strategy, enabling the sector to meet rising consumer demand while reducing dependency on imports and improving food security.

Figure 1: Conceptual Framework



3. Methodology

This study employed a mixed-method approach utilizing a convergent parallel research design to comprehensively explore the factors influencing dairy supply chain efficiency in Arusha City. By integrating quantitative and qualitative data collected simultaneously, the research design allowed for a robust analysis that combined numerical insights with the depth and context of qualitative findings (Dimoso & Andrew, 2021). This approach ensured a holistic understanding of the research problem, addressing both measurable and experiential dimensions of supply chain operations.

The target population for this study consisted of 163 members from 13 dairy processing centers. To ensure representativeness, a sample size of 105 respondents was selected. Managers were chosen using purposive sampling due to their strategic oversight and detailed knowledge of operational and supply chain practices. Random sampling techniques were applied to select other

staff members, ensuring diverse perspectives from various roles within the processing centers. This combination of sampling methods provided a balanced representation of stakeholders involved in the supply chain.

Data collection employed a combination of tools tailored to suit the mixed-method approach. Structured questionnaires were administered to collect quantitative data on factors such as raw milk availability, inventory management practices, and production scheduling. Additionally, qualitative data were gathered through semi-structured interviews and focus group discussions, which explored deeper insights into challenges, experiences, and perceptions related to supply chain efficiency. This dual approach ensured a comprehensive dataset that addressed both specific metrics and contextual nuances.

For data analysis, qualitative and quantitative methods were employed to derive meaningful insights. Thematic analysis was applied to qualitative data, enabling the identification and interpretation of recurring patterns and themes related to input factors, operational practices, and external influences on supply chain efficiency. Quantitative data were analyzed using descriptive statistics, including frequencies, means, and standard deviations, to summarize the findings. Regression analysis further examined relationships between variables, providing statistical validation and insights into how input factors and practices impact supply chain efficiency.

The study adhered to rigorous ethical standards to protect participants' rights and ensure the integrity of the research process. Informed consent was obtained from all participants, ensuring they were fully aware of the study's objectives, methods, and their voluntary participation. Confidentiality was strictly maintained by anonymizing responses and securely storing data. Additionally, formal authorization to conduct the study was secured from the Institute of Accountancy Arusha, ensuring compliance with institutional and ethical research protocols. This methodological framework allowed for a detailed and nuanced exploration of the research topic, ensuring that the findings were both reliable and insightful. By integrating diverse data sources and adhering to ethical standards, the study provides a robust foundation for understanding and addressing inefficiencies in the dairy supply chain.

4. Data Analysis and results

Demographic Characteristics of Respondents

The gender distribution of respondents provides valuable insight into the representation of male and female workers within the dairy micro-processing centres in Arusha City. From the sample of 105 respondents, Male 64 respondents (61.9%), Female 41 respondents (38.1%). This indicates a higher proportion of male participants compared to female participants in the dairy micro-processing centres. The gender disparity reflects broader trends in employment practices within the dairy sector, where male workers may be more prevalent in certain technical or management roles. The findings suggest that gender plays a role in the workforce composition of the dairy supply chain in the region, which may have implications for future policies and training programs aimed at increasing gender equity in the industry.

Most respondents fall within the 31-40 years age group (39.13%), followed by those in the 18-30 years range (34.78%). The least representation is in the 51 years and above category, with only 8.70% of respondents. A significant portion of respondents has completed secondary school

(34.78%), followed by those holding a diploma (30.43%). The respondents with a bachelor's degree account for 17.39%, while only a small number have post-secondary qualifications, such as postgraduate degrees or no formal education.

Table 1: Reliability statistics

Reliability Statistics	
Cronbach's Alpha	N of Items
0.975	30

Source: Field Data, (2024).

The Cronbach's Alpha value for the study's 30 items was found to be 0.975, indicating excellent internal consistency. This high value suggests that the items used in the survey are highly reliable and consistent in measuring the constructs related to the efficiency of the dairy supply chain in the selected micro-processing centres in Arusha City, Tanzania. This level of participation is considered high with response rate of 91.3% and indicates a strong representation of the population under study.

Input factors affecting efficiency of dairy supply chain

The survey results reveal a generally positive perception of the consistency and adequacy of raw milk supply, with a high mean score indicating its importance for steady production in dairy processing. While most respondents agree on the significance of raw milk availability, the moderate standard deviation suggests some variability in experiences, likely due to differing access levels at various micro-processing centres. Seasonal fluctuations in raw milk supply, reflected by a mean score of 4.21, are recognized as a challenge, with higher variability in respondent experiences, especially during off-peak seasons when shortages may disrupt production.

