E-ISSN: 2676-6167 | P-ISSN: 2538-5100

Journal of Applied Research on Industrial Engineering

www.journal-aprie.com

J. Appl. Res. Ind. Eng. Vol. x, No. x (xx) x–x.

Paper Type: Original Article

Postharvest Losses of a Developing Nation's Tomatoes Value Chain- Evidence from Actors' Perspectives in Nigeria

Abdulrahman, Ibrahim Madugu [1], Umar, Ali Umar [2,*], Oyedeji, Ayodeji Nathaniel[3]

[1] Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria; Email Address; madoggs2012@gmail.com
[2] Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria; Email Address; umaraliumar@yahoo.co.uk
[3] Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria; Email Address; oyedejiayodeji@yahoo.com

Citation:

LastName, (Abreviation of FirstName)., & LastName, (Abreviation of FirstName. (Date). Paper Title. Journal of applied research on industrial engineering, Volume (Issue), PP

Received: Reviewed: Revised: 202 Accepted:

Abstract

Despite being the 16th-largest tomato producer in the world with the potential to dominate tomato exports, Nigeria still faces challenges, including a lack of crucial production inputs, low yields, outdated technology, significant postharvest losses (PHL), and a lack of infrastructure for processing and promotion. Although the PHL in tomato production and promotion are well understood worldwide, Nigeria still has a sizable knowledge gap in postharvest handling and management. So, to evaluate the perspectives of the key players (farmers, traders/middlemen, transporters/logistics, and processors) in this value chain, this study constructed a zone-specific production system, postharvest handling, and losses model for tomatoes. Three hundred fifty samples from the four districts comprised the value chain actors' survey, comprising 200 farmers, 115 traders/middlemen, 25 transporters/logistics, and 10 processors. A standardised questionnaire was used to perform the one-on-one quantitative interview. The study's findings indicated that most transporters had at least two losses, and at least one dealer had lost money. The main players in the supply chain cited problems such as the lack of market avenues, storage technologies, processing factories, close markets, and inefficient transportation methods. Furthermore, loading and unloading, breakage, rot, and accidents account for most tomato PHL losses. Therefore, it is advised that Nigeria's rich tomato market be exploited by establishing suitable processing facilities, appropriate sponsorship for farmers, and developing suitable transportation routes.

Keywords: Value chain; Tomato farming; Postharvest losses; Developing nation; Agricultural sustainability.

Corresponding Author: umaraliumar@yahoo.co.uk

1 | Introduction

Nigeria is now the 16th-biggest tomato-producing country globally but can dominate global tomato production and exports [1]. Unfortunately, the nation continues to struggle with a shortage of essential production inputs, low yields, outdated technology, significant postharvest losses (PHL), and a lack of infrastructure for processing and promotion [2], [3], [4]. There is far more demand for tomatoes and their by-products than there is supply from nearby producers, especially when it is out of season [5]. There is little question that Nigeria, as a country, has a sizable market for tomato harvests that are processed given the nation's population of over 200 million, an anticipated annual average economic growth rate over the past five years of 3.5 percent, with a population growth rate of 5.7 percent [6]. In addition to the Nigerian market, the benefit of globalisation in the West African economy might be used to boost the sale of packaged tomato products there [7]. Importing a sizable portion of processed tomato products used in Nigeria puts undue strain on the country's foreign exchange reserves [6].

The conceptual framework for this study on PHL in the Nigerian tomato value chain is grounded in key theoretical perspectives that guide the exploration of the intricate dynamics within this agricultural context. The framework draws inspiration from value chain analysis, a conceptual lens that allows the dissection of the tomato value chain into distinct stages and identifies the various actors involved, ranging from farmers to processors and retailers. In this study, the actors were the farmers, traders/middlemen, transporters/logistics, and processors. By examining the pre-harvest practices of farmers, the efficiency of trade and logistics operations, and the processing methods employed, this study unravels the complexities of PHL throughout the entire value chain, recognising that each stage contributes uniquely to the outcome. PHL transcend a singular cause, instead manifesting as a multi-dimensional phenomenon [8], [9]. The roots of PHL are embedded in pre-harvest practices, harvesting techniques, transportation methods, storage facilities, and market dynamics [10], [11]. By considering these various dimensions, this study seeks to provide a comprehensive understanding of the factors contributing to PHL, thereby informing targeted interventions at specific stages of the value chain.

Incorporating economic and institutional factors is also imperative to grasp the broader context in which PHL occur [8]. Drawing from agricultural economics, this study considers market demand, price fluctuations, and access to markets as critical economic determinants. Simultaneously, institutional factors such as government policies, infrastructure, and support systems are woven into the fabric of this study's framework, recognising their profound influence on the efficiency and resilience of the tomato value chain. Technological innovation is a pivotal element catalyses reducing PHL [8], [11]. This encompasses adopting improved storage facilities, transportation methods, and processing technologies. Furthermore, environmental and climate considerations form another integral component of agricultural activities, and the impact of weather conditions, pest management strategies, and climate resilience on PHL is enormous [9]. This framework is a structured guide for investigating the multifaceted factors influencing PHL in the Nigerian tomato value chain.

Of the challenges responsible for the shortage in the supply of tomatoes in Nigeria, this study considers PHL. PHL refers to the deficits that occur at every stage of the food supply chain, with the final destination in the plate of the final consumer as it transits from the farm [12], [13]. Losses experienced in handling, storing, shipping, and processing agricultural commodities result in a drop in their amount, grade, and market worth [14]. In underdeveloped nations, concerns regarding losses in nutritive value, nutrient content, energetic value, and consumer acceptance of the food are given lower importance than worries about quantifiable losses (i.e., quantity, volume, or total wastage of farm produce) [13]. In Nigeria, this is especially true. Furthermore, it is widely known that nutritive value losses are typically considerably more difficult to assess than numerical losses [15].

