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Performance of Food and Beverage Manufacturing Firms in Kenya**



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Circular Inventory Management Practices and Environmental Performance of Food and Beverage Manufacturing Firms in Kenya

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Abstract

Purpose: The purpose of this study was to examine how shelf-life extension and lean stock holding affected the environmental performance of food and beverage manufacturing firms in Kenya. Grounded in circular economy principles, the study focused on reducing waste associated with overproduction and product spoilage. It sought to provide evidence on how improved inventory practices enhanced sustainability and minimized environmental degradation in the sector.

Methodology: The study adopted a descriptive research design to enable systematic data collection and analysis. The target population comprised 329 food and beverage manufacturing firms listed by the Kenya Association of Manufacturers, from which a sample of 181 firms was selected using Yamane's formula and simple random sampling. Primary data were collected using structured questionnaires administered to supply chain managers. Data were analyzed using both descriptive and inferential statistics, including correlation and regression analysis.

Findings: The findings revealed that both shelf-life extension and lean stock holding have significant positive effects on environmental performance. Shelf-life extension practices such as cold chain management and inventory rotation were found to reduce product spoilage and waste, thereby improving resource efficiency. Lean stock holding practices minimized excess inventory, reduced overproduction, and lowered environmental impacts associated with storage and disposal. Inferential results confirmed that both variables are statistically significant predictors of environmental performance.

Unique Contribution to Theory, Policy and Practice: This study contributes to theory, policy, and practice by demonstrating how specific inventory management practices enhance environmental performance in manufacturing contexts. Practically, it shows that food and beverage firms can improve sustainability by investing in efficient cold chain systems, strengthening demand forecasting, and adopting lean practices such as Just-in-Time to reduce waste and optimize resources. Theoretically, it provides empirical evidence on the role of shelf-life extension and lean stock holding within circular economy frameworks.

Keywords: *Shelf-Life Extension, Lean Stock Holding, Environmental Performance, Circular Economy, Kenya*

1. Introduction

The Circular Economy (CE) has emerged as a transformative industrial paradigm that seeks to decouple economic growth from the unsustainable consumption of finite resources by promoting the continuous use, recovery, and regeneration of materials. As articulated by the Ellen MacArthur Foundation (2019), CE advances a restorative system in which products and materials are maintained at their highest utility for as long as possible through strategies such as reuse, recycling, and product life extension. This approach challenges the dominant linear model of “take–make–dispose,” which has been widely associated with environmental degradation, resource depletion, and waste accumulation (Stewart & Niero, 2018). Within this paradigm, environmental performance is conceptualized as an organization’s ability to minimize its ecological footprint through efficient resource utilization, reduced waste generation, and lower emissions (Kazancoglu et al., 2018). The food and beverage manufacturing sector is particularly vulnerable to environmental inefficiencies due to its reliance on perishable inputs, high energy consumption, and susceptibility to product spoilage, making it a critical area for the application of circular economy principles (UNEP, 2021).

Inventory management occupies a central position in determining both operational efficiency and environmental impact within manufacturing systems. Traditional inventory models have historically prioritized cost minimization and service level optimization, often at the expense of environmental considerations, leading to overproduction, excessive stock holding, and significant material waste (Ahi & Searcy, 2019). In contrast, circular inventory management emphasizes practices that enhance resource efficiency and minimize waste throughout the product lifecycle (Stewart & Niero, 2018). Among these practices, shelf-life extension and lean stock holding have emerged as critical mechanisms for improving environmental performance, particularly in industries characterized by high perishability such as food and beverage manufacturing. Shelf-life extension focuses on prolonging product usability through interventions such as improved cold chain systems, effective inventory rotation, and accurate demand forecasting, thereby reducing spoilage and waste (Falcone et al., 2017). Lean stock holding, on the other hand, seeks to maintain optimal inventory levels through approaches such as Just-in-Time systems, minimizing excess stock, reducing storage-related emissions, and enhancing overall efficiency (Ahi & Searcy, 2019).

At the global level, the integration of circular principles into inventory management has gained increasing prominence as firms respond to mounting environmental pressures and resource constraints. Advances in digital technologies, including the Internet of Things (IoT), artificial intelligence, and data analytics, have enabled organizations to optimize inventory flows, enhance traceability, and extend product lifecycles (Govindan & Hasanagic, 2018). These developments have facilitated more efficient management of perishable goods, enabling firms to reduce waste and improve environmental performance. However, despite these advancements, the adoption of such practices remains uneven, particularly in developing regions where infrastructural limitations,

technological gaps, and financial constraints hinder implementation (Howard et al., 2018). Across Africa, circular inventory management is gradually evolving through a combination of policy initiatives and emerging innovations aimed at improving resource efficiency and waste management, although implementation remains fragmented and inconsistent (Adewumi, 2021).

In Kenya, the food and beverage manufacturing sector faces acute challenges related to inventory management, including inadequate cold chain infrastructure, poor demand forecasting, and high levels of perishable inventory. These challenges contribute significantly to food waste, resource inefficiency, and environmental degradation (UNEP, 2022). While national policy frameworks such as the Green Economy Strategy and Sustainable Waste Management initiatives emphasize the importance of resource efficiency and sustainability (Ministry of Environment and Forestry, 2021), the practical adoption of circular inventory practices at the firm level remains limited. Moreover, existing empirical studies have largely focused on broad supply chain sustainability without isolating the specific contribution of inventory management practices to environmental performance (De Angelis et al., 2018). This creates a critical knowledge gap, particularly in understanding how targeted practices such as shelf-life extension and lean stock holding influence environmental outcomes within the Kenyan context. This study therefore seeks to bridge this gap by examining the effect of these two practices on the environmental performance of food and beverage manufacturing firms in Kenya.

