
Assessing the Impact of Supply Chain Management Practices on Food Wastage: Tomato Transport from Sokoto to Imo State

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Abstract: *Food wastage, particularly in perishable supply chains, represents a critical challenge to food security and economic sustainability in Nigeria. Tomato postharvest losses are especially severe, often exceeding 45%, yet the specific impact of supply chain management (SCM) practices during long-distance transportation remains underexplored. This study assessed the impact of SCM practices on tomato wastage during transport from Sokoto to Imo State, Nigeria, identifying key contributing factors and evaluating their sustainability implications. A convergent mixed-methods design was employed. Quantitatively, 500 questionnaires were purposively administered to farmers, transporters, wholesalers, and retailers along the corridor. Qualitatively, 20 key informant interviews were conducted with supply chain managers, policymakers, and agricultural officers. Quantitative data were analyzed using SPSS (v23.0) for descriptive statistics and Mann-Whitney U tests, while qualitative data underwent thematic analysis. Findings reveal a dominance of inefficient traditional practices: 77.5% of tomatoes are transported in raffia baskets and 82.5% in open trucks, with only 5% using refrigerated transport. Transportation delays (54.7%) and poor handling (62.1%) were primary wastage drivers. Significant sustainability impacts were observed, with economic viability perceptions significantly lower in Sokoto (producers) than Owerri (consumers) (2.7 ± 0.9 vs. 3.4 ± 0.8 , $p < 0.001$). A critical paradox emerged: while 76.8% of stakeholders expressed willingness to adopt improved practices, actual adoption remains minimal, hindered by cost, infrastructure, and coordination barriers. Tomato wastage is a systemic outcome of interdependent SCM failures, not isolated incidents. The study concludes that effective reduction requires integrated, multi-level interventions. Immediate actions should include crate subsidies and handling training; medium-term strategies should focus on cold chain and road infrastructure development; and long-term policy must foster an integrated national strategy for postharvest loss reduction to enhance food security and supply chain sustainability.*

Keywords: Food wastage, supply chain management, postharvest loss, tomato, cold chain logistics, Nigeria, sustainability.

INTRODUCTION

Food wastage is one of the most key issues of the 21st century, affecting the food supply chain around the globe socially, economically, and environmentally. The Food and Agriculture Organization (FAO, 2020) estimates that

about a third of the annual food produced for intake by man is wasted, of which the world produces about 1.3 billion tons of these goods. This wastage is experienced throughout the food supply chain starting with the production of agricultural products all the way to the household consumption. The economic scale of this challenge is simply overwhelming, and Quedsted et al. (2020) have estimated that the world wastes about 1 trillion worth of food every single year, including 630 billion in the developed world and 310 billion in the developing world.

The environmental impact is also very serious. Food wastage is also a major source of greenhouse gas emissions, according to FAO (2013), food wastage contributes approximately 3.3 gigatonnes of CO₂-equivalent amount of greenhouse gases each year and hence it is one of the biggest sources of greenhouse gas emission in the world. Decompositions of food in landfills produce methane- a strong greenhouse gas that has a global warming capacity of 25 times that of carbon dioxide on a 100-year basis (FAO, 2013). Food wastage is an enormous waste of valuable natural resources in addition to the effects of climate, such as water, land, and energy used in production, processing and distribution (Gustavsson et al., 2011).

Nigeria is holding a very problematic position in the world food waste hierarchy. Nigeria is the most populous African country with more than 200 million people and ironically, there is a high level of food insecurity and a large scale of food wastage. Kolawole et al. (2024) put it at approximately 40 percent of overall food production in Nigeria, which can be seen as millions of tons of food wasted or lost that could otherwise have nourished over 200 million people, as per the basic food needs. This marks wastage when hunger and malnutrition prevail in diverse social-economic cadres demonstrating a crucial lack of touch with the food system in the country (Ojo and Adebayo, 2012).

Food loss in the economy of developing economies such as Nigeria has an economic effect that goes beyond direct financial losses. Nigerian Stored Products Research Institute (NSPRI) indicates that the postharvest food losses in all crop varieties stand at 51.3 million tonnes that are worth \$8.9 billion (FAO, 2013; NSPRI surveys). Such losses decrease the profitability of agriculture, decrease the income of farmers, raise the consumer prices, and put a burden on the national food security. These systemic inefficiencies are especially vulnerable to the agricultural sector of Nigeria, which employs around 70% of the labor force and provides 23% of the GDP of this country (FMARD, 2016).

More so, there is a sharp issue of tomato wastage. Nigeria is the second-largest tomato farmer in Africa, although it loses between 30 and 60 percent of the output (Ugonna et al., 2015; Bolarin and Bosa, 2015). The example of the national challenge is the transport corridor between Sokoto State, which is a large production area, and Imo State, which is a high-density consumption area. This 1,200 kilometer trip exposes tomatoes to various stress factors that intensify the process of spoilage, but the supply chain management (SCM) practices that add to the wastage in this route are not well researched.

There exist theoretical lapses in the application of Systems Theory (Bertalanffy, 1968) to perishable food supply chains in developing situations. In practice, Nigeria wastes approximately 750,000 metric tonnes of tomatoes each year because of the ineffective SCM (Global Alliance for Improved Nutrition, 2022), which has a direct effect on food security. The policy interventions need an evidence-based comprehension of the loss processes, particularly when perishable produce losses extend to 60 percent (FMARD, 2016). This study aims to comprehensively assess the impact of supply chain management practices on tomato wastage during transportation from Sokoto to Imo State, Nigeria.