Table 2: Descriptive statistics for the input factors

	N	Mean	Std. Deviation	Variance
Raw Milk Supply Volume	105	4.50	0.652	0.425
Seasonal Variations in Raw Milk Supply	105	4.21	0.987	0.975
Technology Adoption	105	4.64	0.590	0.349
Technical expertise (Staff Training)	105	4.58	0.647	0.419
Valid N (listwise)	105			

Source: Field Data, (2024).

The adoption of modern processing technologies received the highest mean score of 4.64, showing strong agreement that technology enhances operational efficiency, with a lower standard deviation indicating broad consensus on its benefits. Additionally, the high mean score of 4.58 for staff training emphasizes its critical role in improving both technological and operational capabilities, although the standard deviation suggests some differences in the implementation and effectiveness of training programs across centres.

Correlation of input factors affecting efficiency of dairy supply chain

The study found a strong positive correlation (0.906) between raw milk supply and volume and staff training, suggesting that effective training is closely linked to a steady supply of high-quality milk. Raw milk supply also showed moderate correlations with technology adoption (0.770) and seasonal variations (0.599). Seasonal variations, particularly during dry seasons, affect the supply volume and, in turn, influence the efficiency of technology use and the need for staff training, as indicated by the moderate correlations with technology (0.412) and training (0.395). The highest correlation was observed between staff training and raw milk supply volume (0.906), highlighting the critical role of well-trained personnel in managing milk supply and ensuring smooth operations.

Table 3: Correlation matrix for input factors

		Raw Milk Supply Volume	Seasonal Variations in Raw Milk Supply	Technology Adoption	Technical expertise (Staff Training)
Raw Milk Supply Volume	Pearson Correlation	1	0.599**	0.770**	0.906**
	Sig. (2-tailed)		0.000	0.000	0.000
	N	105	105	105	105
Seasonal Variations in Raw Milk Supply	Pearson Correlation	0.599**	1	0.412**	0.395**
	Sig. (2-tailed)	0.000		0.000	0.000
	N	105	105	105	105
Technology Adoption	Pearson Correlation	0.770**	0.412**	1	0.858**
	Sig. (2-tailed)	0.000	0.000		0.000
	N	105	105	105	105
Technical expertise (Staff Training)	Pearson Correlation	0.906**	0.395**	0.858**	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	105	105	105	105

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Field Data, (2024).

The interview responses further emphasized these findings, with respondents noting that consistent raw milk supply is essential for meeting production targets, while seasonal fluctuations lead to challenges such as production delays and increased costs. The availability of modern technologies, such as automated machines, was praised for improving processing efficiency by reducing manual labour, minimizing waste, and enhancing product consistency. Additionally, regular staff training was cited as key to optimizing technology use, with respondents acknowledging that while initial challenges existed, continuous training has ensured staff proficiency in operating new equipment and adapting to evolving processing techniques.

Operational practices affecting efficiency of dairy supply chain

The study results highlight that dairy micro-processing centres in Arusha City prioritize skilled personnel, with a high mean score of 4.58, indicating that experienced staff are crucial for smooth operations and effective supply chain management. Similarly, value-adding activities, quality control, and inventory management each received mean scores of 4.50, reflecting the emphasis

placed on optimizing operations, maintaining high product standards, and ensuring efficient inventory practices. These efforts are essential for reducing inefficiencies, minimizing defects, and managing costs, particularly in handling perishable goods like raw milk, all of which contribute to enhancing productivity and maintaining competitiveness in the market.

Table 4: Descriptive statistics for operational practices

	N	Mean	Std. Deviation	Variance
Skilled Personnel	105	4.58	0.647	0.419
Value-Adding Activities	105	4.50	0.652	0.425
Quality Control	105	4.50	0.652	0.425
Inventory Management	105	4.50	0.652	0.425
Valid N (listwise)	105			

Source: Field Data, (2024).

Correlation factors for Operational practices affecting efficiency of dairy supply chain

There is a strong positive correlation (0.906) between skilled personnel and other operational practices in dairy processing, indicating that a focus on well-trained staff significantly improves value-adding activities, quality control, and inventory management. Skilled personnel play a crucial role in enhancing the overall efficiency of the dairy supply chain. The correlation between value-adding activities and other practices is perfect (1.000), suggesting that improvements in value-adding activities directly lead to better efficiency, quality control, and waste reduction. Quality control also shows strong positive correlations with other practices, emphasizing the importance of consistent product monitoring to reduce defects and ensure high-quality outputs.