The main causes of PHL include surface defects, metabolic decline, and biological factors, such as postharvest infections and insect infestation [13]. Animals and birds are also responsible for PHL, particularly in crops like tomatoes [15]. However, these costs are frequently modest compared to damages from improper handling, insufficient wrapping, and value losses brought on by temperature extremes [16], [17]. PHL of vegetables like tomatoes is sometimes attributed to socioeconomic and institutional factors, including insufficient marketing information and support systems, inappropriate transportation infrastructure, unfavourable public policies, the failure to implement regulations and laws, an absence of adequate tools and equipment, inadequate expertise, and a poor maintenance culture for existing facilities [18], [19]. Most developing nations, including Nigeria, lack the necessary roadways for the efficient transportation of horticulture products, and there is a dearth of transport vehicles and other modes, particularly those appropriate for the timely delivery of perishable horticultural goods [20]. Additionally, the degree of losses is significantly influenced by elements including cultivar and soil types, crop management strategies, unfavourable weather patterns, insect pest prevention strategies, reaping, and packaging and processing processes [16], [19].

PHL differs significantly depending on the commodities, production regions, seasons, and the degree of infrastructure and technological development for postharvest management and the market system [18]. However, information on the PHL of vegetables in developing countries, both quantitatively and qualitatively, is still hard to come by and is frequently dependent on educated guesses rather than official quantitative field assessments. Despite the world's extensive understanding of PHL in tomato production and marketing, Nigeria has a significant knowledge gap regarding postharvest handling and management. Additionally, it is difficult to estimate the size of the losses. Furthermore, most of the horticultural crops considered in previous research were not tomatoes [3], [4]. Therefore, the goal of this study is to create information that is country-specific for tomatoes about the production system, postharvest handling, and losses, as well as to examine the perspective of the major actors (farmers, traders/middlemen, transporters/logistics and processors) in this value chain. The study's methodology, major findings, and conclusions are all described in the article's sections two, three, and four respectively.

2 | Method

2.1 | Description of the Study Area

The study was carried out in four districts (Makarfi, Kubau, Ikara and Soba) in Kaduna State, which lies in the North-central area of Nigeria. Based on the projected number, the four districts' combined population was 959,741. Geographically speaking, the study districts are situated between 11.2804° N and 10.3853° N and between 8.0029° E and 8.5735° E (as shown in Figure 1). Kaduna state is one of Nigeria's highest tomatoes producing states, with a production volume of about 1.1 million tonnes, though majorly from the small-scale farmers [21]. The state is renowned for its excellent road system and other essential amenities, including institutions, transportation, telecommunications, and power. Additionally, it houses one of the newly developed tomato processing factories in the country (Tomato Jos Farming and Processing Limited) [6], [22]. In intensive small-scale farming, farmlands are utilised for tomato production 2-3 times annually under irrigated and rain-fed circumstances [23].

Specifically, the Kubau, Makarfi, Ikara, and Lere districts in Kaduna State, Nigeria, contribute significantly to the diverse and dynamic landscape of the region. In Kubau, agriculture plays a crucial role in the local economy, with the district being known for cultivating crops such as grains and legumes. Makarfi, on the other hand, is characterised by its rich cultural heritage, evident in traditional practices and festivals that reflect the historical roots of the community. Ikara, with its strategic location and vibrant markets, serves as a hub for trade and commerce, fostering economic activities that contribute to the overall development of the district. Meanwhile, Lere, known for its agricultural productivity, particularly in cultivating fruits and vegetables, is essential to Kaduna State's agrarian landscape. These

research regions also present major obstacles that nationwide tomato farmers confront. The difficulties include a knowledge and ability deficit for managing PHL and restricted access to markets for viable goods.

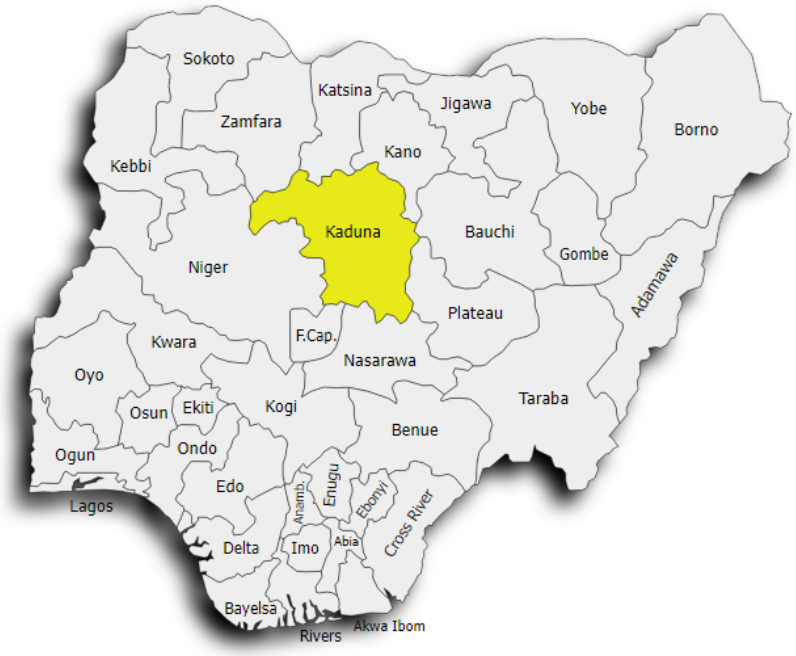

Fig. 1. Map of the study districts.

2.2 | Data Collection and Analysis

Information for the study was gathered from both primary and secondary sources. Primary data were gathered through one-on-one interviews with value chain actors in the sector, including farmers, traders/middlemen, transporters/logistics and processors and key informant interviews. The value chain actors' survey involved 350 samples from the four districts, including 200 farmers, 115 traders/middlemen, 25 transporters/logistics, and 10 processors. The sample for this study was derived through a random sampling procedure, encompassing these key actors in the tomato value chain. A convenient sample from the entire study area aligned with the research focus was drawn to mitigate potential biases and ensure true representation [24], [25], [26]. This approach aimed to minimise systematic biases associated with a specific sampling technique, ensuring a more comprehensive and diverse representation of stakeholders.

The one-on-one quantitative interview was conducted using a standardised questionnaire (see Appendix A). The questionnaire addressed various topics, including tomato production, product use, marketing, postharvest handling, transportation, PHL and their management, and PHL-causing variables. The acquired data were encoded and input into version 21 of the Statistical Package for the Social Science (SPSS) Software and Microsoft Excel spreadsheets. Triangulation, consistency checks, and analysis were done on data from diverse sources, and the results were presented in cumulative percentages summing up to 400% from the 4 district areas understudied. Furthermore, the One-way analysis of variance (ANOVA) was used to compare the challenges and causes identified in the four districts that comprised the study area. The null hypothesis assumed no significant difference in identified challenges and causes of PHL across the four districts, while the alternative hypothesis suggested a significant difference in at least one of the districts.