Food wastage is one of the most challenging socio-economic and environmental issues of the 21st century in the globe. The Food and Agriculture Organization (FAO, 2020) estimates that about a third of the total food produced in the yearly intake by man is lost or wasted, of which the world produces about 1.3 billion tons of these goods.

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Used in the context of transportation of tomatoes in Sokoto to Imo State, Systems Theory is used to conceptualize the supply chain as an integrated system having interdependent nodes such as farmers, aggregators, transporters, wholesalers, retailers, and final consumers. All nodes connect with one another in terms of tomatoes, information and finances flows. Any disruption at any stage e.g. transportation delays, poor handling during loading, poor storage at transit hubs, or failure of coordination between buyers and sellers all impact the overall system and add to wastage of food. The tomato supply chain can be seen as a system, which will make it possible to analyze the impact of actions at every stage on the quality of the product, losses, and efficiency as a whole. It also assists in diagnosis of failures and the impact that change in one aspect of the chain may improve the efficiency of the entire

system hence minimizing wastage. In practice, Nigeria wastes approximately 750,000 metric tonnes of tomatoes each year because of an ineffective Supply Chain management (Global Alliance for Improved Nutrition, 2022), which has a direct effect on food security. The policy interventions need an evidence-based comprehension of the loss processes, particularly when perishable produce losses extend to 60 percent (FMARD, 2016).

In developing countries like Nigeria, losses predominantly occur upstream in the supply chain—during production, postharvest handling, and distribution—due to limitations in infrastructure, technology, and knowledge (World Bank, 2020). This contrasts with developed countries where waste primarily occurs at the consumer end (Halloran et al., 2014). For tomatoes in Nigeria, postharvest losses are particularly severe, with studies indicating losses between 30% to 60% (Bolarin & Bosa, 2015; Ugonna et al., 2015). These losses encompass both quantitative reductions (physical disappearance of produce) and qualitative deterioration (reduced nutritional value, appearance, or safety). Närvänen et al. (2020) characterize food waste as a complex, multifaceted, and persistent challenge, noting its unstructured nature due to difficulties in defining the problem. Xue et al. (2017) identified six "hotspots" along the food supply chain where losses occur: agricultural production and harvesting, postharvest handling and storage, manufacturing, distribution, retailing, and consumption. Understanding where in this continuum tomato losses occur in Nigeria is essential for designing targeted interventions.

Food wastage impacts sustainability across three interconnected dimensions: economic, environmental, and social. Economically, postharvest losses represent wasted investments in production inputs, labor, and transportation, reducing profitability for farmers and increasing costs for consumers (Hailu & Derbew, 2015). For tomato farmers in Nigeria, these losses directly undermine income generation and livelihood security, with significant implications for poverty reduction and rural development. Environmentally, food wastage has severe consequences. Decomposing food in landfills generates methane, a potent greenhouse gas (FAO, 2013). Furthermore, wasted food represents inefficient use of natural resources including water, land, and energy invested in production (Gustavsson et al., 2011). Crippa et al. (2021) estimate that food loss and waste contribute approximately one-third of the world's total anthropogenic greenhouse gas emissions. For tomatoes specifically, every production stage—from fertilizer and pesticide use to irrigation, harvesting, packaging, transportation, and storage—emits greenhouse gases (Zhu & Miller, 2025). Discarded tomatoes that decompose in landfills release additional methane, further intensifying climate impacts (FAO, 2013). Socially, food wastage exacerbates food insecurity and inequality. In Nigeria, where malnutrition remains a persistent challenge, the loss of nutritious foods like tomatoes directly undermines food access and dietary quality (Ojo & Adebayo, 2012). Wastage also affects social relations within supply chains, as losses may create tensions between farmers, transporters, and traders regarding responsibility and compensation. At the community level, postharvest losses can reduce the availability of affordable, nutritious foods, particularly affecting vulnerable populations.

Research specific to Africa and Nigeria provides crucial context for understanding local supply chain dynamics. Arah et al. (2015) conducted a comprehensive review of postharvest losses in tomato production in Africa, identifying key factors including inappropriate harvesting periods, poor packaging, inadequate storage, and transportation challenges. Their work highlights how these factors interact to create substantial losses in African tomato supply chains.

In Nigeria specifically, multiple studies have documented tomato wastage challenges. Ugonna et al. (2015) estimated annual tomato losses at 45% of total production, while Bolarin and Bosa (2015) reported wastage between 30% to 60%. More recent research by Ojeleye et al. (2023) evaluated postharvest losses of tomato fruits during the COVID-19 lockdown, finding significant losses due to factors like bumper harvests, conveyance delays, lack of storage facilities, and poor-quality fruits. Their study recommended policy interventions including improving road

networks, installing affordable cold storage facilities, and training on best postharvest handling practices. Atman et al. (2021) examined causes of fresh tomato losses among supply chain actors in Bauchi State, Nigeria, identifying high temperatures, lack of ready markets, diseases, inadequate storage facilities, and vehicle breakdowns as significant contributors. Their research recommended the provision of large cold storage facilities to reduce losses. Similarly, Zailani (2023) explored post-harvest losses and waste in tomato supply chains in Kaduna State, revealing that the highest amount of tomato waste was generated by farmers, followed by intermediaries and traders, primarily due to overripe tomatoes, damaged produce, and inadequate storage facilities.

