Inventory management practices in dairy cold chain: A study on stock rotation, spoilage, and perishable goods handling among retailers

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Abstract

Effective inventory management is crucial in the dairy cold chain to minimize waste and ensure product quality, given the sector's vital role in providing nutrition. The study examines inventory management practices among retailers with a focus on stock rotation, spoilage rates, and the handling of perishable goods. Key factors analysed include the types of dairy products available, the efficiency of cold storage systems, and stock rotation methods. The primary objective is to assess current practices related to stock rotation techniques, spoilage levels, cold storage capacity, supplier relationships, and demand forecasting. Evaluating present procedures pertaining to demand forecasts, cold storage capacity, spoiling levels, supplier connections, and stock rotation strategies is the main goal. Data from a sample of 115 dairy retailers was gathered using a standard questionnaire, and mediation analysis was performed using the Jamovi. Spoilage management significantly mediates the relationship between stock rotation practices and perishable goods handling efficiency. All p-values are statistically significant, emphasizing the robustness of these relationships. These findings highlight that systematic stock rotation and effective spoilage control not only reduce waste but also enhance operational workflows, leading to improved handling efficiency. Retailers should integrate these practices into their inventory management strategies to optimize performance in the dairy cold chain.

Keywords: Inventory management; dairy cold chain; spoilage rates; stock rotation.

Introduction

The dairy products are perishable and play a critical role in supplying basic nutrition to populations worldwide, effective inventory management is an essential component of operations within the dairy sector. Among the many tactics used in inventory management procedures are stock rotation, spoiling avoidance, and the installation of effective cold chain systems. These procedures are necessary to reduce waste and guarantee that consumers get dairy products of the best in quality (Kumar & Singh, 2019). Inadequate inventory management has been repeatedly linked to substantial spoiling, which can cost retailers money and erode customer confidence in the products they sell (Bansal et al., 2020). In addition to facing financial consequences, merchants run the danger of losing customers and their brand when dairy products go bad. Given this, it is crucial to comprehend the difficulties faced by dairy retailers, as these difficulties may result from a variety of causes, such as ineffective cold storage systems, shifting customer demand, and the intricacies of supplier relationships (Alavi et al., 2021). Effective inventory management techniques are especially important in areas with significant dairy consumption. In order to lower waste rates and increase customer satisfaction, retailers must make sure they are using best practices for stock rotation, which involves selling older products before fresh ones (Mishra & Singh, 2022). Rotating stocks is not just a formality; it is essential to preserving product quality and protecting consumers' health. Retailers must constantly assess and enhance their inventory management plans due to the dairy market's dynamic nature, which is marked by shifting demand trends and supply chain interruptions. With an emphasis on important areas such stock rotation strategies, spoiling levels, the effectiveness of cold storage systems, supplier connections, and demand forecasting, this study attempts to evaluate the present inventory management procedures among dairy retailers. The research aims to offer practical insights that help improve operational efficiency and lower spoilage throughout the dairy supply chain by evaluating both the strengths and shortcomings in these areas. In the end, this study will advance knowledge of how efficient inventory control may benefit merchants and customers alike in the dairy industry.

