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Influence of Cold Chain Management on Supply Chain Performance in the Kenya Horticultural Export Sector

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Abstract

The study sought to establish the influence of cold chain management on supply chain performance in Kenya horticultural export sector. It was guided by three objectives: to assess the influence of cold chain infrastructure, to examine the role of temperature control, and to determine the effect of cold chain personnel on supply chain performance. A descriptive research design was adopted, and data were collected from key stakeholders in the horticultural export sector. The findings revealed that cold chain infrastructure ($r = 0.712$, $p < 0.05$), temperature control ($r = 0.728$, $p < 0.05$), and cold chain personnel competence ($r = 0.693$, $p < 0.05$) all had significant positive effects on supply chain performance. Collectively, the three variables explained 64.2% of the variation in supply chain performance ($R^2 = 0.642$). The study concluded that investing in modern infrastructure, ensuring effective temperature regulation, and enhancing personnel skills are critical in improving efficiency and competitiveness in horticultural exports. It recommended that exporters strengthen cold chain facilities, adopt advanced monitoring technologies, and prioritize staff training to minimize postharvest losses and enhance global market competitiveness.

Key Words: Cold Chain Management, Horticultural Exports, Supply Chain Performance, Temperature Control, Cold Chain Infrastructure

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1. Introduction

Cold chain management has emerged as a pivotal element in shaping the performance of supply chains within the horticultural export sector. This concept broadly refers to the coordinated management of temperature sensitive products through an uninterrupted series of refrigerated production, storage, and distribution activities that maintain optimal conditions until final consumption. In horticultural exports, where products like fresh fruits, vegetables, and flowers are highly perishable, cold chain systems ensure product quality, safety, and extended shelf life while meeting stringent international market standards. Effective cold chain logistics reduce spoilage and waste, enhance customer satisfaction, and strengthen competitiveness in export markets, particularly as consumers increasingly demand premium quality and traceability (Sotelo et al., 2021). Consequently, the ability of exporters to develop robust cold chain infrastructure has become directly linked to supply

chain performance indicators, including delivery reliability, inventory turnover, and overall profitability (Ndraha et al., 2023).

In the Netherlands, widely recognized as a global leader in horticultural exports, cold chain management has become a sophisticated system combining automation, advanced temperature monitoring, and multimodal transport integration. Dutch exporters leverage high capacity refrigerated warehouses near Schiphol Airport and Rotterdam Port to maintain consistent cold temperatures and reduce handling times, thereby ensuring flowers and fresh produce reach global markets in optimal condition. However, increasing energy costs and stricter environmental regulations around refrigerant gases have driven firms to adopt innovative sustainable cooling technologies, such as carbon dioxide based refrigeration, to maintain competitiveness while meeting environmental targets (Stellenboom et al., 2022). These cold chain innovations directly support supply chain performance by improving order fulfillment rates and reducing product rejection due to spoilage (Munir et al., 2021).

South Africa's horticultural exports, particularly citrus and table grapes, rely heavily on advanced cold chain management practices to access European and Asian markets. South African exporters employ cold sterilization treatments to meet phytosanitary standards, supported by modern containerized cold storage at the Port of Cape Town (Louw et al., 2017). Nevertheless, the sector continues to face energy supply disruptions and port congestion, which can compromise cold chain integrity and delay shipments, eroding trust with international buyers and affecting supply chain reliability (Chikozho et al., 2021).

In Ghana, emerging horticultural exports including pineapples and mangoes often suffer from inadequate cold chain infrastructure, which increases postharvest losses and limits market access. Donor supported initiatives have piloted solar powered cold rooms and mobile cooling solutions to extend shelf life and reduce wastage (Ambaw et al., 2022). While promising, these efforts require scaling and integration into national logistics networks to significantly improve horticultural supply chain outcomes (Kitinoja & Kader, 2023).

Kenya's horticulture export sector remains the country's second-largest foreign exchange earner after tea, with export revenues touching approximately KShs 157 billion (around $1.21 billion) in 2023, before dipping to KShs 137 billion (~$1.06 billion) in 2024. The downturn stems largely from decreased export volumes of vegetables volumes to the EU plunged by 54.7% from 164,100 t to 74,300 t and from logistical disruptions tied to inflation, currency fluctuations, and the Red Sea crisis. These dynamics have strained farm incomes and reduced competitiveness, as rising costs push buyers toward cheaper regional suppliers (Ministry of Trade and Industrialization, 2023).