Research on cold chain adoption in developing countries highlights both challenges and opportunities. Mejeha et al. (2025) analysed cold chain systems for fruits and vegetables in Southeast Nigeria, finding that while awareness of cold chain importance was high among retailers, adoption remained limited due to cost constraints. Their study revealed that temperature control significantly correlated with freshness and produce cost, and the cost component significantly predicted adoption of cold chain practices. Aworh (2021) notes that cold chain logistics in Nigeria remains very limited, with operations largely concentrated in urban centers. Despite being the most populous nation in sub-Saharan Africa, Nigeria has yet to fully develop cold chain infrastructure that matches its demand. Cassou et al. (2020) emphasize that cold chain systems are essential for proper storage and transportation of perishable foods, particularly tomatoes, which are highly temperature sensitive.

Nguyen et al. (2022) emphasize that cold chain logistics stakeholders' operations minimize product losses within the cold value stream by utilizing internal benefits of business assets for cold storage and providing transportation, storage, and personnel needed to create a supply network that meets high quality standards. However, significant barriers persist. High initial investment costs, unreliable power supply, lack of technical expertise, and fragmented supply chains constrain cold chain adoption in Nigeria and similar contexts. Research by Khan and Ali (2021) suggests that sustainable cold chain development requires not only infrastructure investment but also capacity building, policy support, and innovative financing mechanisms tailored to developing country contexts.

Despite substantial research on tomato supply chains and postharvest losses, several gaps remain. First, few studies have specifically examined the Sokoto-Imo transport corridor, which represents a critical link between major production and consumption zones in Nigeria. Second, existing research often focuses on either quantitative loss measurements or qualitative assessments of challenges, with limited integration of mixed methods approaches. Third, while sustainability implications of food wastage are recognized globally, few studies have systematically assessed economic, environmental, and social dimensions of tomato losses in Nigerian contexts. Fourth, research on cold chain adoption in Nigeria has predominantly examined export commodities or urban retail, with limited attention to domestic interregional transportation of perishable foods. This study addresses these gaps by employing a mixed-methods approach to examine SCM practices and wastage along the Sokoto-Imo tomato transport corridor, assessing sustainability implications across multiple dimensions, and providing context-specific recommendations for cold chain development and supply chain improvement

METHODOLOGY

Research Philosophy and Design

This study adopted a pragmatic research paradigm, which prioritizes the research problem and values the use of multiple approaches to derive practical, actionable knowledge (Creswell, 2013). A convergent mixed-methods design was employed, where quantitative and qualitative data were collected concurrently during the same phase (February–May 2025) and then integrated during analysis and interpretation. This design was justified by the need to both quantify the extent and key factors of tomato wastage and to gain in-depth, contextual understanding of the

underlying practices, challenges, and stakeholder perspectives (Creswell, 2013). The combination of methods allows for triangulation, providing a more comprehensive and validated assessment of the complex supply chain issues than a single-method approach.

Population and Sampling

Quantitative Phase: The target population comprised stakeholders directly involved in the tomato supply chain. Using Cochran's formula with a 95% confidence level and ± 5 margin of error, a minimum sample size of 384 was calculated. This was increased by 30% to 500 to account for non-responses. A purposive sampling technique was used to select 201 farmers and 90 transporters in Sokoto, and 75 wholesalers and 134 retailers in Imo, based on their active involvement in the Sokoto-Imo tomato trade during the study period.

Qualitative Phase: Twenty (20) key informants were selected via expert sampling, including supply chain managers, transportation officials, policymakers, and agricultural officers. Selection was based on their professional roles and a minimum of 7–15 years of relevant experience. Saturation was deemed reached when no new themes emerged from consecutive interviews.

Data Collection Instruments

Quantitative Instrument: A structured, interviewer-administered questionnaire was developed based on a review of existing tools (Khatun et al., 2019; Kikulwe et al., 2015). It covered socio-demographics, SCM practices, wastage factors, and recommendations. Pilot testing confirmed clarity, and reliability analysis yielded a Cronbach's alpha of 0.81, indicating good internal consistency.

Qualitative Instrument: A semi-structured interview guide was created, with questions tailored to each stakeholder category (e.g., supply chain managers, policymakers). The guide was validated by four experts and pre-tested to ensure relevance and comprehensiveness.

Data Collection Procedures

Data collection occurred from February to May 2025. For the quantitative phase, trained enumerators administered questionnaires face-to-face, with translation support in Hausa (Sokoto) and Igbo (Imo) where needed. For the qualitative phase, key informant interviews were conducted in person or virtually, recorded with consent, and supplemented with notes.

Data Analysis Techniques

Quantitative Analysis: Data were coded and analysed using SPSS Version 23.0. Descriptive statistics (frequencies, percentages, means) summarized the data. The Mann-Whitney U test was used to compare sustainability perception scores between Sokoto and Imo respondents.

Qualitative Analysis: Interview recordings were transcribed and analysed thematically using NVivo software. The process involved familiarization, coding, theme development, and interpretation, with triangulation against quantitative findings to enhance validity.

Ethical Considerations

Ethical approval was obtained from the Federal Ministry of Agriculture and Food Security (FMAFS/ETHS/Vol.2/813) and the Nigerian Association of Road Transport Owners

Publication of the European Centre for Research Training and Development-UK (NARTO/ETH.C/Vol.1/02/156). Informed consent was secured from all. Confidentiality was maintained through anonymization, and data were stored securely on password-protected devices.