Table 4: Correlations for Operational Practices

		Skilled Personnel Expertise	Value-Adding Activities Process Efficiency	Quality Control Product Monitoring	Inventory Management Waste Reduction
Skilled Personnel	Pearson Correlation	1	0.906**	0.906**	0.906**
	Sig. (2-tailed)		0.000	0.000	0.000
	N	105	105	105	105
Value-Adding Activities	Pearson Correlation	0.906**	1	1.000**	1.000**
	Sig. (2-tailed)	0.000		0.000	0.000
	N	105	105	105	105
Quality Control	Pearson Correlation	0.906**	1.000**	1	1.000**
	Sig. (2-tailed)	0.000	0.000		0.000
	N	105	105	105	105
Inventory Management	Pearson Correlation	0.906**	1.000**	1.000**	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	105	105	105	105

**. Correlation is significant at the 0.01 level (2-tailed).

Similarly, inventory management is strongly correlated with all other operational practices, underscoring the importance of efficient inventory management and waste reduction strategies for

optimizing the dairy supply chain. Improvements in inventory practices are closely linked to enhanced quality control, skilled personnel, and value-adding activities. Interview responses further illustrate these points, with dairy processors emphasizing how value-adding activities streamline operations, how quality control systems ensure product quality, and how just-in-time inventory systems and waste reduction training for staff contribute to improved operational efficiency.

Table 5: External factors affecting operation efficiency of dairy supply chain

	N	Mean	Std. Deviation	Variance
Regulatory Compliance	105	4.58	0.647	0.419
Logistics	105	4.50	0.652	0.425
Market Opportunities	105	4.50	0.652	0.425
Market Access Barriers	105	4.50	0.652	0.425
Valid N (listwise)	105			

Source: Field Data, (2024).

Regulatory compliance received the highest mean score of 4.58, highlighting its importance in enhancing the efficiency of the dairy supply chain, with a low standard deviation of 0.647 indicating a consistent perception among respondents. Logistics and market opportunities both scored 4.50, reflecting their critical role in smooth dairy supply chain operations, with moderate variation in responses (standard deviation of 0.652) suggesting differing perceptions of their importance. Similarly, market access barriers, also scoring 4.50, were identified as a significant challenge, with the standard deviation further suggesting that these barriers are perceived differently across various dairy processing units.

Table 6: Correlation factors for external factors affecting operation efficiency of dairy supply chain

		Regulatory Compliance	Logistics	Market Opportunities	Market Access Barriers
Regulatory Compliance	Pearson Correlation	1	0.906**	0.906**	0.906**
	Sig. (2-tailed)		0.000	0.000	0.000
	N	105	105	105	105
Logistics	Pearson Correlation	0.906**	1	1.000**	1.000**
	Sig. (2-tailed)	0.000		0.000	0.000
	N	105	105	105	105
Market Opportunities	Pearson Correlation	0.906**	1.000**	1	1.000**
	Sig. (2-tailed)	0.000	0.000		0.000
	N	105	105	105	105
Market Access Barriers	Pearson Correlation	0.906**	1.000**	1.000**	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	105	105	105	105

**. Correlation is significant at the 0.01 level (2-tailed).

The strong positive correlations (ranging from 0.906 to 1.000) emphasize that external factors, including regulatory frameworks, logistics systems, market competition, and access barriers, significantly affect the operational efficiency of the dairy supply chain. Changes in one factor are likely to influence improvements in others, highlighting the importance of coordinated interventions to enhance overall efficiency. Interview responses reveal mixed views on government regulations, with some challenges in compliance but recognition of its role in maintaining product quality. Logistics and cold chain infrastructure are seen as critical for preserving product quality, while market opportunities encourage efficiency improvements. However, barriers such as high transportation costs and limited market access hinder profitability and growth, prompting efforts to improve logistics and explore new market partnerships

Regression Analysis

The value of R (0.916) demonstrates a very strong positive correlation between the independent variables (input factors, operational factors, and external factors) and the dependent variable, which is the efficiency of the dairy supply chain. This indicates that the factors studied collectively have a significant impact on operational efficiency. The R Square value of 0.839 suggests that approximately 83.9% of the variation in supply chain efficiency can be explained by these factors, making the model a good fit for the data. The Adjusted R Square (0.833) further supports the model's effectiveness, with a slight decrease accounting for the number of predictors, indicating no overfitting. Additionally, the Standard Error of the Estimate (0.278) shows that the model provides accurate predictions, as the value represents a small deviation between observed and predicted values.

Table 7: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.916[a]	0.839	0.833	0.278

a. Predictors: (Constant), Input factors, Operational factors, External Factors

ANOVA [a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	40.330	4	10.082	130.477	0.000[b]
	Residual	7.727	100	0.077		
	Total	48.057	104			

a. Dependent Variable: Efficiency of Dairy Supply Chain

b. Predictors: (Constant), Input factors, Operational factors, External Factors

Source: Field Data, (2024).