1.1 Statement of the Problem

The food and beverage (F&B) manufacturing sector in Kenya is a critical contributor to the national economy, accounting for over 30% of total manufacturing output and employing more than 200,000 people (KNBS, 2023). Despite its economic significance, the sector's environmental footprint remains a growing concern. High levels of greenhouse gas emissions, excessive water consumption, and substantial solid waste generation continue to pose environmental challenges (FAO, 2019). A particularly pressing issue is food loss, with over 30% of food produced in Kenya wasted before consumption, largely due to weak cold chain systems, poor demand forecasting, and inefficient inventory management (UNEP, 2021; FAO, 2023). These inefficiencies are closely linked to traditional inventory practices that prioritize throughput and cost efficiency while neglecting environmental considerations, thereby contributing to resource depletion, increased emissions, and waste accumulation.

The underlying problem lies in ineffective inventory management practices, particularly in relation to shelf-life management and stock control. Inadequate shelf-life extension mechanisms, such as poor cold storage infrastructure and weak inventory rotation systems, result in high levels of product spoilage and waste. Similarly, the absence of lean stock holding practices leads to overstocking, unnecessary storage, and increased disposal of expired goods. These practices not only increase operational inefficiencies but also exacerbate environmental degradation through higher energy consumption, emissions, and waste generation (Ahi & Searcy, 2019; Kazancoglu et

al., 2018). While Circular Economy (CE) principles advocate for sustainable approaches such as resource efficiency and waste minimization, their application within inventory management remains limited in the Kenyan context (Stewart & Niero, 2018).

Empirical evidence on the relationship between inventory management practices and environmental performance remains fragmented and insufficient, particularly in developing economies. Most existing studies focus on broader supply chain sustainability or general circular practices without isolating specific inventory-related variables such as shelf-life extension and lean stock holding (Govindan & Hasanagic, 2018; De Angelis et al., 2018). In Kenya, available studies tend to generalize across industries or focus on unrelated practices, limiting their applicability to the food and beverage manufacturing sector. Furthermore, there is limited empirical analysis quantifying how improved shelf-life management and lean inventory systems directly influence environmental outcomes such as waste reduction, emission control, and resource efficiency.

This lack of context-specific and inventory-focused evidence creates a significant gap for both policymakers and industry practitioners. While national frameworks such as Vision 2030 and the Green Economy Strategy emphasize sustainability, the absence of empirical guidance on effective inventory practices hinders practical implementation at the firm level. Consequently, firms lack actionable insights to transition toward environmentally sustainable operations. This study therefore seeks to address this gap by examining the effect of shelf-life extension and lean stock holding on environmental performance in Kenya's F&B manufacturing sector. By focusing on these two critical practices, the study aims to provide empirical evidence that can inform policy, guide industry adoption, and enhance environmental sustainability within the sector.

1.2 Research objectives

The general objective of this study was to determine the effect of Circular Inventory Management Practices on Environmental Performance of Food and Beverage Manufacturing Firms in Kenya. Specific objectives included;

1. To assess the effect of Shelf-Life Extension on the environmental performance of food and beverage manufacturing firms in Kenya
2. To examine the effect of Lean stock holding on the environmental performance of food and beverage manufacturing firms in Kenya.

2. Literature Review

2.1 Theoretical Literature

This study was guided by Contingency Theory and the Theory of Constraints (TOC), which provide complementary perspectives for explaining how inventory management practices influence environmental performance in dynamic and resource-constrained environments. Contingency Theory, as advanced by Donaldson (2001), argues that there is no single best way to organize or manage operations; instead, effectiveness depends on aligning organizational practices with contextual conditions. Kihyun (2011) further emphasizes that firms must adapt their

structures and processes to environmental uncertainty, technological changes, and market dynamics in order to achieve optimal performance. Within supply chain management, Fawcett et al. (2006) highlight that firms operating in volatile environments require flexible and responsive systems to manage variability. This perspective is particularly relevant in the food and beverage manufacturing sector, where perishability and demand fluctuations create continuous uncertainty that requires adaptive inventory strategies.

In this context, shelf-life extension can be understood as a strategic response to environmental and operational uncertainty. Liu et al. (2010) observe that organizations with higher levels of flexibility and responsiveness are better positioned to manage disruptions and improve performance outcomes. Practices such as cold chain improvement, effective inventory rotation, and accurate demand forecasting enable firms to extend product usability while reducing spoilage. These approaches allow firms to align inventory levels with actual demand conditions, thereby minimizing waste and improving resource efficiency. In environments characterized by infrastructural limitations and market unpredictability, such as Kenya's food and beverage sector, the adoption of shelf-life extension practices reflects the need for strategic fit between operational systems and contextual realities. This alignment not only enhances operational efficiency but also contributes to improved environmental performance through reduced waste and emissions .

The Theory of Constraints (TOC), developed by Goldratt (1984), provides a systems-oriented framework for improving organizational performance by focusing on the most critical limiting factor within a process. According to Dettmer (1996), organizations achieve optimal performance when they identify and manage constraints that restrict throughput and efficiency. Rather than attempting to optimize all aspects of a system simultaneously, TOC emphasizes targeted interventions aimed at alleviating bottlenecks. In supply chain management, this approach has informed the development of lean operational strategies that prioritize flow efficiency and the elimination of non-value-adding activities. William (1996) notes that organizations applying TOC principles often achieve significant improvements in process efficiency and cost reduction by concentrating efforts on critical constraints.