RESULTS AND DISCUSSION

Results

A total of 500 questionnaires were administered and retrieved, yielding a 100% response rate. Respondents comprised 291 stakeholders from Sokoto State (201 farmers, 90 transporters) and 209 from Imo State (75 wholesalers, 134 retailers).

A comparison on pre-transportation storage methods was conducted and the results are shown in Figure 4. Results show that Pre-transport storage methods remain predominantly traditional. As shown in **Figure 4**, local baskets (44%) and open-field storage (33%) were most common, while plastic crate usage was limited to 18%.

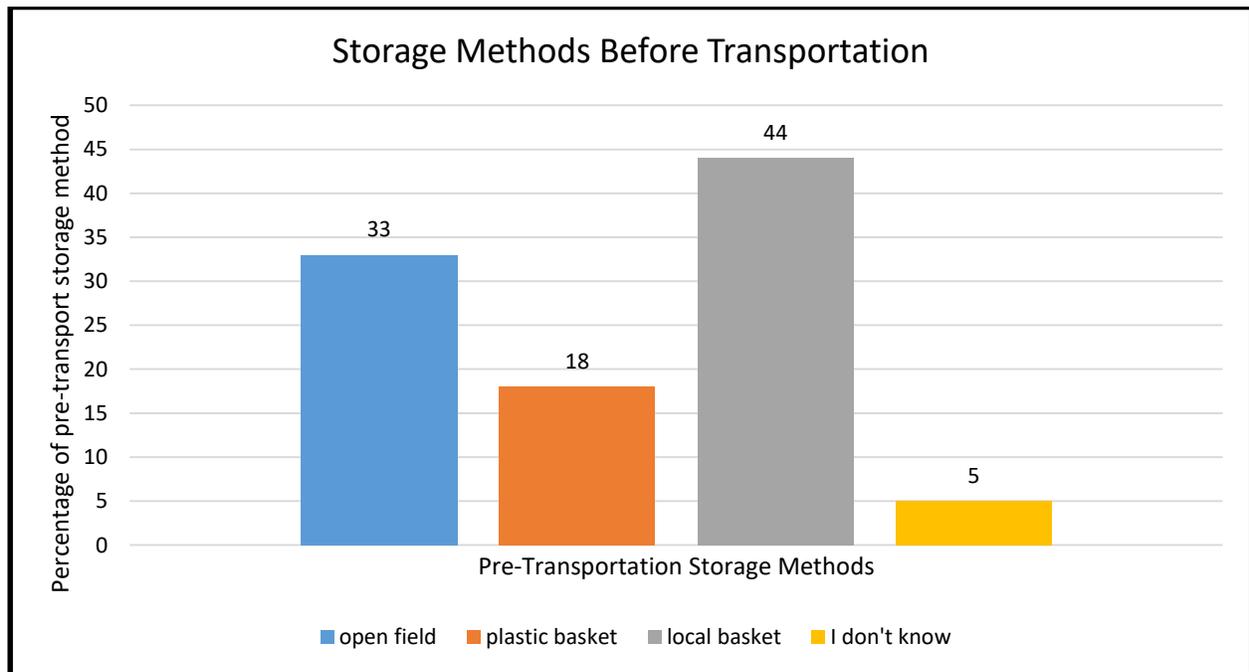


Figure 4: Storage Methods before Transportation (%)

Transportation and packaging methods were also compared as shown in Figure 5, which illustrates that open trucks (94%) dominate transportation, with only 6% using refrigerated trucks. Within open trucks, 75% of tomatoes were transported in local baskets and 19% in plastic crates.