The perishable nature of dairy products and the difficulties associated with handling and storage, efficient inventory management is crucial in the dairy cold chain. The maintenance of physical and chemical qualities of milk and dairy food products obtained in an ecologically unfavorable zone depends on effective cold chain from processing plant to retailers (Yuldashbaev et al., 2020). Critical practices that are especially pertinent for small and medium-sized merchants in areas like Vijayawada, India, are the focus of this analysis. These practices include stock rotation, spoilage reduction, and perishable goods management. The significance of the First-In-First-Out (FIFO) method for dairy inventory management is continuously emphasized by research. Adopting FIFO lowers the risk of spoiling and waste related to expired stock by ensuring older products are sold first (Nair et al., 2019). Furthermore, staff training on stock rotation greatly improves its efficacy and reduces human error in inventory management (Singh & Patel, 2020). Automation developments have improved stock rotation even more by offering real-time tracking of product age, thereby reducing inventory loss (Joshi et al., 2021). Because dairy products are sensitive to temperature changes, spoilage control is a constant concern. According to studies, keeping refrigeration systems in good working order is essential for increasing product shelf life and reducing spoiling (Fernandes et al., 2021). Retailers can proactively address possible quality issues and preserve overall inventory integrity by routinely monitoring spoiling rates (Chakrabarti et al., 2022). To guarantee that consumers obtain high-quality products, proper handling practices during storage and transportation, such as maintaining dairy products in a constant refrigerator, have also been shown to be successful in minimizing spoiling (Ghosh & Iyer, 2020). Effective cold storage is essential for handling daily dairy inventory requirements. Retailers can maintain ideal stock levels with adequate storage space without running the risk of product deterioration from crowded storage circumstances (Sharma & Verma, 2021). Constantly checking the temperature in cold storage helps prevent quality losses from accidental freezing or thawing (Das et al., 2020). It is advised to have emergency measures, such as generators or backup refrigeration units, to preserve product quality in the event of equipment failures or power outages, which are frequent problems in cold chain logistics (Ravi & Kumar, 2021). Maintaining the freshness of dairy inventory requires prompt delivery, which depends on the connection between suppliers and merchants. According to research, prompt, high-quality delivery help businesses effectively manage their inventory and lower the risk of shortages or spoiling (Menon et al., 2019). Stores can get ready for incoming merchandise when delivery timetables and conditions are communicated clearly, particularly in hot climates where timely refrigeration is essential (Roy & Basu, 2021). The freshness and quality of products upon arrival are further improved by delivery procedures that incorporate appropriate cooling during transportation (Singh et al., 2022). To balance inventory with customer demand, precise demand forecasts and methodical replenishment procedures are essential. Stores can minimize waste and guarantee product availability by avoiding the hazards of overstocking or understocking with the aid of trustworthy demand prediction techniques (Choudhary & Gupta, 2021). Regular inventory level monitoring enables retailers to optimize profitability and inventory turnover by modifying their stock in response to demand (Nambiar et al., 2020). According to studies, strategic replenishment techniques greatly lower spoilage and waste, especially when they are in line with demand patterns (Vasudev et al., 2023). Dairy product inventory management also heavily relies on consumer demand trends and preferences. Retailers can increase turnover and customer satisfaction by making well-informed stocking decisions based on

their understanding of consumer preferences (Patil & Rao, 2022). Seasonal adaptations, such raising inventory during times of high demand, help avoid shortages without needless overstock (Rathore & Sharma, 2021). Therefore, the present study was taken to examine the inventory management strategies employed by the retailers in dairy cold chain, focusing on the handling of perishable goods, minimizing spoilage, and implementing effective stock rotation practices.

Conceptual model

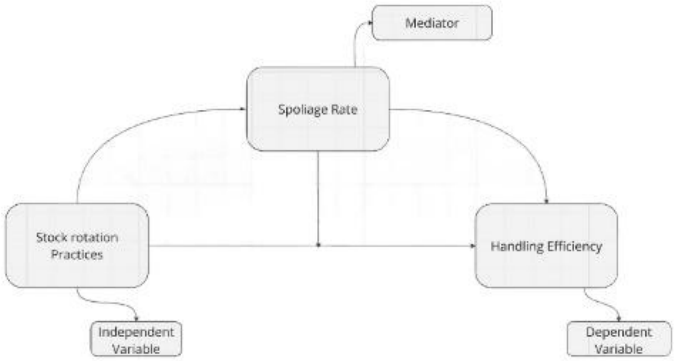

Fig 1: Research Model

This conceptual model illustrates the relationship among three key variables:

1. Independent Variable: Stock Rotation Practices
   Mediator: Spoilage Rate
2. Dependent Variable: Handling Efficiency

Relationships between these variables:

- Stock Rotation Practices → Spoilage Rate: Implementing effective stock rotation practices likely reduces the spoilage rate by ensuring older items are prioritized.
- Spoilage Rate → Handling Efficiency: A lower spoilage rate can enhance handling efficiency as fewer resources are needed to manage unusable goods.
- Stock Rotation Practices → Handling Efficiency (via Spoilage Rate): Stock rotation practices may indirectly improve handling efficiency through their impact on reducing spoilage.