The ANOVA analysis confirms that the model is statistically significant, showing that input factors, operational factors, and external factors collectively have a meaningful impact on dairy supply chain efficiency. The high F-value (130.477) and p-value (0.000) indicate a strong relationship, suggesting the model effectively explains variations in supply chain efficiency across the selected dairy micro-processing centres. This supports the conclusion that these factors are significant predictors of operational efficiency.

Table 9: Regression coefficients

Coefficients [a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.180	0.220		0.820	0.414
	Seasonal Variations in Raw Milk Supply	-0.022	0.039	-0.031	-0.546	0.586
	Technology Adoption	-0.005	0.092	-0.004	-0.052	0.958
	Regulatory Compliance	0.995	0.141	0.947	7.069	0.000
	Market Access Barriers	-0.018	0.128	-0.017	-0.140	0.889

a. Dependent Variable: Efficiency of Dairy Supply Chain

Source: Field Data, (2024).

The regression analysis reveals the coefficients for each factor affecting dairy supply chain efficiency. The constant term (0.180) represents the baseline efficiency when all predictors are set to zero. Among the variables, Regulatory Compliance shows the most significant impact on supply chain efficiency with a high positive unstandardized coefficient (0.995) and a statistically significant t-value (7.069, $p = 0.000$), indicating that regulatory support plays a crucial role in improving operational efficiency. On the other hand, Seasonal Variations in Raw Milk Supply, Technology Adoption, and Market Access Barriers show low and non-significant coefficients with p-values well above 0.05, suggesting these factors have minimal influence within this specific context.

5. Discussion

This study underscores the interplay of input factors, operational practices, and external conditions in shaping the efficiency of the dairy supply chain in Arusha City. By examining the micro-processing centers, it becomes evident that addressing inefficiencies in these areas is key to unlocking the sector's potential. The findings align with the lean supply chain model, emphasizing waste minimization and optimization of resources.

Input factors such as raw milk supply, technology adoption, and staff training emerge as critical determinants of supply chain efficiency. Consistent and adequate raw milk supply is foundational for maintaining uninterrupted production. However, seasonal fluctuations in milk yield, driven by climatic conditions, pose significant challenges. During dry seasons, milk yield declines, leading to shortages that disrupt processing schedules (Hassan & Msangi, 2024; Salas-Navarro et al., 2024). As highlighted by Kisawike et al. (2021), these fluctuations necessitate strategic sourcing and storage mechanisms to ensure year-round availability.

The adoption of modern technologies, such as automated processing equipment, enhances production efficiency and product quality. Advanced machinery reduces manual errors, improves product consistency, and increases processing capacity, allowing micro-processing centers to meet market demands effectively (Kamugisha et al., 2021). However, integrating these technologies requires skilled personnel. Continuous staff training ensures that workers are proficient in operating advanced systems, reducing downtime and optimizing output. As McDonald et al. (2021) observed, investing in human capital alongside technology amplifies the benefits of

mechanization. To address these challenges, stakeholders must prioritize investments in raw milk sourcing, advanced processing technologies, and training programs. This integrated approach not only improves operational efficiency but also strengthens the competitiveness of micro-processing centers in the market (Katjiuongua & Nelgen, 2021).

Operational practices, including inventory management, production scheduling, and quality control, significantly influence the efficiency of dairy supply chains. Effective inventory management ensures that raw materials, particularly perishable milk, are available in the right quantities. Poor inventory practices lead to spoilage or stockouts, both of which disrupt production and inflate costs (Sumuni et al., 2023). The implementation of just-in-time (JIT) principles, as suggested by Christopher & Towill (2022), can mitigate these risks by aligning inventory levels with production needs. Additionally, production scheduling further optimizes the use of resources, reducing idle time and ensuring that processing activities align with supply and demand. Proper scheduling minimizes operational bottlenecks, leading to cost-effective production (Javadi et al., 2024). Quality control practices are equally critical, as they ensure that dairy products meet safety and consistency standards. High-quality products enhance consumer trust and competitiveness in both local and international markets (Akyoo et al., 2021; Davenport & Short, 2021). Micro-processing centers that effectively implement these operational practices are better positioned to minimize waste, streamline processes, and maintain a competitive edge in the dairy market. As highlighted by Lammers & Huffman (2023), strong operational frameworks not only reduce inefficiencies but also create value throughout the supply chain.