3 | Results and Discussion

3.1 | Demographic Characteristics of the Actors of the Value Chain

From Fig. 2, it can be seen that the majority of the tomato farmers, transporters, traders, and processors across the districts of the study area have an age range that peaks around the age group of 25-40 years with a cumulative percentage of 173%, 220.8%, 176% and 189.2% respectively. On the other hand, the age group below 18 years had the least representation, with cumulative percentages of 23.4%, 6.7%, 9.1% and 0% respectively. This result suggests that a significant number of the actors of the tomato value chain in the study area are youths who are considered the strength of every society [23]. Similarly, Fig. 2 shows the years of experience of the farmers and processors who were considered the key actors affected by years of experience. The result shows that most farmers' respondents have 6-10 years (108.7% cumulative percentage) and 11-15 years (100.5 cumulative percentage) of experience. Additionally, the majority of the processors of tomato have 0-5 years (130% cumulative percentage) and 11-15 years (117.5% cumulative percentage) of experience. This result denotes a fair amount of experience among the farmers, while the processors have a reasonable number of industry newcomers, as stated by Maritz & Peters [6]. Furthermore, of the four districts of the study area, Fig. 2 shows that most of the tomato farmers understudy have less than 9 hectares farming capacity, with 185.2% cumulative percentage having 5-9 hectares and 184.7% cumulative percentage with below 1 hectare. This result implies that most tomato farmers are small-scale farmers as stated by previous studies [21], [22]. The unit of the traders, however, also showed that the majority of the traders' understudy are retailers (with a cumulative percentage of 254.1%), which is expected since the farm capacity consists of small-scale farmers.

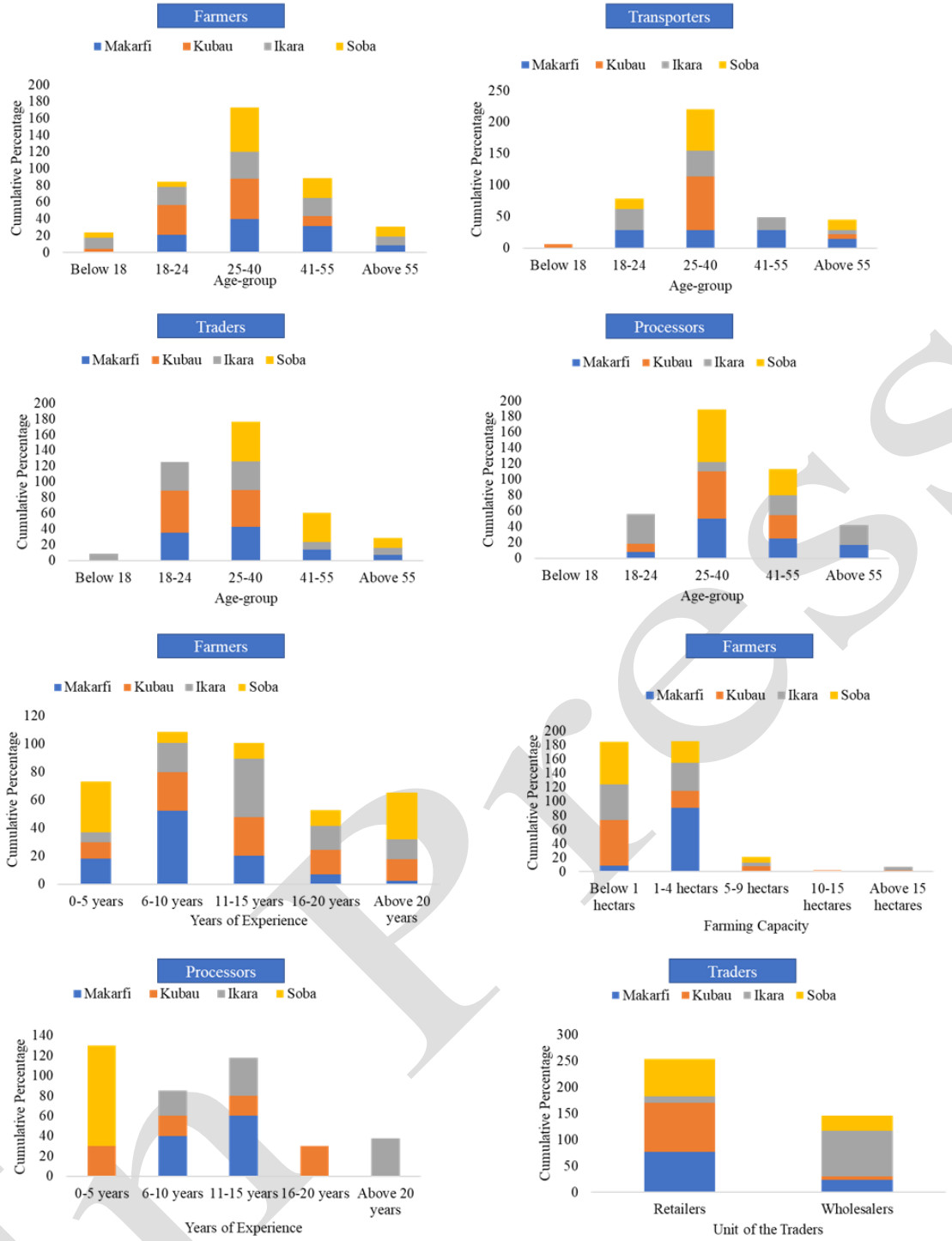

Fig. 2. Demographic characteristics of the farmers, traders, transporters, and processors.