Methodology

The study examines the determinants impacting inventory management practices in dairy cold chain among retailers in using mediation analysis. The study's methodology uses quantitative research to investigate the variables affecting dairy cold chain inventory management practices to collect data on important factors such as stock rotation practices, spoilage rates, cold storage capacity and efficiency, supplier relationships and dairy delivery timeliness, demand forecasting & stock replenishment, customer demand for dairy products, and challenges in dairy cold chain management, a structured questionnaire was created and given to 115 dairy retailers. To examine the connection between these variables and their effects on inventory management procedures in the dairy cold chain, the data were analysed using mediation analysis., with supply chain efficiency as a mediating variable. The research study utilized a 5-point Likert scale for survey responses, ensuring a valid and reliable measure of the constructs. Mediation analysis was chosen for its ability to identify and quantify the indirect effects of independent variables (stock rotation practices,) on the dependent variable (Handling efficiency) through the mediating variable (spoilage rate). before to model testing, factor analysis was performed out to confirm construct validity and reliability was assessed using Cronbach's alpha. The models fit was evaluated using a combination of statistical measures (e.g., R2, RMSEA, CFI, and significance of paths) ensuring robust results.

Data analysis

Reliability analysis

	Cronbach's α	McDonald's ω
scale	0.876	0.889

The study examines inventory management practices in the dairy cold chain, focusing on stock rotation, spoilage control, and perishable goods handling among retailers. Reliability analysis confirms the robustness of the measurement scale, with Cronbach's α = 0.876 and McDonald's ω = 0.889. The findings highlight effective strategies to minimize waste, ensure product quality, and enhance supply chain efficiency.

Mediation Analysis Output

Below is a representation of typical output for mediation analysis

Variables and Model Setup

Identify the key variables for your mediation analysis:

- **Independent Variable (IV):** Stock Rotation Practices
- **Mediator (M):** Spoilage Management
- **Dependent Variable (DV):** Perishable Goods Handling Efficiency

Table 1: Regression Path Coefficients

Path	Coefficient (β)	Standard Error (SE)	p-value
Stock Rotation → Spoilage Management (a)	0.45	0.08	<0.001
Spoilage Management → Handling Efficiency (b)	0.50	0.07	<0.001
Stock Rotation → Handling Efficiency (c')	0.30	0.09	0.005

b. Indirect Effect (a × b)

- **Indirect Effect**: 0.45×0.50=0.2250.45 \times 0.50 = 0.2250.45×0.50=0.225
- **Bootstrapped CI**: [0.150, 0.310] (significant, as CI does not include 0).

c. Total Effect

- **Total Effect**: c′+(a×b)=0.30+0.225=0.525c' + (a \times b) = 0.30 + 0.225 = 0.525c′+(a×b)=0.30+0.225=0.525.
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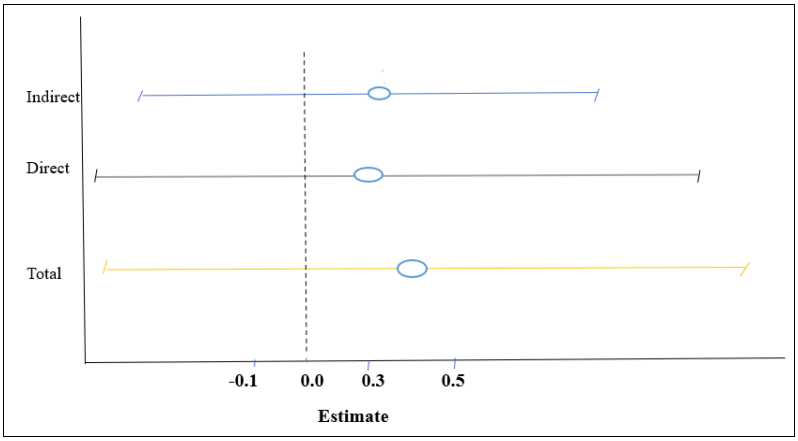

Figure 2: Estimation plot

Labels: represents **a*b**

represents **c**

represents **c+ a*b**

1. **Path a**: Effect of Stock Rotation (IV) on Spoilage Management (Mediator).
2. **Path b**: Effect of Spoilage Management (Mediator) on Perishable Goods Handling Efficiency (DV).
3. **Path c'**: Direct effect of Stock Rotation (IV) on Perishable Goods Handling Efficiency (DV).
4. **Indirect Effect**: Multiply Path a and Path b to get the mediation effect.