The application of TOC is particularly evident in lean stock holding practices, which focus on maintaining minimal inventory levels to reduce waste and improve efficiency. Excess inventory in the food and beverage sector often leads to product spoilage, increased energy consumption, and higher disposal costs, all of which negatively impact environmental performance. By identifying constraints such as inaccurate forecasting or slow-moving inventory, firms can implement lean strategies that enhance inventory flow and reduce inefficiencies. Lean approaches such as Just-in-Time systems align with TOC by minimizing buffers and ensuring that inventory levels closely match demand. This not only improves operational performance but also reduces environmental impact through lower resource consumption and waste generation. In this way, the Theory of Constraints provides a strong foundation for understanding how lean stock holding contributes to environmental sustainability by addressing inefficiencies at their source.

2.2 Empirical Literature

Empirical studies on shelf-life extension consistently demonstrate its potential to enhance environmental performance, particularly through the reduction of food waste and improved resource efficiency across supply chains. Bacenetti et al. (2018) conducted a Life Cycle Assessment to evaluate the environmental benefits of extending the shelf life of bakery products using natural antioxidants such as rosmarinic acid. Their findings indicated that reducing product losses across the distribution and consumption stages significantly lowered environmental impacts in most assessed categories, highlighting the importance of minimizing waste as a sustainability strategy. However, the study's focus on a single product category limits its generalizability, especially in a sector like food and beverage manufacturing where perishability varies widely across products. Villanova-Estors et al. (2024) extended this line of inquiry by comparing active packaging with conventional packaging in fresh-cut salads. Their results showed that active packaging significantly reduced food waste and greenhouse gas emissions, demonstrating that technological interventions can play a critical role in enhancing environmental performance. Despite these promising findings, the study assumes consistent consumer behavior and does not sufficiently account for post-purchase waste, which remains a major contributor to overall food loss in real-world settings.

Further empirical contributions highlight the growing role of digital technologies in optimizing shelf-life management and environmental outcomes. Reyes et al. (2024) developed a digital food waste estimator capable of quantifying reductions in waste, emissions, and water consumption resulting from shelf-life extension practices. Their findings showed that even modest improvements in shelf life could generate significant environmental benefits, including substantial reductions in carbon emissions and water usage. While this approach offers valuable insights into the potential of data-driven decision-making, its effectiveness depends heavily on the availability of accurate data and the level of technological adoption within firms. In many developing economies, including Kenya, limited digital infrastructure and capacity constraints may hinder the practical application of such tools. Falcone et al. (2017) examined shelf-life extension in the dairy sector by introducing antimicrobial treatments to prolong the usability of mozzarella cheese. Their findings revealed that although the innovation slightly increased production inputs, it significantly reduced product loss, resulting in net environmental and economic benefits. However, the study does not adequately address logistical challenges such as cold chain reliability and distribution inefficiencies, which are critical determinants of shelf-life effectiveness in developing country contexts.

While these studies collectively affirm the environmental benefits of shelf-life extension, they also reveal several critical limitations. Most notably, the majority of research is conducted in controlled environments or developed economies with advanced infrastructure, raising concerns about the applicability of findings to developing regions. Additionally, many studies focus on technological innovations such as packaging and preservatives while overlooking operational factors such as

forecasting accuracy, inventory rotation, and supply chain coordination, which are equally important in determining shelf-life outcomes. There is also limited consideration of contextual variables such as infrastructure reliability, market dynamics, and consumer behavior, all of which influence the effectiveness of shelf-life strategies.

Empirical research on lean stock holding similarly demonstrates its potential to enhance organizational performance, although the primary focus has largely been on operational efficiency rather than environmental sustainability. Wainaina and Odari (2023) investigated lean supply chain practices in Kenyan supermarkets and found that practices such as demand management and process standardization significantly improved efficiency and responsiveness. Their findings suggest that minimizing excess inventory reduces operational waste and enhances performance outcomes. However, the study does not explicitly examine environmental indicators, leaving a gap in understanding how lean practices translate into environmental benefits. Odoyo and Arasa (2020) also established a positive relationship between lean inventory management systems and supermarket performance, with Just-in-Time practices emerging as a key driver of efficiency. While these findings reinforce the importance of lean systems in reducing operational inefficiencies, they focus primarily on financial and operational metrics without addressing environmental outcomes such as waste reduction and emissions.

In a broader manufacturing context, Nimeh et al. (2018) found that lean supply chain practices significantly improve supply chain and market performance by enhancing coordination, reducing waste, and improving responsiveness. These findings suggest that lean systems can indirectly contribute to environmental performance by minimizing non-value-adding activities and reducing resource consumption. However, the study does not explicitly measure environmental impacts, making it difficult to establish a direct relationship between lean stock holding and sustainability outcomes. Nyile (2023) provides additional insights by demonstrating that lean-oriented supply chain practices improve performance in resource-constrained environments through enhanced responsiveness and efficiency. Although the study is based in a humanitarian context, its findings highlight the importance of efficient stock management in minimizing waste and improving system performance. Nevertheless, the contextual differences between humanitarian operations and commercial manufacturing limit the direct applicability of these findings to the food and beverage sector.