3.2 | Current State of Post harvesting System

Fig. 3 shows the current state of the value chain in terms of losses among the transporter and traders, sources of capital for the processors, source of tomato to the transporter, and means of transportation for the traders and processors. It was observed that while some of the transporters have never experienced losses, at least one of the traders has experienced losses. The result also showed that a cumulative percentage of 157.5% of the transporters has experienced at least twice losses, while a cumulative percentage of 243.9% of the traders has experienced losses for some time now. Furthermore, the processors get most of their capital from personal savings (cumulative percentage of 184.5%) and family (cumulative percentage of 137.7%). For the transporters in the value chain, the major source of tomato distributed to the traders and processors comes from the local farmers (cumulative percentage of 335.7%), implying that despite small-scale farmers operating small-scale farming, the quantity produced is still sufficient for the chain. In terms of means of transportation, Fig. 3 shows that the majority (with a

cumulative percentage of 247.1%) of the traders use bicycles/bikers, while the majority (with a cumulative percentage of 278.6%) of the processors use cars/lorries. The obtained result can be linked with previous studies such as that of Nwabuogo et al. [27], who observed losses among tomato traders in Lagos, Nigeria; Plaisier et al. [28], who observed substantial losses among tomato transporters in Kano, Nigeria; Oyedele et al. [29], who observed the difficulties of obtaining capital for tomato processors and when small-scale industries are set up for this purpose, the capital comes from family and personal savings, who uses vehicles for transportation.

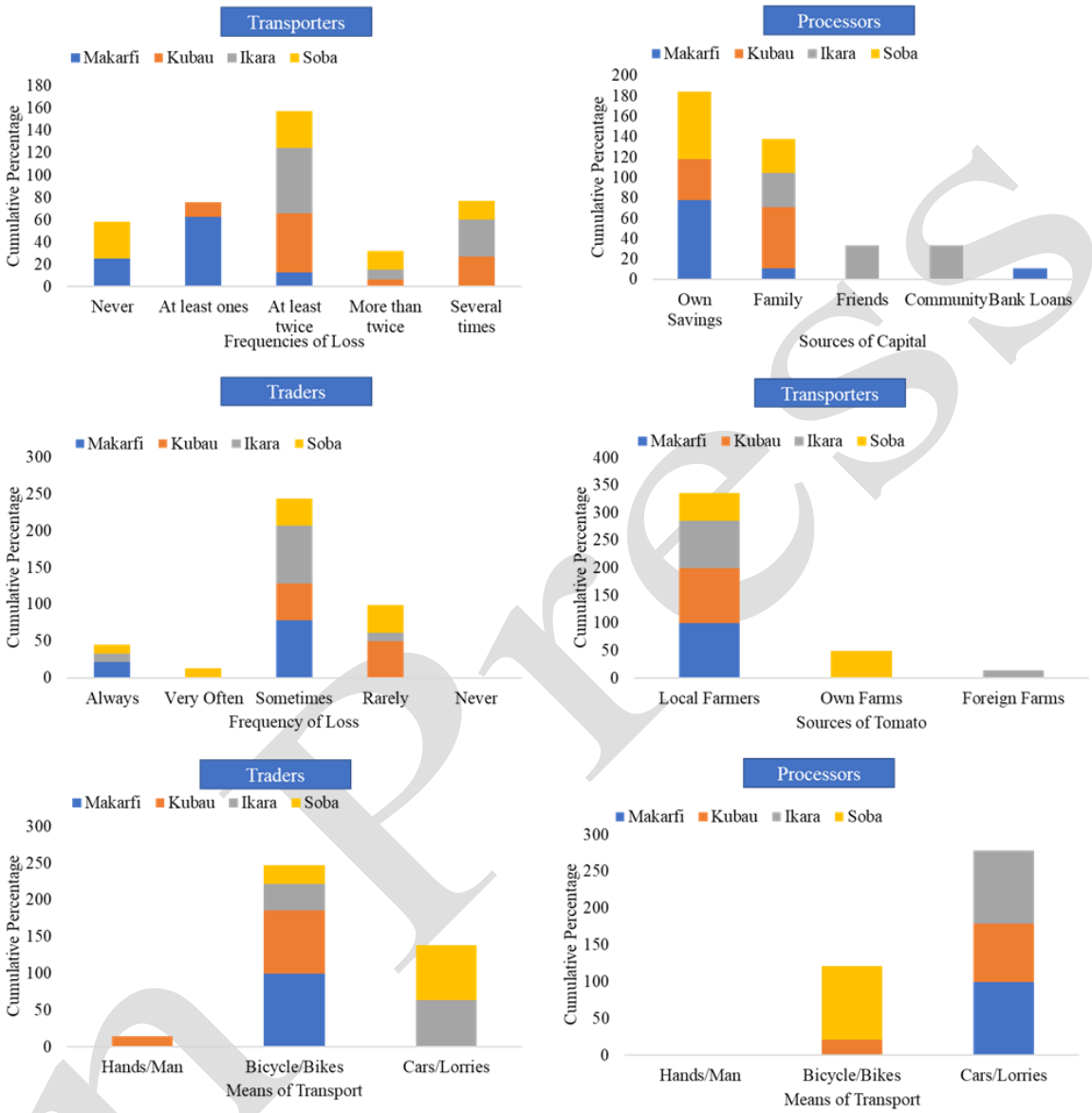

Fig. 3. Current state of the post-harvesting system for the transporters, processors, and traders.

The average estimated losses associated with the tomato value chain across different key actors and districts in Table 1 present a nuanced picture of the challenges faced in Makarfi, Ikara, Kubau, and Soba. Notably, farmers in Kubau and Makarfi districts experience relatively higher average losses, with 3,090 kg and 2,960 kg, respectively, than Ikara and Soba. Transporters in Makarfi also face substantial losses, reflecting potential vulnerabilities in the transportation process. The trade sector in Ikara stands out with significant losses, possibly due to challenges in storage or market dynamics. Interestingly, processors in the Makarfi and Kubau districts encounter notable losses, emphasising the need for efficient processing and preservation methods. The total estimated losses for each district underscore the overall magnitude of postharvest losses in the tomato value chain. The disparities between districts highlight the importance of district-specific interventions, considering factors such as infrastructure, market accessibility, and agricultural practices. To bring into context the effect of tomato PHL, 350 respondents lost 37,459.6kg of tomatoes over the years, translating to approximately US$ 77,000 (US$2.04 per kg).