1.2 Statement of the Problem

The Kenyan horticultural export sector, which employs over six million people across production, logistics, and export operations and contributed approximately Kshs 153 billion to the economy in 2022 (Horticultural Crops Directorate, 2023), faces persistent challenges in cold chain management that have significantly weakened supply chain performance. Despite Kenya's strong market position as Africa's leading exporter of cut flowers and

vegetables, recent data show that up to 40% of fresh produce destined for export is lost to post-harvest spoilage (Ministry of Trade and Industrialization, 2023). These losses not only erode revenue for farmers and exporters but also jeopardize Kenya's reputation as a reliable supplier to premium international markets.

In addition to infrastructure deficiencies, the sector faces a critical shortage of trained cold chain personnel, with more than 60% lacking formal training in temperature-sensitive logistics. This has resulted in improper equipment handling, inconsistent monitoring, and non-compliance with international quality standards. Temperature control remains a major challenge, with minor deviations causing significant reductions in product shelf life, leading to increased rejection rates and financial losses. As export volumes continue to grow against constrained cold chain capacity, and global market requirements become more stringent, Kenya risks losing its competitive edge to regional rivals unless urgent measures are taken (Kitinoja & Kader, 2023).

This problem statement highlights the urgent need for a comprehensive strategy to improve cold chain infrastructure, develop skilled human resources, and strengthen temperature control throughout the supply chain. The ultimate goal is to reduce post-harvest losses, enhance compliance with international standards, and sustainably improve the supply chain performance of Kenya's horticulture export sector, securing livelihoods and maintaining national competitiveness.

1.3 Objective of the Study

General Objective

To establish the influence of cold chain management on supply chain performance in the Kenya horticultural export sector.

Specific Objectives

i. To assess the influence of cold chain infrastructure on supply chain performance in the Kenya horticultural export sector.
ii. To examine the influence of temperature control on supply chain performance in the Kenya horticultural export sector.
iii. To determine the influence of cold chain personnel on supply chain performance in the Kenya horticultural export sector.

1.4 Hypothesis of the Study

The study will be guided by the following hypotheses

H_{01} There is no significant statistical influence of cold chain infrastructure on supply chain performance in the Kenya horticultural export sector.

H_{02} There is no significant statistical influence of temperature control on supply chain performance in the Kenya horticultural export sector.

H_{03} There is no significant statistical influence of cold chain personnel on supply chain performance in the Kenya horticultural export sector.

1.5 Significance of the Study

This study is significant to Kenyan horticultural export sector as it provides practical insights into how cold chain infrastructure, skilled personnel, and temperature control systems influence supply chain performance, helping exporters reduce post-harvest losses, improve product quality, and meet international standards. It offers valuable guidance to government agencies in identifying policy gaps and designing targeted incentives, infrastructure investments, and training programs. Stakeholders such as logistics providers, cold storage firms, and farmer cooperatives can use the findings to align operations with quality and delivery requirements, while policymakers gain evidence to shape effective regulatory frameworks. Additionally, the study serves as a foundation for future academic research on cold chain systems and export logistics in Kenya and beyond.

1.6 Scope of the Study

This study focused on examining the influence of cold chain management on the supply chain performance of the horticultural export sector in Kenya. It specifically narrowed down to three core components of cold chain management: cold chain infrastructure, cold chain personnel, and temperature control. These variables were selected due to their critical role in maintaining product integrity and ensuring timely delivery of horticultural produce to international markets.

Geographically, the study concentrated on key horticultural exporting regions in Kenya, including areas such as Naivasha, Thika, Meru, and parts of the Rift Valley, where a majority of export-oriented floriculture and fresh produce farms are located. These regions were selected due to their established linkages with global markets and reliance on cold chain logistics to meet international quality standards.

2. Literature Review

2.1 Theoretical Framework

Systems Theory

Systems Theory, first introduced by Ludwig von Bertalanffy in the 1950s and later adapted to organizational management by Katz and Kahn (1966), views an organization as a cohesive system of interdependent subsystems working toward a common goal. In recent years, the theory has been expanded and applied to supply chain logistics by scholars such as Lambert and Cooper (2022), who emphasized the importance of coordination, integration, and feedback loops in maintaining system efficiency. This theoretical lens is particularly relevant to cold chain management in the Kenyan horticulture export sector, where the performance

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of the supply chain depends on the seamless interaction of key elements like infrastructure, personnel, and temperature control.