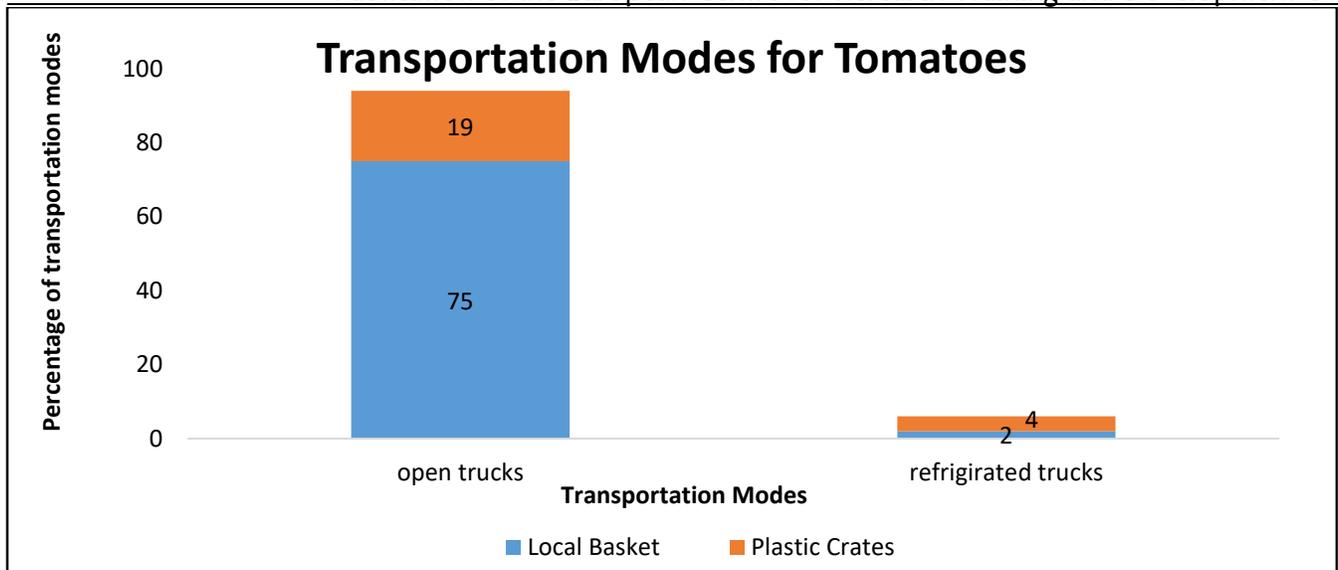


Figure 5: Transportation Modes for Tomatoes (%)

Key factors affecting tomato wastages were also investigated and results from figure 6 show that transportation delays (44%) and poor handling practices (26%) as the leading causes of tomato wastage, followed by poor storage conditions (18%) and harsh weather (12%)

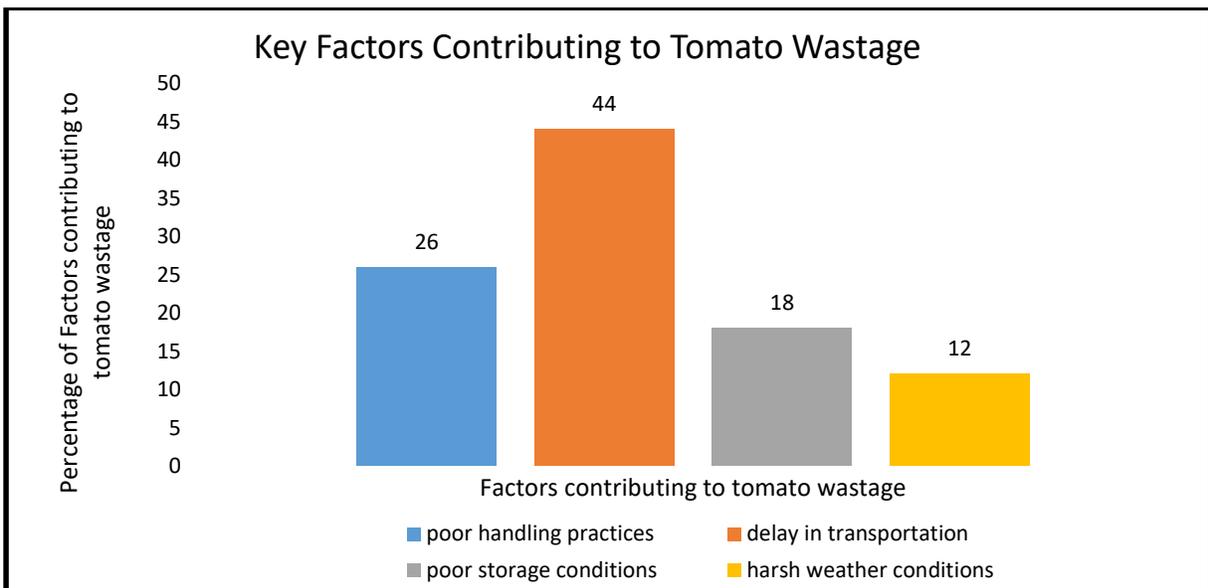


Figure 6: Key Factors Contributing to Tomato Wastage (%)

Stakeholders identified infrastructure improvement as the primary need (**Figure 7**), with 38% prioritizing better roads, 29% advocating for refrigerated trucks, 20% recommending improved packaging, and 13% suggesting handling training.

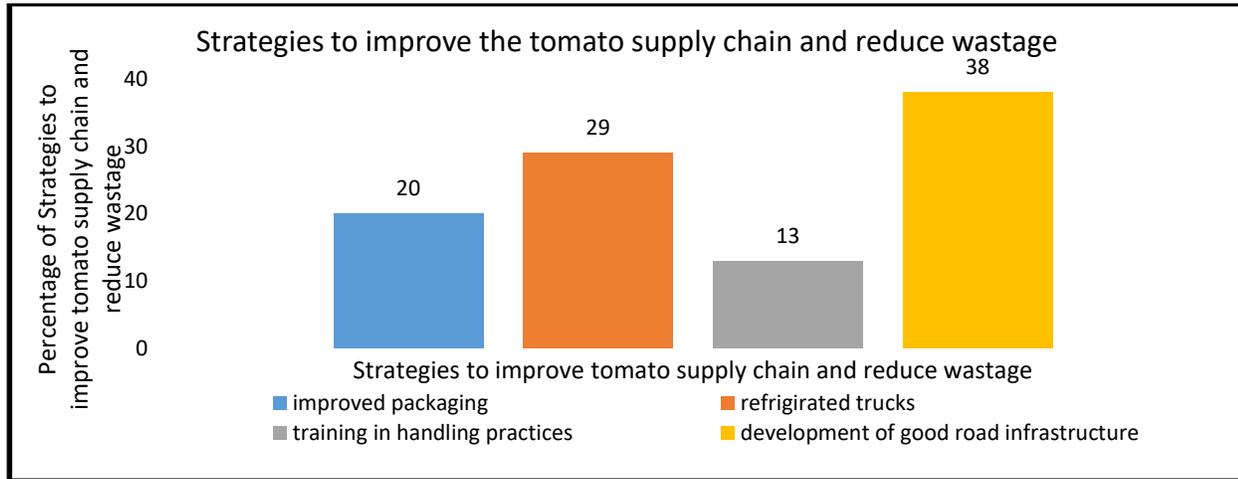


Figure 7: Strategies to improve the tomato supply chain and reduce food waste (%)

Figure 8 shows the willingness of stakeholders to adapt new practices to reduce waste in which 76.8% of respondents were willing to adopt new practices to reduce waste, while 17.0% were undecided and only 6.3% were unwilling.