A broader synthesis of lean supply chain literature further underscores the importance of lean practices in improving organizational performance. Khawka et al. (2024) identified key lean practices such as inventory optimization, information sharing, and logistics coordination as critical drivers of competitive advantage. While their review provides valuable theoretical insights, it remains largely conceptual and lacks empirical validation at the firm level. Moreover, the study does not explicitly link lean practices to environmental performance, reinforcing the observation that most lean research prioritizes efficiency and cost reduction over sustainability outcomes. This

highlights a critical gap in the literature, as lean stock holding inherently involves reducing excess inventory and waste, which are directly related to environmental performance.

A critical evaluation of the empirical literature reveals several overarching gaps that justify the need for this study. First, there is a strong bias toward studies conducted in developed economies, where advanced infrastructure and technological capabilities support the implementation of circular and lean practices. This limits the transferability of findings to developing contexts such as Kenya, where infrastructural constraints and resource limitations significantly influence inventory management practices. Second, much of the existing research adopts a broad supply chain perspective without isolating inventory-specific practices such as shelf-life extension and lean stock holding as key determinants of environmental performance. As a result, the specific contribution of these practices remains underexplored. Third, there is a notable lack of empirical studies that directly measure environmental performance outcomes in relation to inventory practices. While many studies infer environmental benefits from improved efficiency, few explicitly quantify impacts such as waste reduction, emissions, and resource utilization. Fourth, methodological limitations such as cross-sectional designs and reliance on single-case studies reduce the ability to generalize findings and establish causal relationships.

2.3 Conceptual framework

A conceptual framework provides a structured representation of the variables under investigation and the hypothesized relationships among them. It serves as a visual and theoretical guide that links the independent variables to the dependent variable, offering clarity on how specific constructs interact to influence research outcomes. In the context of this study, the framework illustrates how selected circular inventory management practices shelf-life extension and lean stock holding are expected to influence environmental performance within Kenya's food and beverage manufacturing sector. These relationships are informed by established theoretical perspectives and grounded in both global and local empirical evidence. Conceptual framework is presented in figure 1.

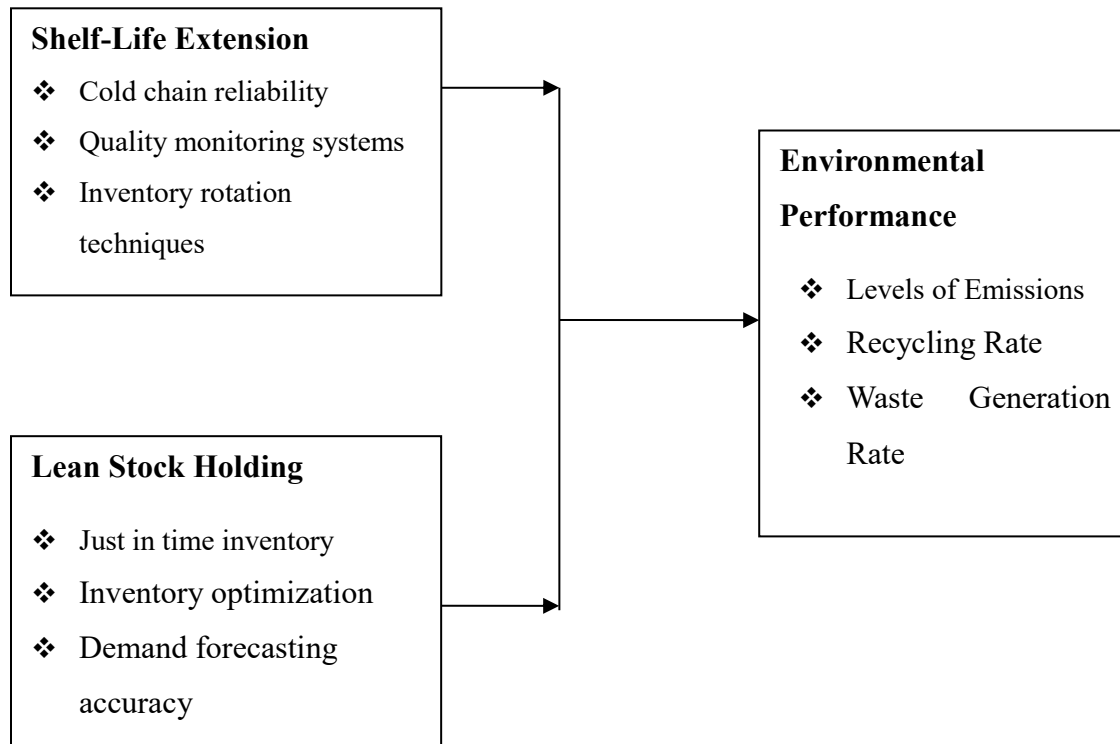


Figure 1: Conceptual framework

3. Research Methodology

This study adopted a descriptive research design to provide a structured and systematic approach for examining the relationship between inventory management practices and environmental performance. A research design serves as a blueprint that guides data collection, measurement, and analysis to ensure that the research problem is addressed effectively and objectively. Descriptive research was considered appropriate because it allows for the observation and analysis of phenomena as they occur naturally without manipulation of variables. This approach enabled the study to capture real-world practices, perceptions, and relationships among variables within food and beverage manufacturing firms in Kenya. By focusing on existing operational conditions, the design facilitated a comprehensive understanding of how shelf-life extension and lean stock holding influence environmental performance .