The theory's significance to this study lies in its ability to explain how inefficiencies in one component of the cold chain, such as delays in temperature regulation or gaps in personnel training can negatively impact the entire system, leading to product losses, increased costs, and reduced customer satisfaction (Githinji & Njeru, 2023). Cold chain infrastructure acts as the physical backbone of the system, personnel provide the human expertise to manage operations, and temperature control ensures quality is maintained during transit. When viewed through Systems Theory, these variables are not isolated; they operate in a tightly linked network where real-time data, responsive actions, and effective communication are essential (Kimani & Mwangi, 2024).

2.2 Conceptual Framework

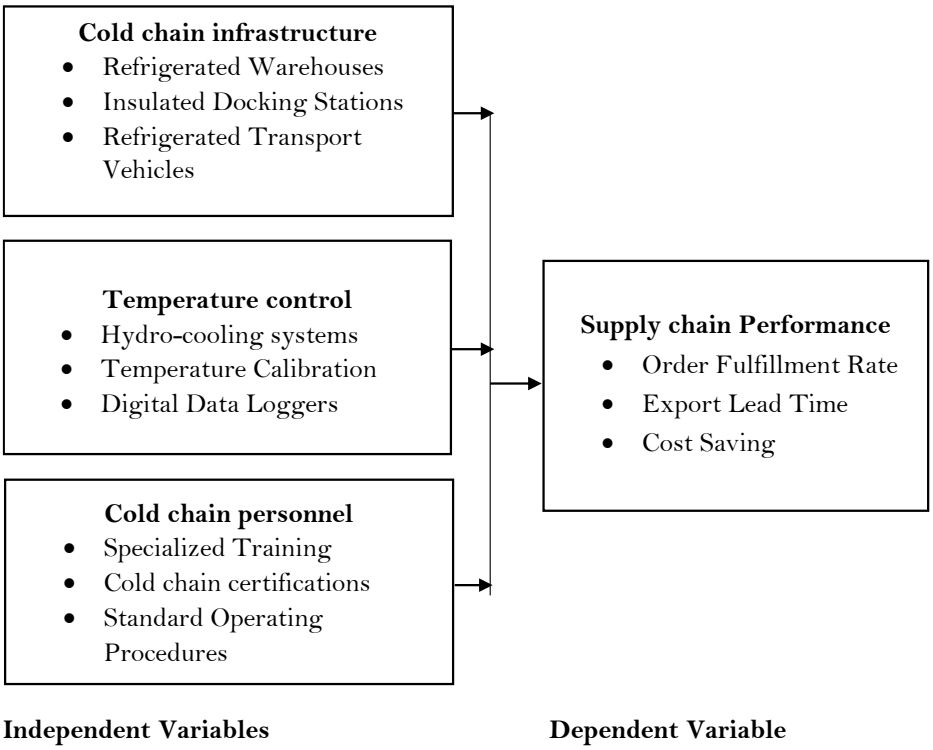

Figure 1: Conceptual Framework

2.3 Review of Literature on Study Variables

This section presents a review of literature on study variables.

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Cold Chain Infrastructure

Cold chain infrastructure plays a central role in the efficiency and reliability of horticultural export supply chains, particularly in economies that rely on the export of perishable goods. In Kenya, the absence of adequate infrastructure such as pre-cooling facilities at farms, refrigerated trucks, and cold storage at exit points continues to undermine the quality of exports. Reports from the Horticultural Crops Directorate (2023) reveal that less than 30% of horticultural exporters have access to modern cold rooms and that most smallholder farmers lack pre-cooling units, which results in the deterioration of produce before it reaches packaging centers. These infrastructural limitations cause delays, high rejection rates, and loss of market credibility (Horticultural Crops Directorate, 2023).