Table 1. Tomato average estimated losses incurred within the study area

Key Actor	Makarfi (kg)	Ikara (kg)	Kubau (kg)	Soba (kg)
Farmers	2,960	196	3090	1,099
Transporters	8000	34.3	3,927	198.3
Trades	1320	2575	637	3,325
Processors	6000	233.3	3,865	-
Total	18,280	3,038.6	11,519	4,622

3.3 | Challenges Faced by the Major Actors

Fig. 4 shows some of the challenges faced by the major actors of the tomato value chain in the study area. The challenges identified from the interactions with the key players are lack of market avenue, storage technology, processing plants, close market, and unreliable transport means. The result implies that most actors (cumulative percentage of 298.6%) within the study area agreed that lack of market avenue to quickly dispose of their products before getting spoilt is a major challenge. Similarly, the majority of the actors (cumulative percentage of 324.3%) in the value chain believe that inadequate storage technology, inadequate processing plants (as stated by 303.5% cumulative percentage of the respondents), and lack of close markets resulting in the need to transport products (as stated by 256.2% cumulative percentage) and unreliable transport means in the process of transporting the products (as stated by 293.7% cumulative percentage) are key challenges encountered in the tomato value chain. Previous studies identified similar challenges [6], [30].

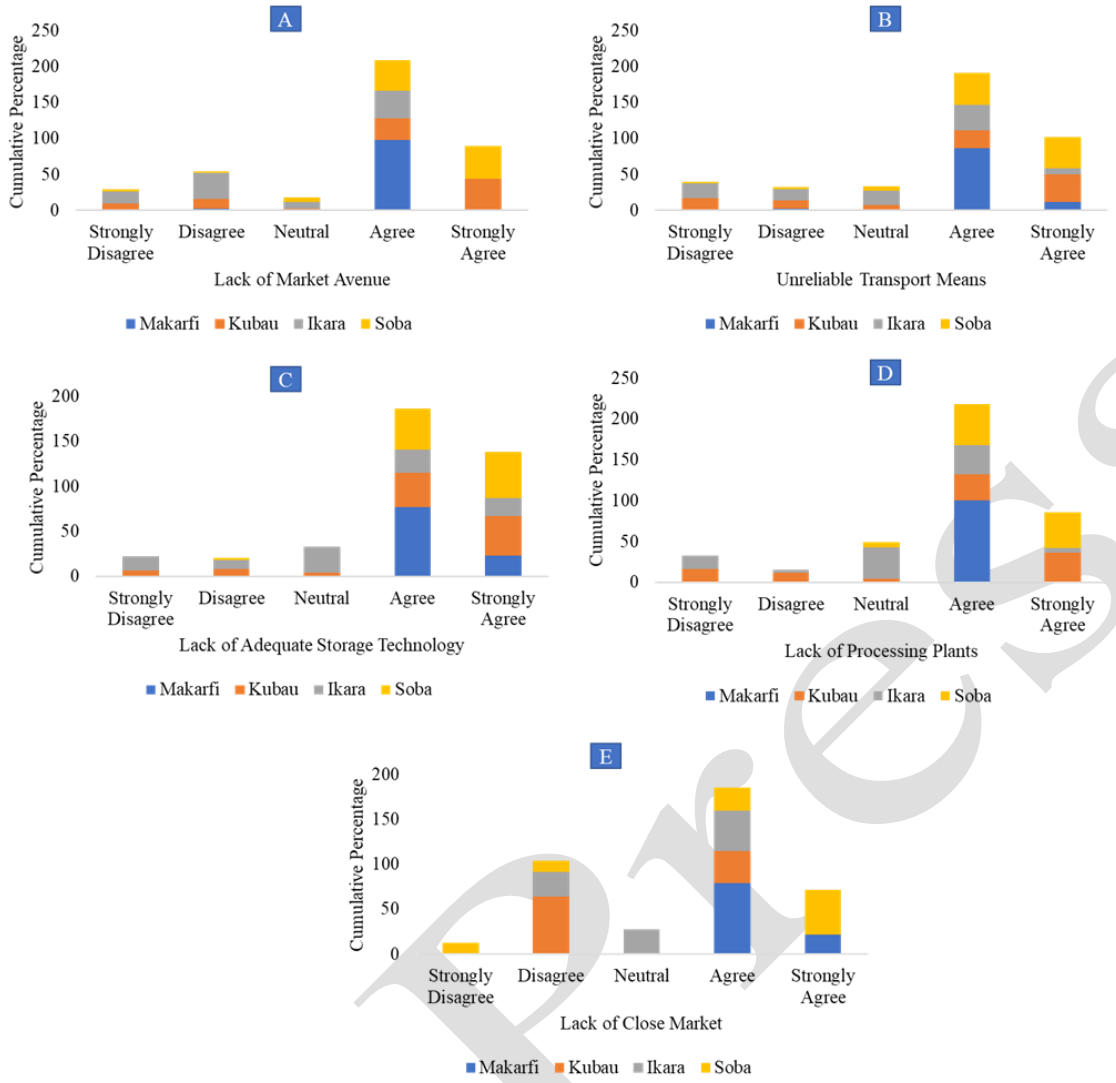

Fig. 4. Challenges faced by the major actors in the tomato value chain.

The analysis of variance (ANOVA) for the challenges faced by major actors in different districts (Table 2) reveals a significant source of variation between groups, as evidenced by a high F-value of 78.0075 and an associated p-value of 1.65×10^{-43}, which is well below the conventional significance level of 0.05. This indicates that the challenges experienced by major actors differ significantly across the districts of Kubau, Makarfi, Ikara, and Lere in Kaduna State. The substantial variation observed between groups (districts) suggests that local factors within each district contribute significantly to the unique challenges faced by major actors in the tomato value chain. Potential district-specific factors influencing these challenges may include differences in agricultural practices, infrastructure, market dynamics, and socioeconomic conditions.

Table 2. ANOVA of the challenges faced by the major actors in the different districts.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	153.8544	3	51.28479	78.0075	1.65E-43	2.6177
Within Groups	457.5742	1740	0.657434			
Total	611.4286	1743				

3.4 | Causes of Postharvest Losses

This result shed light on the multifaceted causes of postharvest losses. According to the result obtained in Fig. 5, 350.9% cumulative percentage agreed to losses due to loading and unloading. This indicates a consensus among participants regarding the adverse impact of these processes on the preservation of harvested produce. Furthermore, breakage garnered considerable attention, with a substantial number (311%) highlighting its contribution to losses. Additionally, the rot prevalence, though rated relatively lower on the scale (285.5%), signifies a recognised concern. While not as universally acknowledged, accidents during transportation still draw attention from a notable percentage of respondents (303.3% cumulative percentage). Previous studies reported similar causes [18], [20], [21].