The target population comprised food and beverage manufacturing firms in Kenya listed by the Kenya Association of Manufacturers, totaling 329 firms. This sector was selected due to its significant contribution to industrial output and its exposure to environmental challenges related to waste generation and resource consumption. A sampling frame derived from this population provided a complete and reliable basis for selecting study units. Using Yamane's formula with a 5% margin of error, a sample size of 181 firms was determined. The unit of observation was supply

chain managers or their equivalents, given their direct involvement in inventory-related decision-making. To ensure representativeness and minimize bias, the study employed simple random sampling, allowing each firm an equal probability of selection. This approach enhanced the generalizability of the findings and supported the validity of subsequent statistical analysis.

Primary data were collected using a structured questionnaire designed to capture information on shelf-life extension, lean stock holding, and environmental performance. The questionnaire incorporated closed-ended items measured on a five-point Likert scale to facilitate quantification and statistical analysis, alongside a few open-ended questions to capture additional insights. Questionnaires were distributed both electronically and physically to accommodate variations in technological access across firms. This method was selected due to its efficiency in collecting standardized data from a relatively large and geographically dispersed sample. Data collection was supported by research assistants, and follow-up strategies such as reminder emails and phone calls were employed to improve response rates and ensure completeness of responses.

To enhance the quality of the research instrument, a pilot study was conducted involving approximately 10% of the sample, equivalent to 19 respondents. The pilot phase enabled the identification and correction of ambiguities, ensuring clarity and relevance of questionnaire items. Reliability of the instrument was assessed using Cronbach's Alpha, with a threshold of 0.70 indicating acceptable internal consistency. Validity was ensured through expert review, where specialists evaluated the instrument for content adequacy and alignment with the study objectives. Construct validity was achieved by linking questionnaire items to the theoretical constructs under investigation, ensuring accurate measurement of the variables.

Data analysis involved both qualitative and quantitative techniques. Qualitative responses from open-ended questions were analyzed thematically to identify recurring patterns and insights. Quantitative data were processed using the Statistical Package for Social Sciences (SPSS), where descriptive statistics such as means, frequencies, and standard deviations were used to summarize the data. Inferential analysis was conducted using correlation and multiple regression techniques to examine the relationships between the independent variables and environmental performance. Correlation analysis assessed the strength and direction of relationships, while regression analysis determined the extent to which shelf-life extension and lean stock holding influenced environmental outcomes. The results were presented using tables and charts to enhance clarity and interpretation.

The model for the study was:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

Where:

Y =Environmental Performance

X_1 = Shelf-Life Extension X_2 = Lean stock Holding β_0 = Constant β_1 – β_2 = Beta Coefficients ε = Error Term

4. Findings and Discussion

This chapter presents the findings of the study alongside analysis and discussion of the data collected on shelf-life extension, lean stock holding, and environmental performance among food and beverage manufacturing firms in Kenya. It begins by examining the response rate to assess the adequacy and reliability of the data obtained. Subsequently, the chapter outlines the results of the pilot study conducted to evaluate the reliability and validity of the research instrument. It also provides an analysis of the demographic characteristics of respondents, followed by descriptive statistics that summarize the key study variables. Further, inferential statistical techniques, including correlation and regression analysis, are applied to establish the relationships between shelf-life extension, lean stock holding, and environmental performance. The findings are presented in tables and interpreted in line with the study objectives.

A total of 181 questionnaires were administered to supply chain managers and relevant personnel within the selected firms. Out of these, 153 were properly completed and returned, resulting in a response rate of 84.7%, while 28 questionnaires were either not returned or incomplete, representing a non-response rate of 15.3%. As shown in Table 4.1, the achieved response rate is considered adequate for statistical analysis. A response rate above 70% is generally regarded as sufficient for minimizing non-response bias and ensuring reliability of findings, thereby confirming that the data collected was appropriate for subsequent analysis and interpretation.

Table 1: Response rate

Category	Frequency	Percent
Response	153	84.7
Non-response	28	15.3
Total	181	100

4.1 Descriptive Findings for Shelf-Life Extension

Shelf-life extension practices are a critical component of circular inventory management, particularly in the food and beverage manufacturing sector where products are highly perishable.

Effective shelf-life management enables firms to minimize spoilage, enhance inventory efficiency, and reduce environmental waste associated with expired products. The study examined the extent to which firms in Kenya adopt these practices.

Table 1: Descriptive Findings for shelf-life extension

Statement	SD	D	N	A	SA	Mean	SD
Our firm uses reliable cold chain systems to extend product shelf life	2.0%	6.5%	17.0%	41.2%	33.3%	3.97	0.97
We rely on accurate demand forecasting to manage inventory shelf life	2.0%	2.6%	9.8%	51.0%	34.6%	4.14	0.84
First-In-First-Out (FIFO) is practiced to minimize spoilage	3.3%	5.2%	17.0%	39.2%	35.3%	3.98	1.02
Packaging and storage methods help preserve product quality	0.7%	4.6%	9.8%	47.7%	37.3%	4.16	0.83
Technological tools are used to monitor product freshness and expiry	2.0%	7.8%	12.4%	45.1%	32.7%	3.99	0.97
Shelf-life extension helps reduce inventory-related waste	0.7%	3.3%	14.4%	47.1%	34.6%	4.12	0.82
Shelf-life practices align with environmental sustainability targets	0.0%	4.6%	9.8%	52.9%	32.7%	4.14	0.77

The results presented in Table 1 indicate that shelf-life extension practices are widely implemented among food and beverage manufacturing firms in Kenya, with mean scores ranging between 3.97 and 4.16. These values suggest strong agreement among respondents that their firms actively adopt strategies aimed at prolonging product usability and minimizing spoilage. The relatively low standard deviations, ranging from 0.77 to 1.02, indicate consistency in responses, suggesting that shelf-life management is becoming a standardized operational practice within the sector.