Cold Chain Personnel

Skilled cold chain personnel are essential to the smooth operation and maintenance of temperature-sensitive logistics systems. In Kenya's horticultural export sector, many postharvest losses are linked to human errors caused by untrained or underqualified handlers. According to a study by Ambaw et al. (2022), over 60% of cold chain workers lack formal training in refrigeration, handling protocols, and temperature monitoring, which leads to mishandling of sensitive commodities and equipment failures. The absence of specialized personnel, particularly at farm and transport levels, results in breakdowns in the cold chain and reduces the ability to maintain export-grade quality.

Personnel competence directly influences how efficiently infrastructure is used and maintained. Even with adequate cold chain infrastructure in place, poorly trained staff often fail to correctly operate cooling equipment, calibrate temperatures, or detect system malfunctions. This has led to recurring issues such as ethylene exposure in fresh produce or microbial contamination due to temperature fluctuation. When staff are well-trained, exporters report lower product rejections and faster customs clearance since temperature logs and quality certifications are properly managed (Kitinoja & Kader, 2022). Thus, human capital is as vital as physical infrastructure in enhancing supply chain performance.

Temperature Control

Temperature control is a foundational element of cold chain management and a determinant of product shelf life, market acceptability, and overall export value. In Kenya, horticultural products such as French beans, snow peas, avocados, and cut flowers are highly sensitive to temperature fluctuations. A deviation of just 2–4°C during transport can reduce the shelf life of fresh produce by 30–50% (Kitinoja & Kader, 2022). Yet, many transporters and handling centers in Kenya lack real time temperature monitoring systems, making it difficult to detect or correct excursions in time, leading to product spoilage and increased waste.

The impact of poor temperature control extends across the entire supply chain. In-transit losses, temperature abuse during customs clearance, and delayed loading at cargo airports are among the leading causes of product rejection. According to the Horticultural

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Crops Directorate (2023), over 38% of horticultural export losses in 2022 were linked to temperature-related issues. These problems severely affect the reliability of Kenya's horticultural supply chain, resulting in financial losses, delayed payments, and strained relationships with international buyers (Ministry of Trade and Industrialization, 2023).

Supply Chain Performance in the Horticultural Export Sector

Supply chain performance in the horticultural export sector refers to the effectiveness, efficiency, and responsiveness of the processes involved in delivering perishable products to end markets. In Kenya, this performance is assessed using metrics such as order fulfillment rates, delivery timeliness, inventory turnover, and product rejection levels. The sector's supply chain is particularly vulnerable to breakdowns due to the perishability of goods and the fragmented nature of the export logistics network. High rejection rates, averaging 20% in some seasons, directly reduce profitability and market competitiveness (Horticultural Crops Directorate, 2023).

Improving supply chain performance requires a holistic approach that addresses cold infrastructure gaps, strengthens human capital, and modernizes quality assurance systems. Investments in digitization, capacity building, and regional cold logistics hubs will be essential to improve Kenya's competitiveness in the global horticulture trade. Without these interventions, the sector risks stagnation and loss of market share to regional rivals such as Ethiopia and Morocco, which are aggressively upgrading their supply chain ecosystems (Ambwa, 2022).

2.4 Empirical Review

The study by Aung and Chang (2022) sought to investigate how temperature control practices impact the quality and performance of perishable food supply chains globally, with horticultural products as a primary focus. The main variables examined were temperature monitoring practices (independent variable) and supply chain performance metrics such as spoilage rates and customer satisfaction (dependent variable). The researchers employed a systematic literature review and case study methodology, synthesizing evidence from multiple developed economies. The study was underpinned by the Resource-Based View theory, which positions temperature management capabilities as strategic resources. Findings revealed that advanced temperature tracking systems and integrated cold chain logistics significantly reduce spoilage and improve delivery reliability. However, the research noted a gap in empirical studies documenting these practices in developing countries like Kenya, where infrastructure and resources are limited.

Louw (2023) conducted a regional study across Sub-Saharan Africa to examine the role of cold chain infrastructure in postharvest loss reduction and supply chain efficiency. The objective was to evaluate the influence of refrigerated storage facilities and temperature-controlled transport on export performance among smallholder horticultural producers. The study applied a mixed methods approach, combining surveys of exporters and logistic providers in South Africa, Kenya, and Ghana with secondary data analysis. Transaction Cost

Economics was used as the theoretical framework to explain how cold chain investments reduce inefficiencies and costs. Results showed that limited access to cold storage increases transaction costs and loss rates by up to 35%. The research identified a gap in country specific investigations that isolate Kenyan horticultural exports to understand unique logistical constraints and supply chain dynamics.