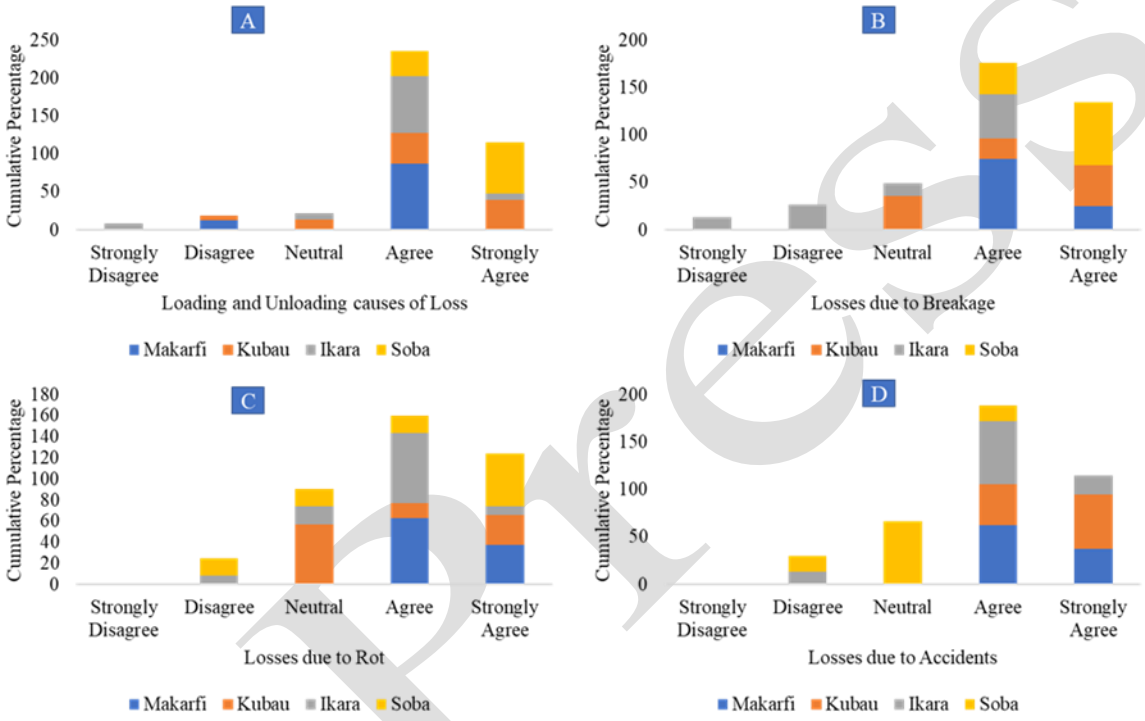

Fig. 5. Causes of Tomato PHL in the study area.

Similarly, Table 3 shows the ANOVA results for the causes of PHL in different districts, indicating a statistically significant difference in the reported causes across these regions. The high F-value of 39.84762 and a corresponding p-value of 3.91 x 10^{-22}, well below the conventional significance level of 0.05, demonstrate substantial variability in the identified causes of PHL among the districts. The critical F crit value further reinforces the significance of these differences. The observed variation implies that local factors within each district significantly contribute to the unique causes of PHL. Understanding these localised influences is crucial for tailoring interventions that address the specific challenges contributing to postharvest losses in each district, thereby enhancing the overall resilience of the tomato value chain.

Table 3. ANOVA of the causes of tomatoes PHL in the different districts.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	122.7375	3	40.91248	39.84762	3.91E-22	2.630792
Within Groups	354.2196	1392	1.026723			
Total	476.957	1395				

3 | Conclusion and Implications

Although Nigeria is the 16th-largest tomato-producing country with great potential to dominate global tomato production and exports, the nation continues to struggle with a shortage of essential production inputs, outdated technology, low yield and productivity, significant PHL, and a lack of infrastructure for processing and marketing. Furthermore, there is a significant knowledge gap in Nigeria regarding postharvest handling and management despite the world's extensive understanding of PHL in tomato production and marketing. Hence, this study developed a zone specific for tomatoes with regard to the production system, postharvest handling, and losses, as well as to examine the perspective of the major actors (farmers, traders/middlemen, transporters/logistics and processors) in this value chain. The analysis of average estimated losses unveils district-specific disparities, emphasising the need for targeted interventions. Farmers in Kubau and Makarfi experience higher losses, while transporters in Makarfi face substantial challenges, suggesting vulnerabilities in transportation processes. Notably, processors in Makarfi and Kubau encounter significant losses, emphasising the necessity for improved processing and preservation methods. The total estimated losses underscore the magnitude of postharvest losses in the tomato value chain. The challenges identified by major actors, including the lack of market avenues, storage technology, processing plants, proximity to markets, and unreliable transportation, highlight critical areas that require attention. The ANOVA results indicate significant variation in challenges among districts, emphasising the influence of local factors on the hurdles faced by major actors in the tomato value chain. Moreover, the causes of postharvest losses, such as loading and unloading, breakage, rot, and accidents during transportation, showcase multifaceted challenges that contribute to losses in the tomato value chain. The ANOVA results reinforce the district-specific nature of these causes, emphasising the need for tailored interventions based on local factors.

These findings have profound implications for policy and interventions. Targeted strategies addressing specific challenges in each district, such as improving transportation infrastructure, promoting efficient processing methods, and enhancing market access, can significantly reduce postharvest losses. Additionally, investing in training programs and technological solutions tailored to major actors' demographic characteristics and experience levels can contribute to a more resilient and sustainable tomato value chain in similar communities. The district-specific variations in challenges and causes of losses highlight the importance of localised strategies, guiding policymakers to address unique issues in each district. Interventions can include improving transportation infrastructure in areas with high losses during transportation, enhancing market access to reduce spoilage, and investing in storage technology and processing plants where inadequacies exist. The study's results provide a foundation for informed decision-making, guiding stakeholders towards effective measures to enhance the efficiency and profitability of the tomato value chain.