The use of reliable cold chain systems recorded a mean score of 3.97 with a standard deviation of 0.97, indicating that most firms rely on temperature-controlled storage and transportation to preserve product quality. However, the variability in responses suggests that some firms may still face infrastructural limitations. Demand forecasting practices recorded a higher mean of 4.14 and a lower standard deviation of 0.84, demonstrating strong agreement and consistency that accurate forecasting plays a key role in managing inventory shelf life. This highlights the importance of aligning production with demand to reduce excess inventory and spoilage.

The use of FIFO inventory systems recorded a mean of 3.98 with a standard deviation of 1.02, indicating moderate variability in implementation across firms. This suggests that while FIFO is

widely recognized as an essential inventory control method, its application may differ depending on operational capacity. Packaging and storage practices recorded the highest mean score of 4.16 with a standard deviation of 0.83, indicating strong consensus that appropriate packaging and storage conditions are critical for preserving product quality and extending shelf life.

The use of technological tools to monitor product freshness and expiry recorded a mean score of 3.99 with a standard deviation of 0.97, reflecting growing adoption of digital inventory monitoring systems. Similarly, respondents strongly agreed that shelf-life extension reduces inventory-related waste, as indicated by a mean of 4.12 and a standard deviation of 0.82. The alignment of shelf-life practices with environmental sustainability targets also recorded a high mean of 4.14 with the lowest variability (0.77), suggesting strong agreement that these practices contribute to broader environmental objectives.

These findings align with Bacenetti et al. (2018), who found that extending shelf life significantly reduces environmental impacts by minimizing product losses across supply chains. Falcone et al. (2017) similarly demonstrated that shelf-life extension technologies reduce waste even when production inputs slightly increase. The results are further supported by Villanova-Estors et al. (2024), who showed that advanced packaging reduces food waste and emissions, while Reyes et al. (2024) emphasized the role of digital tools in enhancing shelf-life management and sustainability outcomes.

Qualitative responses revealed that firms rely on cold chain systems, FIFO practices, and improved packaging technologies to extend product usability. However, challenges such as unreliable electricity supply, high energy costs, and limited access to advanced technologies were identified as barriers. Respondents emphasized the need for investment in cold chain infrastructure, digital monitoring systems, and staff training. Overall, while shelf-life extension is widely adopted, its effectiveness depends on strengthening infrastructure, technological capacity, and supply chain coordination.

4.2 Descriptive Findings for Lean Stock Holding

Lean stock holding is a key component of circular inventory management that focuses on minimizing excess inventory while maintaining operational efficiency. In the food and beverage sector, where products are highly perishable, lean practices are essential in reducing spoilage, lowering storage costs, and improving resource utilization. The study assessed the extent to which firms in Kenya implement lean stock holding practices.

Table 2: Descriptive statistics on lean stockholding

Statement	SD	D	N	A	SA	Mean	SD
We practice Just-in-Time (JIT) inventory to avoid overstocking	3.9%	5.2%	13.7%	35.9%	41.2%	4.05	1.06
Inventory levels are optimized to reduce waste and costs	1.3%	3.3%	15.7%	41.2%	38.6%	4.12	0.88
Value stream mapping is used to identify inefficiencies in our inventory processes	2.0%	2.6%	16.3%	43.8%	35.3%	4.08	0.89
Inventory decisions are guided by real-time data and demand signals	3.9%	5.9%	9.2%	41.8%	39.2%	4.07	1.04
We regularly monitor and reduce obsolete or slow-moving stock	3.9%	3.9%	15.0%	41.8%	35.3%	4.01	1.01
Lean inventory contributes to reduced environmental impact	0.7%	5.2%	10.5%	49.0%	34.6%	4.12	0.84
Our lean inventory practices have improved operational efficiency	2.6%	2.6%	9.8%	50.3%	34.6%	4.12	0.88

The results presented in Table 2 indicate that lean stock holding practices are widely adopted among food and beverage manufacturing firms in Kenya, with mean scores ranging between 4.01 and 4.12. These values reflect strong agreement among respondents that lean inventory strategies are actively applied within their organizations. The standard deviations, ranging from 0.84 to 1.06, indicate relatively consistent responses across firms, although some variation exists in specific practices. Overall, the findings suggest that lean inventory management is increasingly recognized as an important strategy for improving both operational efficiency and environmental sustainability.

The adoption of Just-in-Time (JIT) inventory systems recorded a mean score of 4.05 with a standard deviation of 1.06, indicating that most firms use JIT practices to align inventory levels with demand and production requirements. However, the relatively higher variability suggests differences in implementation, likely influenced by supply chain reliability and supplier coordination. Inventory optimization practices recorded a higher mean of 4.12 with a standard deviation of 0.88, demonstrating strong agreement that firms actively manage inventory levels to reduce waste and operational costs. This indicates that inventory control is increasingly being treated as a strategic function within organizations.