In Kenya, Muthoni and Wangari (2020) explored how cold chain management practices affect the performance of flower export firms in Nairobi County. The study's objectives were to assess the role of cold storage capacity, staff competence in cold chain handling, and temperature monitoring technologies in influencing supply chain responsiveness and product rejection rates. The researchers used a descriptive survey research design targeting fourty export firms, collecting data through structured questionnaires. The study adopted the Theory of Constraints to explain how bottlenecks in cold chain processes limit performance. Findings indicated that firms with integrated cold chain systems had 25% lower rejection rates and significantly higher customer satisfaction. However, the authors noted a gap in research linking these cold chain practices to other horticultural exports such as fruits and vegetables.

2.5 Research Gap

The growing importance of cold chain management in enhancing the performance of horticultural export supply chains is well documented in global and regional literature. However, the empirical evidence reveals specific contextual gaps that limit the transferability of existing insights to the Kenya horticultural export sector. Most studies have either focused on developed countries, emphasized single horticultural products, or overlooked the combined effect of critical cold chain elements such as infrastructure, personnel, and temperature control on supply chain performance.

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3. Methodology

The study adopted a descriptive research design to assess the relationship between cold chain management practices specifically infrastructure, personnel, and temperature control and supply chain performance in Kenya's horticulture export sector. The target population was 215 individuals, comprising 98 supply chain managers, 100 operations personnel, 5 regulatory body officers, and 12 industry consultants. A sample size of 140 was drawn using stratified random sampling to ensure proportional representation across job functions. Data

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was collected through structured questionnaires administered both physically and electronically. A pilot study was conducted with 14 respondents to test the reliability and validity of the instrument. SPSS version 29 was used for data analysis, applying descriptive statistics to summarize responses and inferential statistics such as Pearson correlation and multiple regression, to examine the relationships between the independent variables (cold chain infrastructure, personnel, and temperature control) and the dependent variable (supply chain performance). Findings were presented in tables, charts, and graphs.

4. Results and discussion

4.1 Descriptive and Correlational Analysis

The study confirmed that cold chain management significantly influences supply chain performance in Kenya horticultural export sector.

Table 1: Correlation Results for Cold Chain Management Variables and Supply Chain Performance

Variable	Correlation Coefficient (r)	Significance (p-value)	Interpretation
Cold Chain Infrastructure	0.712	< 0.05	Strong positive, significant correlation
Cold Chain Personnel	0.693	< 0.05	Strong positive, significant correlation
Temperature Control	0.728	< 0.05	Strong positive, significant correlation
Overall Model (R^2)	0.642	—	64.2% variation explained

Correlation analysis demonstrated strong associations between the independent variables and supply chain performance. Cold chain infrastructure was strongly correlated with supply chain performance ($r = 0.712$, $p < 0.05$), indicating that investments in pre-cooling units, refrigerated transport, and cold storage reduce postharvest losses and ensure timely deliveries.

Similarly, cold chain personnel competence showed a strong correlation ($r = 0.693$, $p < 0.05$), highlighting the importance of skilled staff in adhering to temperature standards, minimizing product mishandling, and ensuring proper documentation. Trained personnel play a pivotal role in safeguarding product quality and meeting export standards.

Temperature control registered the strongest correlation with supply chain performance ($r = 0.728$, $p < 0.05$). This underscores the necessity of consistent monitoring and regulation of temperature across the supply chain, which is critical in preserving freshness, extending shelf-life, and reducing spoilage of horticultural exports.

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4.2 Regression Analysis

Table 2: Regression Coefficients for Cold Chain Management and Supply Chain Performance

Predictor	Unstandardized Coefficient (B)	Std. Error	Standardized Coefficient (Beta)	t-value	Sig. (p-value)
(Constant)	0.842	0.214	—	3.935	0.000
Cold Chain Infrastructure	0.317	0.081	0.312	3.914	0.000
Cold Chain Personnel	0.294	0.087	0.297	3.379	0.001
Temperature Control	0.365	0.079	0.384	4.620	0.000

Model Summary: $R^2 = 0.642$, Adjusted $R^2 = 0.635$, $F(3, 146) = 87.12$, $p < 0.001$

The regression analysis provides deeper insights into the relative importance of the three cold chain management dimensions in shaping supply chain performance in Kenya's horticulture export sector. The model was statistically significant ($F(3,146) = 87.12$, $p < 0.001$) and explained 64.2% of the variation in supply chain performance ($R^2 = 0.642$), indicating that cold chain infrastructure, personnel competence, and temperature control collectively play a decisive role in enhancing operational efficiency and export competitiveness.