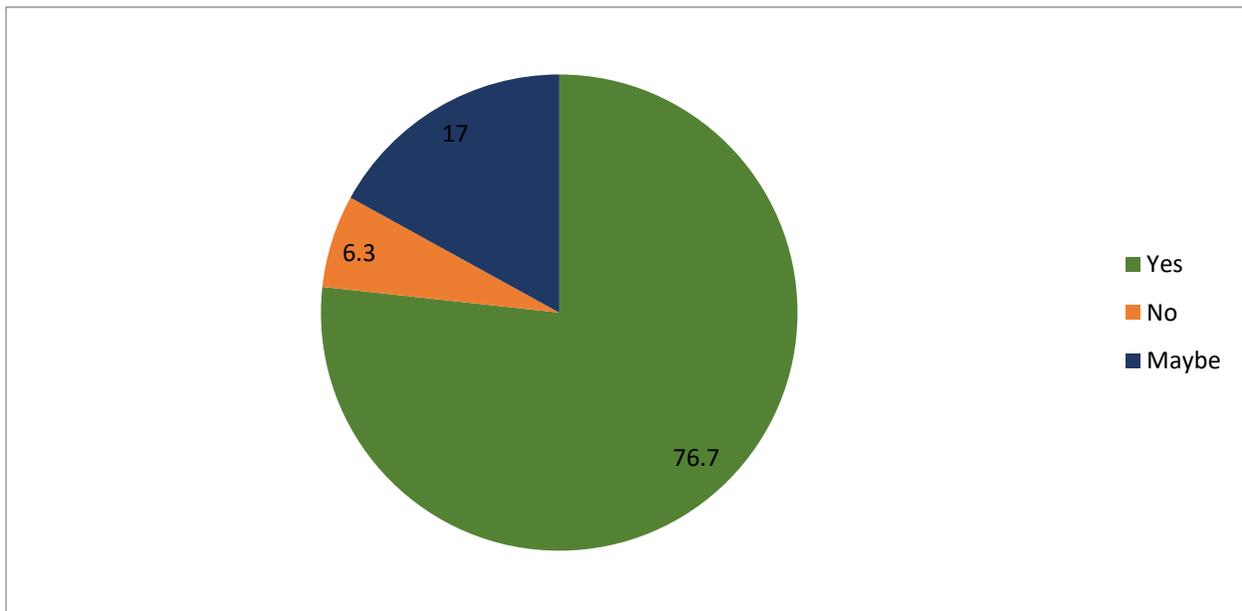


Figure 8: Willingness to Adopt New Practices to Reduce Waste

Perceptions of wastage impacts varied significantly between Sokoto (production zone) and Owerri (consumption zone) respondents, as detailed in Table 1.

Table 1: Implications of Wastage on Sustainability

| Sustainability Indicator | Sokoto (n=291) Mean ± SD | Owerri (n=209) Mean ± SD | Overall (n=500) Mean ± SD | Mann-Whitney U | p-value |
|--------------------------------------|-----------------------------|-----------------------------|------------------------------|----------------|---------|
| Economic Viability Perception | 2.7 ± 0.9 | 3.4 ± 0.8 | 3.1 ± 0.9 | 24,150 | <0.001 |
| Environmental Impact Concern | 3.1 ± 0.8 | 3.5 ± 0.7 | 3.3 ± 0.8 | 27,890 | 0.002 |
| Social Community Support | 2.9 ± 1.0 | 3.6 ± 0.9 | 3.3 ± 0.9 | 23,470 | <0.001 |

Scale: 1=Very Low, 5=Very High

Thematic analysis of 20 key informant interviews were also conducted and revealed four dominant themes:

1. **Infrastructure Deficiencies:** Stakeholders consistently cited poor road conditions, limited cold chain facilities, and inadequate storage as systemic barriers. One supply chain manager noted, *"Tomatoes are transported over roads with potholes, extending the journey to three days or more"* (Transportation Official 4).
2. **Operational Challenges:** Traditional packaging persists despite awareness of better alternatives. A manager stated, *"We still use raffia baskets, which often cause bruising and crushing"* (Supply Chain Manager 3). Checkpoint delays and extortion further exacerbate losses.
3. **Knowledge and Training Gaps:** Limited awareness of postharvest best practices was frequently mentioned. An agricultural officer reported, *"Many farmers are unaware of proper crate stacking and still overload vehicles"* (Agricultural Officer 1).
4. **Policy and Enforcement Issues:** Weak enforcement of existing regulations was highlighted. A policymaker admitted, *"We have laws but no enforcement. Everyone still uses raffia baskets"* (Policymaker 1).