External factors, such as regulatory policies, infrastructure, market access, and climatic conditions, significantly shape the efficiency and sustainability of dairy supply chains. Regulatory compliance ensures product safety and market access but imposes costs that can burden small-scale processors. As noted by Njuguna et al. (2023), balancing regulatory requirements with cost-efficiency is essential for supporting small processors. Also, infrastructure challenges, particularly unreliable transportation and electricity supply, disrupt the smooth flow of production. Perishable products like milk require consistent refrigeration and timely transportation to minimize spoilage (Chasama & Maasawe, 2022). Poor infrastructure not only raises costs but also limits the geographic reach of micro-processors, restricting access to lucrative markets. Addressing these challenges requires coordinated efforts to improve transportation networks, invest in energy solutions, and enhance cold chain logistics (Kolumbia, 2023).

Climatic conditions, such as droughts and seasonal variations, further exacerbate inefficiencies. These conditions affect milk yield, quality, and supply, necessitating adaptive measures like drought-resistant fodder and water conservation strategies (Kimaro et al., 2021). Market access is another critical challenge, with limited distribution channels restricting the ability of micro-processors to scale their operations. Strengthening market integration through partnerships and cooperatives can help processors expand their reach and enhance profitability (Muthoni et al., 2021).

The findings from this study align with previous research, demonstrating that a holistic approach is required to address inefficiencies in the dairy supply chain. Investments in raw milk supply stabilization, advanced technology, and staff training should be complemented by improved operational practices and supportive external environments. As Smith et al. (2022) argue, fostering public-private partnerships can address infrastructure and market access challenges while creating

an enabling environment for small-scale processors. By adopting lean supply chain principles, such as waste minimization and demand-driven production, micro-processing centers in Arusha can achieve greater efficiency and sustainability. This transformation will not only enhance the competitiveness of the dairy sector but also contribute to economic growth and food security in Tanzania (Lunogelo et al., 2021). Future research should explore the specific impacts of regulatory frameworks and infrastructure investments on the long-term resilience of dairy supply chains in Tanzania.

6. Conclusion

In conclusion, this study offers crucial insights into the factors influencing the efficiency of the dairy supply chain in Arusha City, Tanzania. The research underscores the importance of input factors, operational practices, and external factors in shaping the performance of the dairy industry in the region. Key input factors, such as a consistent raw milk supply, adoption of modern technologies, and ongoing staff training, are vital for ensuring efficient processing and smooth operations. However, challenges like seasonal fluctuations in milk production and technological gaps in workforce skills can create bottlenecks, impacting overall supply chain efficiency.

Operational practices, such as effective inventory management, production scheduling, and quality control, are also essential for improving dairy supply chain efficiency. Streamlined inventory management helps to minimize waste and ensure the availability of raw materials, while efficient production scheduling reduces idle time and costs. Furthermore, strong quality control mechanisms ensure that products meet industry standards, which is crucial for maintaining consumer trust and competitiveness in the market. The study emphasizes that addressing these operational factors through better coordination and adopting lean management practices can significantly improve supply chain performance.

External factors, such as regulatory compliance, infrastructure quality, market access, and climatic conditions, were found to have a substantial impact on the dairy supply chain's efficiency. While regulatory challenges and infrastructure limitations often present barriers, market access constraints prevent small-scale processors from reaching broader markets. Climatic conditions also create fluctuations in milk production, further complicating the supply chain's consistency. The study suggests that improving infrastructure, strengthening regulatory support, and investing in technologies can mitigate these external challenges, ultimately enhancing supply chain efficiency.

The study concludes that addressing these challenges through targeted investments, policy interventions, and better infrastructure development can greatly improve the sustainability and efficiency of Arusha City's dairy supply chain. Investing in cold storage facilities, improving transportation, and ensuring reliable power supply will help stabilize production flows and reduce operational costs. Additionally, supporting smallholder farmers with better access to resources, training, and climate-smart practices will ensure a more reliable raw milk supply, further enhancing the efficiency and competitiveness of the dairy sector in the region.

Based on the study's findings, several recommendations are proposed to improve the dairy supply chain's efficiency and sustainability in Arusha City. These include investing in cold storage and milk collection points, encouraging the adoption of modern technologies, and implementing lean management practices. Policymakers are encouraged to create an enabling environment by reducing regulatory barriers and providing incentives for sustainable practices. Investment in cold

chain logistics and establishing partnerships between processors and retailers will improve market access and increase profitability. Moreover, climate-smart practices should be introduced to help farmers adapt to changing climatic conditions. Future studies should explore additional factors such as climate change, digital technologies, consumer preferences, and environmental impacts to further enhance the development and efficiency of Tanzania's dairy supply chain

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