The use of value stream mapping to identify inefficiencies recorded a mean of 4.08 with a standard deviation of 0.89, suggesting that firms are adopting process improvement tools to enhance inventory flow and eliminate bottlenecks. Similarly, inventory decisions guided by real-time data

and demand signals recorded a mean of 4.07 and a standard deviation of 1.04, reflecting growing reliance on information systems and data analytics to support inventory planning. Monitoring and reducing obsolete or slow-moving stock recorded a mean score of 4.01 with a standard deviation of 1.01, indicating that firms are actively managing aging inventory, although implementation varies across organizations.

Lean inventory practices were also strongly associated with environmental and operational benefits. The perception that lean stock holding contributes to reduced environmental impact recorded a mean score of 4.12 with a standard deviation of 0.84, while the statement that lean practices improve operational efficiency also recorded a mean of 4.12 with a standard deviation of 0.88. These results suggest that firms recognize the dual benefits of lean inventory systems in enhancing efficiency and reducing waste. The findings are consistent with Wainaina and Odari (2023), who found that lean practices significantly improve operational performance. Similarly, Odoyo and Arasa (2020) demonstrated that lean inventory systems such as JIT enhance efficiency and reduce waste.

The results also align with findings by Nimeh et al. (2018), who established that lean supply chain practices improve performance and competitiveness in manufacturing firms. Nyile (2023) further emphasized that lean-oriented strategies enhance responsiveness and efficiency in resource-constrained environments, while Khawka et al. (2024) identified lean inventory optimization as a key driver of competitive advantage. These studies support the current findings that lean stock holding contributes significantly to both operational performance and environmental sustainability.

Qualitative responses revealed that while lean practices are widely adopted, several challenges affect their effectiveness. Respondents highlighted supply chain disruptions and unreliable supplier deliveries as key barriers, particularly because lean systems operate with minimal inventory buffers. Limited technological infrastructure and partial reliance on manual systems were also identified as constraints to real-time decision-making. Additionally, fluctuations in demand and internal coordination challenges were noted as factors that complicate lean implementation.

4.3 Correlation analysis

Correlation analysis was conducted to determine the strength and direction of the relationship between shelf-life extension, lean stock holding, and environmental performance among food and beverage manufacturing firms in Kenya. Pearson's product-moment correlation coefficient (r) was used, with values ranging from -1 to +1, where values closer to +1 indicate strong positive relationships. This analysis provides preliminary insights into the association between variables before regression analysis.

Table 3: Correlation analysis

		Shelf-life extension	Lean stock holding	Environmental Performance
Shelf-life extension	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	153		
Lean stockholding	Pearson Correlation	.373**	1	
	Sig. (2-tailed)	.000		
	N	153	153	
Environmental Performance	Pearson Correlation	.552**	.583**	1
	Sig. (2-tailed)	.000	.000	
	N	153	153	153

The results indicate that shelf-life extension and lean stock holding are positively and significantly related, with a correlation coefficient of $r = 0.373$ ($p < 0.01$). This suggests a moderate positive relationship, implying that firms that actively implement shelf-life extension practices are also likely to adopt lean stock holding strategies. The relationship indicates that these two practices are complementary in nature, as both aim to reduce waste and improve inventory efficiency. Firms that invest in extending product usability through better storage, packaging, and forecasting are also inclined to optimize inventory levels to avoid overstocking and spoilage.

Further analysis shows that shelf-life extension has a strong positive and statistically significant relationship with environmental performance, with a correlation coefficient of $r = 0.552$ ($p < 0.01$). This indicates that improvements in shelf-life management are associated with better environmental outcomes. The strength of this relationship suggests that practices such as cold chain management, effective inventory rotation, and demand forecasting play a significant role in reducing product spoilage and minimizing waste. These findings support previous studies which show that extending product shelf life reduces environmental impacts by lowering food waste and associated emissions. The results therefore confirm that shelf-life extension is a key driver of environmental sustainability within the food and beverage manufacturing sector.

Similarly, lean stock holding recorded a strong positive and statistically significant relationship with environmental performance, with a correlation coefficient of $r = 0.583$ ($p < 0.01$). This indicates that firms implementing lean inventory practices tend to achieve improved environmental outcomes. The relatively higher correlation compared to shelf-life extension suggests that lean stock holding may have a slightly stronger influence on environmental performance. By

minimizing excess inventory, reducing obsolescence, and improving resource utilization, lean practices directly contribute to lower waste generation and reduced environmental impact.

4.4 Regression Analysis

Multiple linear regression analysis was conducted to examine the combined effect of shelf-life extension and lean stock holding on environmental performance among food and beverage manufacturing firms in Kenya. This approach allows simultaneous assessment of the two predictor variables while controlling for their individual effects, thereby providing a clearer understanding of their relative and joint contributions to environmental outcomes.

Table 4: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.673	0.453	0.445	3.81

a. Predictors: (Constant), shelf-life extension, lean stock

The model summary indicates an R value of 0.673, suggesting a strong positive relationship between shelf-life extension, lean stock holding, and environmental performance. The R Square value of 0.453 implies that approximately 45.3% of the variation in environmental performance is explained by the two variables. This demonstrates substantial explanatory power, confirming that inventory-specific practices play a significant role in influencing environmental outcomes. The adjusted R Square of 0.445 shows minimal shrinkage, indicating that the model is stable and reliable even after adjusting for the number of predictors.

Table 5: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1842.615	2	921.308	62.255	.000 ^b
	Residual	2219.856	150	14.799		
	Total	4062.471	152			

a. Dependent Variable: Environmental Performance

b. Predictors: (Constant), Returns management, Shelf-life tracking

The ANOVA results indicate that the regression model is statistically significant, with an F-statistic of 62.255 and $p = 0.000$, which is well below the 0.05 threshold. This confirms that shelf-life extension and lean stock holding jointly have a significant effect on environmental performance. The model is therefore suitable for explaining the relationship between the selected inventory practices and environmental outcomes.