DISCUSSION OF RESULTS

The convergent mixed-methods design facilitated the exhaustive triangulation of data sources, which produced consistent and complementary data on quantitative surveys and qualitative interviews. The proposed methodological approach enforced the soundness of findings since quantitative data statistical patterns were constantly interpreted and substantiated through the narratives of stakeholders (Creswell, 2013).

Combination of data sources showed that the prevalence of traditional practices measured in Figures 7-8 (94% open trucks, 77.5% raffia baskets) was directly elucidated through qualitative descriptions of cost limitation, absence of options and traditional practices. The top wastage factor (44% in Figure 9), which was transportation delays, was

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expounded in terms of qualitative reports of potholes that stretch journeys up to three days or longer (Transportation Official 4), and checkpoint extortion that reaches up to ₦450,000.00 a trip (Transportation Official 3). This overlap increases the soundness of the claim of seeing infrastructure and security as main points of intervention.

The mixed-methods approach has been validated in the way in which quantitative willingness to adopt new practices (76.8% in Figure 6) was checked to provide insights of interviews that indicated conditional use, contingent on affordability, training and demonstration of benefits. The expressed willingness is high, versus the actual low adoption rates (only 5% use of refrigerated trucks), which underscores the difference between the intention and actual implementation that the purely quantitative approach could miss.

Patterns of emergence between groups of stakeholders showed varied views that enhance insights. The economic vulnerability (mean 2.7+0.9 on economic viability, Table 1) of farmers in Sokoto (production zone) compared to Owerri-based traders (3.4+0.8), indicating their status in end of the value chain in which any losses directly decrease income. Farmer accounts were more qualitative and concerned only immediate financial rates whereas the traders were more concerned about quality uniformity and reliability of supplies. Transporters made a special mark over the challenges of security and checkpoints, whereas policymakers drew a special reference to the regulatory and coordination gaps. These varied lenses legitimize the Systems Theory outlook that the various nodes of the supply chain feel and think about and take issues differently, which require specific interventions.

The tomato supply chain application to the Systems Theory shows that there are important interdependencies of subsystems that explain the persistence of wastage. The theory which was first postulated by Bertalanffy (1968) is the belief that systems are made of interrelated parts and that their operations influence the entire system. In that, the Sokoto-Imo tomato corridor is a system that consists of a number of sub system: production (farmers), aggregation (collectors), transportation (logistics), distribution (wholesalers/retailers), consumption. The paper reveals how the flaws in one sub-system such as transportation cause a ripple effect across the board.

Alignment with Arah et al. (2015) on packaging issues is striking. Their review of post-harvest losses in African tomato production identified inappropriate packaging as a major contributor, specifically noting that "packaging problem is not only lack of ventilation, but physical damage due to rough surface and excessive pressure due to large depth of tomato leading to excessive weight on bottom layer" (Arah et al., 2015, p. 83). The current study's finding that 77.5% of tomatoes are transported in raffia baskets, with qualitative accounts of crushing and bruising, directly confirms and localizes this general observation to the Sokoto-Imo context. However, this study extends Arah et al.'s work by quantifying the economic implications (farmers' reduced economic viability scores) and documenting stakeholder perceptions of barriers to adopting better packaging like plastic crates.

Confirmation of Emanu et al. (2017) findings on temperature control is evident in the consistency regarding cold chain limitations. Emanu et al.'s study of Ethiopian tomato chains found that "temperature management is essential for preserving the quality of highly perishable crops" (p. 5), with losses exacerbated by high ambient temperatures during transport. The current study's findings of only 5% refrigerated truck usage and qualitative accounts of tomatoes "heating up and rotting quickly" during transit (Supply Chain Manager 4) directly corroborate this. However, this research adds nuance by identifying specific Nigerian barriers including fuel costs for refrigeration, insecurity on northern routes that deters investment in high-value assets, and limited technical maintenance capacity.

Extensions to Gustavsson et al. (2011) work in the Nigerian context are significant. Their global FAO study identified that "losses are higher in developing countries due to deficiencies in infrastructure, technology, and knowledge" (p. 7). This study provides granular, context-specific evidence of these deficiencies: poor roads causing

44% of wastage (Figure 9), limited cold chain technology (5% adoption), and knowledge gaps in proper handling. More importantly, it extends Gustavsson et al.'s work by examining how these factors interact—poor roads not only cause physical damage but extend transit time, exacerbating temperature-related spoilage in the absence of refrigeration. The sustainability dimension analysis (Table 1) also extends their environmental focus by incorporating economic and social implications specific to Nigerian smallholders and traders.

The study both **confirms and challenges World Bank (2020) findings** regarding loss distribution in developing countries. The World Bank reported that in developing countries, "food losses happen mainly at the distribution and transportation phases" (p. 3), which aligns with this study's identification of transportation delays as the leading wastage factor. However, the current research challenges any simplistic attribution by revealing how transportation losses are often consequences of upstream decisions (e.g., packaging choice, harvest timing) and downstream constraints (e.g., market access timing, trader requirements). This systems perspective adds necessary complexity to the World Bank's general observation.

To the Farmers: The direct losses in the livelihoods are converted into the figures. Farmers have a disproportionate financial risk since their average economic viability perception is very low at 2.7/5.0 in Sokoto (Table 1). Qualitative narrations have shown that losses usually compel farmers to accept any price that traders might pay to buy partly damaged products. Costs are not the only adoption barriers to enhanced practices, risk aversion is another one, experimenting with new methods with uncertain returns is a gamble the majority of smallholders simply cannot afford. Nevertheless, the willingness to adopt (76.8) is high meaning that farmers will not resist change but need to have a conducive environment: evidentiary benefits, availability of funds and reduction of risks during changeover. Farmer cooperatives can utilize resources to share refrigerated transport or bulk buying of plastic crates both to overcome cost and risk barriers.