Acknowledgements

Funding

The study did not receive any external funding.

Conflicts of Interest

The authors declare that they have no competing interests.

References

[1] C. C. Obuaku-Igwe, "The AfCFTA: Trade and Investments Benefit for Nigeria," *The Palgrave Handbook of Africa's Economic Sectors*, pp. 745–767, Jan. 2022, doi: 10.1007/978-3-030-75556-0_29/COVER.

[2] A. Odusola, "Africa's Agriculture Today: Performance, Challenges, and Its Political Economy," *Africa's Agricultural Renaissance*, pp. 55–135, 2021, doi: 10.1007/978-3-030-65748-2_3.

[3] U. Kleih *et al.*, "Nigeria – Scoping yam value chain analysis," *Gates Open Research 2019 3:86*, vol. 3, p. 86, Feb. 2019, doi: 10.21955/GATESOPENRES.1114989.1.

[4] E. O. F. and P. U. Okpoko, "Tourism and Agro-Processing Industries: A Qualitative Study of Abakaliki Rice Mill," *International Journal of Horticulture, Agriculture and Food Science*, vol. 2, no. 2, pp. 7–14, 2018, doi: 10.22161/IJHAF.2.2.2.

[5] S. C. Izah and A. O. Aigberua, "Microbial and heavy metal hazard analysis of edible tomatoes (Lycopersicon esculentum) in Port Harcourt, Nigeria," *Toxicol Environ Health Sci*, vol. 12, no. 4, pp. 371–380, Dec. 2020, doi: 10.1007/S13530-020-00060-8/TABLES/7.

[6] J. Maritz and M. Peters, "Tomato Jos: launching a tomato paste brand in Nigeria," *Emerald Emerging Markets Case Studies*, vol. 12, no. 1, pp. 1–16, 2022, doi: 10.1108/EEMCS-04-2021-0118/FULL/PDF.

[7] S. C. Izah and A. O. Aigberua, "Microbial and heavy metal hazard analysis of edible tomatoes (Lycopersicon esculentum) in Port Harcourt, Nigeria," *Toxicol Environ Health Sci*, vol. 12, no. 4, pp. 371–380, Dec. 2020, doi: 10.1007/S13530-020-00060-8/TABLES/7.

[8] A. K. Jaiswal, B. Singh, A. Mehta, and M. Lal, "Postharvest Losses in Potatoes from Farm to Fork," *Potato Res*, vol. 66, no. 1, pp. 51–66, Mar. 2023, doi: 10.1007/S11540-022-09571-Y/FIGURES/2.

[9] S. Bhardwaj, S. Lata, and R. Garg, "Application of nanotechnology for preventing postharvest losses of agriproducts," *J Hortic Sci Biotechnol*, vol. 98, no. 1, pp. 31–44, Jan. 2023, doi: 10.1080/14620316.2022.2091488.

[10] F. Fatima *et al.*, "Trends in Potassium Permanganate (Ethylene Absorbent) Management Strategies: Towards Mitigating Postharvest Losses and Quality of Mango (Mangifera indica L) Fruit," *Food Bioproc Tech*, vol. 16, no. 10, pp. 2172–2183, Oct. 2023, doi: 10.1007/S11947-023-03047-8/TABLES/1.

[11] A. Mohan, R. Krishnan, K. Arshinder, J. Vandore, and U. Ramanathan, "Management of Postharvest Losses and Wastages in the Indian Tomato Supply Chain—A Temperature-Controlled Storage Perspective," *Sustainability 2023, Vol. 15, Page 1331*, vol. 15, no. 2, p. 1331, Jan. 2023, doi: 10.3390/SU15021331.

[12] V. S. M. Magalhães, L. M. D. F. Ferreira, A. da S. César, R. M. Bonfim, and C. Silva, "Food loss and waste in the Brazilian beef supply chain: an empirical analysis," *International Journal of Logistics Management*, vol. 32, no. 1, pp. 214–236, Jan. 2021, doi: 10.1108/IJLM-01-2020-0038/FULL/PDF.

[13] D. I. Onwude, G. Chen, N. Eke-Emezie, A. Kabutey, A. Y. Khaled, and B. Sturm, "Recent Advances in Reducing Food Losses in the Supply Chain of Fresh Agricultural Produce," *Processes 2020, Vol. 8, Page 1431*, vol. 8, no. 11, p. 1431, Nov. 2020, doi: 10.3390/PR8111431.

[14] V. S. M. Magalhães, L. M. D. F. Ferreira, and C. Silva, "Using a methodological approach to model causes of food loss and waste in fruit and vegetable supply chains," *J Clean Prod*, vol. 283, p. 124574, Feb. 2021, doi: 10.1016/J.JCLEPRO.2020.124574.

[15] M. Tolasa, F. Gedamu, and K. Woldetsadik, "Impacts of harvesting stages and pre-storage treatments on shelf life and quality of tomato (Solanum lycopersicum L.)," *Cogent Food Agric*, vol. 7, no. 1, p. 1863620, Jan. 2021, doi: 10.1080/23311932.2020.1863620.

[16] K. Karthick, A. Boris Ajit, V. Subramanaian, S. P. Anbuudayasankar, M. S. Narassima, and D. Hariharan, "Maximising profit by waste reduction in postharvest Supply Chain of tomato," *British Food Journal*, vol. 125, no. 2, pp. 626–644, Jan. 2023, doi: 10.1108/BFJ-06-2021-0702/FULL/PDF.

[17] S. Debebe, "Postharvest losses of crops and its determinants in Ethiopia: tobit model analysis," *Agric Food Secur*, vol. 11, no. 1, pp. 1–8, Dec. 2022, doi: 10.1186/S40066-022-00357-6/TABLES/2.

[18] B. Emana, V. Afari-Sefa, N. Nenguwo, A. Ayana, D. Kebede, and H. Mohammed, "Characterisation of pre- and postharvest losses of tomato supply chain in Ethiopia," *Agric Food Secur*, vol. 6, no. 1, pp. 1–11, Mar. 2017, doi: 10.1186/S40066-016-0085-1/TABLES/13.