The regression coefficients highlight that temperature control ($\beta = 0.384$, $p < 0.001$) had the strongest standardized effect on supply chain performance. This suggests that maintaining the correct temperature across all stages of the supply chain from harvesting and pre-cooling to transportation and export is the single most critical determinant of product quality and shelf life. Even with strong infrastructure, lapses in temperature regulation can result in rapid spoilage of perishable goods, leading to financial losses and reputational damage in international markets. This finding points to the need for investment in advanced monitoring technologies such as Internet of Things (IoT), enabled sensors, real-time data loggers, and automated temperature alerts, which ensure compliance with international food safety and quality standards.

Cold chain infrastructure also showed a strong influence ($\beta = 0.312$, $p < 0.001$). This confirms that the availability of adequate refrigerated trucks, cold storage facilities, and pre-cooling equipment is essential to reduce postharvest losses and ensure consistency in supply. However, infrastructure alone does not guarantee efficiency without proper utilization. Many Kenyan horticultural exporters still face challenges such as inadequate rural cold storage, unreliable electricity supply, and high logistics costs, which limit the full benefits of infrastructure investments. Policymakers and industry stakeholders should therefore prioritize public-private partnerships (PPPs) to expand cold storage facilities in farming zones, supported by sustainable energy solutions such as solar-powered refrigeration units.

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The competence of cold chain personnel was also found to significantly predict supply chain performance ($\beta = 0.297$, $p = 0.001$). While its impact was slightly lower than infrastructure and temperature control, skilled personnel are indispensable for managing the technical and operational aspects of cold chains. Training workers to handle perishable products carefully, follow temperature protocols, and maintain accurate documentation ensures that horticultural products meet the stringent requirements of international buyers. This finding underscores the need for capacity building programs, certification of cold chain handlers, and continuous training initiatives spearheaded by the Kenya Flower Council (KFC), Fresh Produce Exporters Association of Kenya (FPEAK), and relevant government agencies.

4.3 Discussion of Findings

The study found that cold chain management has a significant positive influence on supply chain performance in Kenya's horticulture export sector. Specifically, cold chain infrastructure demonstrated a strong positive correlation with supply chain performance ($r = 0.712$, $p < 0.05$), indicating that well-developed infrastructure such as pre-cooling units, cold storage, and refrigerated transport reduces postharvest losses and enhances delivery efficiency. Cold chain personnel competence also showed a strong correlation with supply chain performance ($r = 0.693$, $p < 0.05$), suggesting that skilled and well-trained staff are essential in maintaining temperature standards, minimizing handling errors, and ensuring accurate documentation. Similarly, temperature control had the highest correlation with supply chain performance ($r = 0.728$, $p < 0.05$), highlighting its critical role in preventing spoilage and maintaining product quality throughout the cold chain. Combined, the three variables explained 64.2% of the variation in supply chain performance ($R^2 = 0.642$), underscoring the strategic value of investing in cold chain infrastructure, skilled personnel, and effective temperature monitoring systems to improve efficiency and competitiveness in Kenya's horticulture exports.

5. Conclusions and Recommendations

5.1 Conclusions

This study investigated the influence of cold chain management on supply chain performance in the Kenya horticultural export sector, focusing on cold chain infrastructure, cold chain personnel, and temperature control. The study concluded that all three components significantly influence supply chain performance, with temperature control emerging as the most critical factor, indicating that weaknesses in Kenya's cold chain systems such as poor access to refrigerated transport, limited pre-cooling facilities, and untrained personnel are major contributors to postharvest losses, export rejections, and revenue losses.

5.2 Recommendations

The study recommends that the government, in collaboration with private exporters, increase investment in cold storage facilities, pre-cooling units, and refrigerated transport systems, especially in horticultural production zones that remain underserved. Exporters and regulatory bodies should implement continuous training and capacity building programs for cold chain personnel, with emphasis on quality control, temperature monitoring, and compliance documentation.

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