To Policymakers: The interconnected deficiencies defined should be tackled through infrastructure investment priorities. Key agricultural routes should be taken as a priority in the rehabilitation of roads, however, it must be with complementary activities: the mere existence of better roads can only encourage quicker transportation of ill-packed tomatoes, which can still reach their destination in a bad shape. The development of regulatory frameworks should provide both standards (e.g., the raffia baskets should be phased out of long-distance transportation) and tools of enforcement. But, according to qualitative findings, enforcement capacity building is no less important than regulation development, as it turned out that we have laws and no enforcement (Policymaker 1). Another key area that policymakers need to tackle appears as the security and checkpoint concerns that have become one of the major sources of wastage, which is not usually addressed during an agricultural policy, but which plays a vital role in the effectiveness of the supply chain.

To Supply Chain Managers: There are several points where there is an opportunity to optimize the processes. Simple, cheap interventions such as harvesting early in the day (mentioned in qualitative accounts early morning harvesting), improved loading methods to minimize compression damage, and simple quality sorting prior to transport might help to improve pre-transport practices. The technology integration plans must take into consideration the level of technology, such as complete refrigeration might be impractical at the moment, but the middle stages such as insulated covers, evaporative cooling, or travelling during night hours to avoid heat during the day may give substantial change. Information flows should also be enhanced by supply chain managers: simple monitoring of transit time and examination of the state would allow identifying the points of the problem instead of the general knowledge of the existence of transportation delays.

CONCLUSION

This study concludes that tomato wastage during transportation from Sokoto to Imo State is predominantly caused by deeply embedded, traditional supply chain practices specifically the widespread use of raffia baskets (77.5%) and open trucks (82.5%) which are sustained by systemic barriers including cost limitations, infrastructural deficits, and weak policy enforcement.

Key factors such as transportation delays (54.7%) and poor handling (62.1%) interact within a fragmented system further strained by checkpoint extortion and inadequate cold chain adoption (only 5%), leading to significant economic, environmental, and social sustainability impacts, with producers in Sokoto bearing the heaviest losses.

The paradox between high stakeholder willingness to change (76.8%) and minimal actual adoption underscores the urgent need for integrated, multi-level interventions that address not only technical and infrastructural gaps but also the coordination failures and financial barriers that prevent the transition to more efficient and sustainable supply chain practices.

This research makes several theoretical contributions to supply chain management and postharvest loss literature.

First, it advances the application of Systems Theory to Nigerian agricultural supply chains by demonstrating how subsystem interdependencies create systemic wastage. The study moves beyond cataloguing individual deficiencies to show how poor roads, inadequate packaging, knowledge gaps, and policy weaknesses interact to create outcomes worse than their sum. This systems perspective helps explain why piecemeal interventions often fail improving one component without addressing related constraints yields limited benefits.

Second, the study develops an integrated loss assessment framework that combines quantitative measurement with qualitative contextualization. This framework recognizes that wastage percentages alone provide limited guidance for intervention understanding why particular practices persist despite their drawbacks is equally important. The mixed-methods approach demonstrates how statistical patterns (e.g., high transportation delay attribution) gain explanatory power when complemented by stakeholder narratives (e.g., checkpoint experiences, road condition descriptions).

Third, the research contributes to postharvest management literature by extending global findings to specific Nigerian contexts while identifying locally distinctive factors. While confirming international observations about packaging and temperature control importance (Emana et al., 2017), the study adds context-specific insights about security challenges, checkpoint dynamics, and the particular resource constraints facing Nigerian smallholders. These contributions help bridge the gap between generic best practices and contextually feasible improvements.

Practical Recommendations

Derived from the integrated analysis of quantitative and qualitative findings, this study proposes a tiered set of evidence-based recommendations aimed at reducing tomato wastage and improving supply chain resilience along the Sokoto–Imo transport corridor. The proposed interventions are structured across short, medium, and long-term timeframes, addressing the root causes identified from immediate practice changes to systemic policy reforms. This multi-phased approach is designed to translate the documented high willingness for change among stakeholders into tangible, sustainable improvements in Nigeria's perishable food logistics.

To immediately reduce tomato wastage, practical actions include introducing subsidized plastic crates to replace raffia baskets, delivering hands-on handling training to farmers and transporters, and streamlining security

checkpoints to cut down delays. These steps directly tackle the main causes of loss poor packaging and slow transit and are supported by the high willingness to change among stakeholders.

In the medium term, strategic investments should focus on developing accessible cold storage solutions, such as solar-powered chilling units, and repairing the worst sections of the Sokoto–Imo road corridor. Encouraging the formation of transport cooperatives can also improve vehicle quality, enable bulk purchasing, and strengthen collective bargaining, building a more efficient and resilient supply network.

For lasting impact, long-term policy should aim at creating a unified national strategy to cut postharvest losses, integrating logistics planning across agricultural and transport ministries, and establishing a certification system that rewards sustainable, low-waste supply chains. These systemic changes will help align market incentives with best practices and ensure coordinated action across all levels of the tomato value chain.

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