Table 6: Regression coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.114	5.621		5.002	.000
	Shelf-life tracking	.221	.109	.158	2.028	0.044
	Lean stockholding	.401	.108	.274	3.713	0.000

a. Dependent Variable: Environmental Performance

The results indicate that lean stock holding has the strongest influence on environmental performance, with a standardized beta coefficient of $\beta = 0.274$, a t-value of 3.713, and $p = 0.000$. The unstandardized coefficient ($B = 0.401$) implies that a one-unit improvement in lean stock holding leads to a 0.401-unit increase in environmental performance, holding other factors constant. This suggests that practices such as Just-in-Time systems, inventory optimization, and reduction of obsolete stock significantly contribute to waste reduction and improved resource efficiency. These findings align with Odoyo and Arasa (2020), who found that lean inventory systems enhance efficiency and reduce waste, as well as Wainaina and Odari (2023), who reported improved operational performance through lean practices.

Shelf-life extension also demonstrates a positive and statistically significant effect, with $\beta = 0.158$, $t = 2.028$, and $p = 0.044$. The unstandardized coefficient ($B = 0.221$) indicates that a one-unit increase in shelf-life extension practices results in a 0.221-unit improvement in environmental performance. This confirms that practices such as cold chain management, improved packaging, and demand forecasting contribute to reducing spoilage and minimizing environmental waste. These findings are consistent with Bacenetti et al. (2018), who showed that extending shelf life reduces environmental impacts, and Falcone et al. (2017), who demonstrated that shelf-life technologies significantly lower product losses.

5. Conclusion

This study examined the effect of shelf-life extension and lean stock holding on environmental performance among food and beverage manufacturing firms in Kenya. Based on the findings from descriptive, qualitative, correlation, and regression analyses, the study concludes that both practices play a significant and positive role in enhancing environmental sustainability within the sector. The results demonstrate that firms adopting these inventory management strategies are better positioned to reduce waste, improve resource efficiency, and achieve improved environmental outcomes.

The study concludes that shelf-life extension is a critical practice in improving environmental performance. Firms that invest in reliable cold chain systems, adopt effective demand forecasting, implement proper inventory rotation techniques such as FIFO, and utilize improved packaging

technologies are able to significantly reduce product spoilage and waste. By extending product usability, firms minimize losses associated with expired products and enhance overall resource utilization. The statistical findings confirmed that shelf-life extension has a positive and significant influence on environmental performance, indicating that improved shelf-life management directly contributes to sustainability outcomes within food and beverage manufacturing operations.

The study further concludes that lean stock holding has a strong and significant effect on environmental performance, with results indicating a relatively stronger influence compared to shelf-life extension. Firms that adopt lean inventory practices such as Just-in-Time systems, real-time inventory monitoring, and reduction of obsolete stock are able to minimize excess inventory and reduce waste generation. Lean practices enhance operational efficiency by ensuring that inventory levels are aligned with actual demand, thereby preventing overproduction and unnecessary storage. The findings confirm that efficient inventory control systems are essential in reducing environmental impact through improved resource utilization and waste minimization.

6. Recommendations

Based on the findings and conclusions of this study, several recommendations are proposed to enhance the adoption of shelf-life extension and lean stock holding practices in order to improve environmental performance among food and beverage manufacturing firms in Kenya.

Firms should prioritize investment in shelf-life extension practices to reduce product spoilage and environmental waste. This includes strengthening cold chain infrastructure through reliable temperature-controlled storage and transportation systems to maintain product quality throughout the supply chain. Organizations should also adopt advanced packaging technologies such as vacuum packaging and modified atmosphere packaging to enhance product preservation. In addition, firms should improve demand forecasting systems to ensure production aligns with market demand, thereby reducing excess inventory that may lead to expiration. Strengthening inventory monitoring systems, including digital tools for tracking product freshness and expiry dates, will further enhance shelf-life management and minimize waste.

Manufacturing firms should also strengthen the implementation of lean stock holding practices to improve efficiency and reduce environmental impact. Organizations should adopt Just-in-Time inventory systems to maintain optimal stock levels and avoid overstocking. This should be supported by real-time inventory monitoring and data-driven decision-making systems that enhance responsiveness to demand fluctuations. Firms should invest in integrated inventory management systems and data analytics tools to improve inventory visibility and coordination across supply chain functions.

In addition, firms should strengthen collaboration with suppliers and logistics partners to ensure timely and reliable delivery of inputs. Effective supplier coordination is essential for the successful implementation of lean inventory systems, as disruptions can lead to stock shortages or

inefficiencies. Organizations should also promote continuous process improvement by adopting tools such as value stream mapping to identify and eliminate inefficiencies in inventory processes.

Finally, firms should invest in employee training and capacity building to enhance understanding and implementation of both shelf-life extension and lean inventory practices. Skilled personnel are essential for managing inventory systems effectively and ensuring adherence to best practices. Policymakers can support these efforts by promoting investment in cold chain infrastructure and digital technologies through incentives and supportive regulatory frameworks. Overall, adopting these strategies will enable firms to improve environmental sustainability while enhancing operational efficiency.

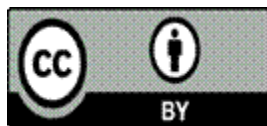
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