[19] E. Surucu-Balci and O. Tuna, "The role of collaboration in tackling food loss and waste: Salient stakeholder perspective," *J Clean Prod*, vol. 367, p. 133126, Sep. 2022, doi: 10.1016/J.JCLEPRO.2022.133126.

[20] E. Etebu, A. Nwauzoma, D. B.-J. of Biology, undefined Agriculture, and undefined 2013, "Postharvest spoilage of tomato (Lycopersicon esculentum Mill.) and control strategies in Nigeria," *core.ac.ukE Etebu, AB Nwauzoma, DDS BawoJournal of Biology, Agriculture and Healthcare, 2013•core.ac.uk*, vol. 3, no. 10, 2013, Accessed: Jan. 17, 2024. [Online]. Available: https://core.ac.uk/download/pdf/234659011.pdf

[21] S. S. Nassarawa and S. A. Sulaiman, "Extending the shelf life of tomato and onion in Nigeria: A review," *International Journal of Food Science and Nutrition*, vol. 4, no. 5, pp. 99–111, 2019, Accessed: Jan. 17, 2024. [Online]. Available: www.foodsciencejournal.com

[22] F. Dodo, "Tomato Jos adventure: competition amidst growing pains," *Emerald Emerging Markets Case Studies*, vol. 8, no. 2, pp. 1–25, Jun. 2018, doi: 10.1108/EEMCS-03-2017-0037/FULL/PDF.

[23] M. U. Dimelu, A. M. Umoren, and J. M. Chah, "Determinants of Youth Farmers' Participation in Agricultural Activities in Akwa Ibom State, Nigeria," *Journal of Agricultural Science*, vol. 12, no. 12, p. 201, Nov. 2020, doi: 10.5539/JAS.V12N12P201.

[24] P. Neminebor, A. U. Umar, and A. N. Oyedeji, "Feasibility Studies for a Biogas Powered Standalone Power Plant: A Case Study of Giwa Community, Kaduna State, Nigeria," *Nigerian Journal of Tropical Engineering*, vol. 16, no. 1, pp. 127–138, Dec. 2022, doi: 10.59081/NJTE.16.1.011.

[25] L. S. Kuburi, U. Umar, and A. N. Oyedeji, "Risk Assessment of Petrol Filling Stations in a Metropolitical City of Kaduna State, Nigeria," *SINERGI*, vol. 27, no. 2, pp. 179–184, 2023, doi: 10.22441/SINERGI.2023.2.005.

[26] B. S. Terab, U. A. Umar, and A. N. Oyedeji, "Information technology in supply chain management: Perspectives from key actors in the Nigerian petroleum sector," *https://doi.org/10.1080/20421338.2023.2221876*, pp. 1–7, Jun. 2023, doi: 10.1080/20421338.2023.2221876.

[27] A. Nwabuogo, M. John, K. M.-P. Book, and undefined 2019, "Determination of factors influencing the adoption of Returnable Plastic Crates (RPCs) in reducing tomato losses among traders in Lagos State, Nigeria," *ageconsearch.umn.eduAC Nwabuogo, M John, K MmatlouProceedings Book, 2019•ageconsearch.umn.edu*, Accessed: Jan. 17, 2024. [Online]. Available:

[28] C. Plaisier, M. Sibomana, J. van der Waal, L. Clercx, C. P. A. van Wagenberg, and Y. Dijkxhoorn, "Approach for designing context-specific, locally owned interventions to reduce postharvest losses: Case study on tomato value chains in Nigeria," *Sustainability (Switzerland)*, vol. 11, no. 1, Jan. 2019, doi: 10.3390/SU11010247.

[29] O. O. Oyedele *et al.*, "Capacity building of smallholder farmers on tomato drying in selected Local Government Areas of Kano state," *Acta Hortic*, vol. 1348, pp. 225–231, Oct. 2022, doi: 10.17660/ACTAHORTIC.2022.1348.31.

[30] G. Baker *et al.*, "Tomato tales : Comparing loss-reduction drivers and opportunities across U.S. fresh tomato supply chains," *The Economics of Food Loss in the Produce Industry*, pp. 131–150, Nov. 2019, doi: 10.4324/9780429264139-10.

Appendix

Section 1: Demographic Characteristics

1. Age Group (for all)

Below 18 Years ( ) 18-24 Years ( ) 25-40 Years ( )

41-55 Years ( ) 55 Years -above ( )

2. Years Experience (for Farmers and Processors)

0-5 Years ( ) 6-10 Years ( ) 10-15 Years ( )

15-20 Years ( ) Above 20 Years ( )

3. Farming Capacity (for Farmers)

Farming Capacity:

0-1 Hectares ( ) 1-5 Hectares ( ) 5-10 Hectares ( )

10-15 Hectares 15-above Hectares ( )

4. Unit of Trading (for Traders)

Retailers ( ) Wholesalers ( )

Section 2: Current State of the Post harvesting System

5. Frequency of Postharvest Tomato Losses (for Transporters and Traders)

Never ( ) At least once ( ) At least twice ( ) More than twice ( )

Several times ( )

6. Sources of Capital for Tomato Processing (for Processors)

Own savings ( ) Family ( ) Friends ( ) Community bank ( )

Loans ( )

7. Sources of Tomato (for Transporters)

Local farmers ( ) Own farms ( ) Foreign farms ( )

8. Means of Transportation (for Traders and Processors)

Hands/Man ( ) Bicycle/Bikes ( ) Car/Lorries ( )

9. Kilogram of tomatoes loss (for all)

Section 3: Challenges Faced by the Major Actors

To what extent do you experience these challenges associated with postharvesting of Tomatoes?

NB: SD – Strongly Disagree, D – Disagree, N – Neutral, A – Agree, and SA – Strongly Agree

Challenges	SD	D	N	A	SA
Lack of market avenue					
Unreliable transport means					
Lack of adequate storage technology					
Lack of processing plants					
Lack of close markets					

Section 4: Causes of Postharvest Losses

To what extent do you believe these factors cause Tomato's postharvest losses?

NB: SD – Strongly Disagree, D – Disagree, N – Neutral, A – Agree, and SA – Strongly Agree

Causes	SD	D	N	A	SA
Loading and unloading					
Breakage					
Rot					
Accidents					