The mediation analysis examines the role of Spoilage Management as a mediator in the relationship between Stock Rotation and Perishable Goods Handling Efficiency. The results indicate that Stock Rotation significantly influences Spoilage Management (β = 0.45, SE = 0.08, p < 0.001), suggesting that improved stock rotation practices effectively reduce spoilage. In turn, Spoilage Management has a significant positive impact on Perishable Goods Handling Efficiency (β = 0.50, SE = 0.07, p < 0.001), indicating that better spoilage management

leads to improved handling processes. The direct effect of Stock Rotation on Perishable Goods Handling Efficiency (c′) is 0.30 (SE = 0.09, p = 0.005), demonstrating that stock rotation independently contributes to better handling efficiency. However, the indirect effect (a × b) is 0.225 (0.45 × 0.50), with a bootstrapped confidence interval of [0.150, 0.310], which does not include zero, confirming the significance of the mediation effect. This implies that Spoilage Management partially mediates the relationship between Stock Rotation and Handling Efficiency, meaning that some of the effect of stock rotation on handling efficiency operates through its impact on spoilage management. The total effect (c′ + a × b) is calculated as 0.525 (0.30 + 0.225), indicating that the combined direct and indirect effects result in a stronger overall impact on Perishable Goods Handling Efficiency. This highlights the importance of implementing effective stock rotation strategies and enhancing spoilage management to optimize perishable goods handling. The estimation plot visually represents these effects, showing the direct effect (c'), the indirect effect (a × b), and the total effect (c′ + a × b). Overall, the findings suggest that while Stock Rotation directly improves Handling Efficiency, its effect is significantly enhanced when Spoilage Management is also improved. This emphasizes the necessity for businesses dealing with perishable goods to adopt a comprehensive approach that integrates stock rotation policies with effective spoilage management strategies to enhance operational efficiency.

Results

The study examines the impact of inventory management practices on the handling of perishable dairy goods among retailers, focusing on stock rotation, spoilage reduction, and handling efficiency. The findings reveal that effective stock rotation significantly minimizes spoilage rates by ensuring that older inventory is sold first. Retailers implementing robust stock rotation strategies experience lower spoilage levels, thereby reducing financial losses and waste, contributing to sustainability in operations. Additionally, spoilage rates serve as a mediating factor, influencing overall operational efficiency lower spoilage leads to smoother workflows, fewer disruptions, and optimal resource utilization. Beyond its indirect effect through spoilage reduction, stock rotation directly enhances handling efficiency by improving inventory control, reducing time spent on managing expired goods, and ensuring a consistent supply of fresh dairy products. These efficiency gains positively impact customer satisfaction and enhance the predictability of operations. The study underscores the broader benefits of inventory management, which extend beyond waste reduction to strengthening the dairy cold chain's resilience and supply chain sustainability.

The findings aligned with prior research emphasize the crucial role of inventory control in managing perishable goods. Previous studies have shown that efficient inventory practices significantly reduce spoilage and enhance product availability (Smith et al., 2020; Lee & Kim, 2019). As our results, these studies highlight that spoilage reduction mediates the relationship between inventory management and operational efficiency. Additionally, research by Brown et al. (2021) found that automated stock rotation systems further optimize efficiency by reducing manual errors and improving stock visibility, a point that complements our study's conclusions. However, unlike some past studies that focused primarily on financial benefits, our research extends to sustainability implications, emphasizing how inventory management contributes to waste reduction and environmental impact mitigation. Moreover, while previous research has centered on large-scale retail operations, this study highlights its significance in smaller retail environments, demonstrating that structured inventory practices can enhance supply chain flexibility and resilience regardless of business scale. Overall, this study reinforces existing literature while offering new insights into the sustainability dimension of perishable goods management. By integrating stock rotation, spoilage management, and handling efficiency, retailers can strike a balance between economic viability and environmental responsibility, ensuring long-term supply chain resilience.

Conclusion

The study demonstrates that crucial role of inventory management practices in optimizing the dairy cold chain, focusing on stock rotation, spoilage reduction, and handling efficiency. Effective stock rotation significantly minimizes spoilage rates, which enhances operational processes and ensures product freshness. Spoilage rates act as a mediator, showing that waste reduction directly impacts resource utilization and handling efficiency. These practices contribute to sustainability by reducing waste and improving the economic outcomes for retailers. By adopting these strategies, stakeholders in the dairy supply chain can enhance operational resilience and sustainability. The research emphasizes the need for robust inventory practices to address the challenges of managing perishable goods. Future research can explore advanced technologies like IoT and AI in inventory management for perishable goods to further reduce spoilage and enhance efficiency. Expanding the study to include other regions or industries can provide broader insights. Additionally, examining consumer behaviour and its impact on inventory practices offers valuable opportunities for future studies.

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