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TRANSPORTATION CHALLENGES IN POSTHARVEST HANDLING: IMPLICATIONS FOR QUALITY, SAFETY, AND LOSSES OF AGRICULTURAL PRODUCTS IN DEVELOPING NATIONS

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ABSTRACT

This study examines the impacts of transportation on post-harvest quality of agricultural products particularly focusing on the effect of poor transport systems on products' deterioration and economic losses. A systematic review of related literature on the subject was utilized in this work. Evidence from the scholarly materials point to the fact that freshness, safety, and marketability of agricultural products are all impacted by transportation, which is an essential link between producing locations, storage facilities, and marketplaces. Conversely, in Nigeria, transportation related problems in agricultural production include poor road networks, insufficient logistics organization, inadequate cold-chain facilities, and lack of handling facilities. These had resulted in substantial post-harvest losses, especially for perishable farm products like fruits, roots, vegetables, fish and animal products. These elements lower the nutritional and aesthetic value of produce by causing biochemical deterioration, microbial infection, and mechanical damage. The study also revealed that enhancing packaging systems, temperature control, and transportation infrastructure are important ways to reduce losses. Ultimately, the research concludes that well-organized and sustainable transportation structures are essential to improving agricultural products' nutritional quality, storability, and profitability for economic growth and food security.

Keywords: Road Transportation, Postharvest Handling, Logistics, Quality, Losses, Safety

1.0 INTRODUCTION

Nigeria's agricultural sector is a cornerstone of the nation's economy, providing a significant source of income and labor, contributing approximately 25% to the GDP, and employing roughly 60% of the population (CBN, 2025). Post-harvest losses (PHL) refer to the extent and quality of crop yield loss, between the point of harvest and the consumption point, mainly caused by deterioration and other anthropogenic actions (Urugo et al., 2024). In the agricultural sector, PHL are one of the major challenges, leading to a drastic reduction in the quantity and quality of crops produced. The FAO stated that about 30% of the food produced globally is lost due to food waste, with PHL contributing a large percentage of the amount (Ijabo et al., 2019; Debebe, 2022; Lahiri et al., 2023). This results in food insecurity, causing a reduction in food availability, economic losses to the farmers, and greater strain on the food supply networks. Food spoilage is a threat to public health, which poses many health risks, nutritional deterioration, and food contamination (Idama and Uguru, 2021; Ibrahim et al., 2022; Vutula, 2024; Erokare et al., 2024). In developing countries like Nigeria, PHL has exacerbated food insecurity problems, mainly due to inadequate social infrastructure, poor transportation systems, and lack of food processing and storage practices (Rahman et al., 2024). Transportation plays an essential part in post-harvest losses, since most of the crops production regions are far from the markets and processing industries. Poor transportation networks - roads, rails and waterways (Figure 1), tend to prolonged transit times

and mechanical stress to the farm products (Al-Dairi et al., 2022; Apubeo, 2022; Olabosinde, 2024; Erokare et al., 2024). This results in mechanical damage, which has the ability to degrade the marketable quality of produce, and facilitates its susceptibility to microbial spoilage (Owusu-Kwarteng et al., 2020; Idama et al., 2021). The World Bank diagnostics indicate that a significant portion of Nigerian postharvest losses occurs during transport, handling, and storage stages of the value chain (Japan International Cooperation Agency, 2024). Furthermore, environmental conditions such as temperature and relative humidity during the transportation process - especially when cold chain facilities are absent and in the case of highly perishable agricultural products, might hasten degradation, dehydration, or microbial growth (Figure 2). These issues, which emphasize the interaction between infrastructure and post-harvest results, are particularly noticeable in rural areas with little access to dependable transportation networks (Hoffmann et al., 2024).

Aside from physical and pathogenic losses assisted by various processes, poor post-harvest operations greatly affect the biochemical qualities of food items. The macronutrients of essential diets - such as vitamins, fats and oils, and proteins, are susceptible to oxidative degradation when exposed to light, oxygen, or high temperatures (Ali et al., 2022; Rajeev et al., 2022; Uguru et al., 2023; Ibrahim et al., 2024). Such losses have significant economic repercussions, including lower resource efficiency, higher food costs, and decreased farmer profitability. A comprehensive strategy that incorporates appropriate effective transportation and prompt market access is needed to address the challenges linked to post-harvest losses (Péra et al., 2023). Therefore, it is essential to comprehend the extent and reasons behind post-harvest losses in order to create efficient interventions that guarantee food security, cut waste, and enhance the standard of living for those involved in agriculture. The integrity of fruits and vegetables might be further jeopardized when they are transported on subpar roads or in unfavorable weather circumstances like intense rain (Rajapaksha et al., 2021; Nath et al., 2024).

Figure 1: Rural farm roads (source: Apubeo, 2022)

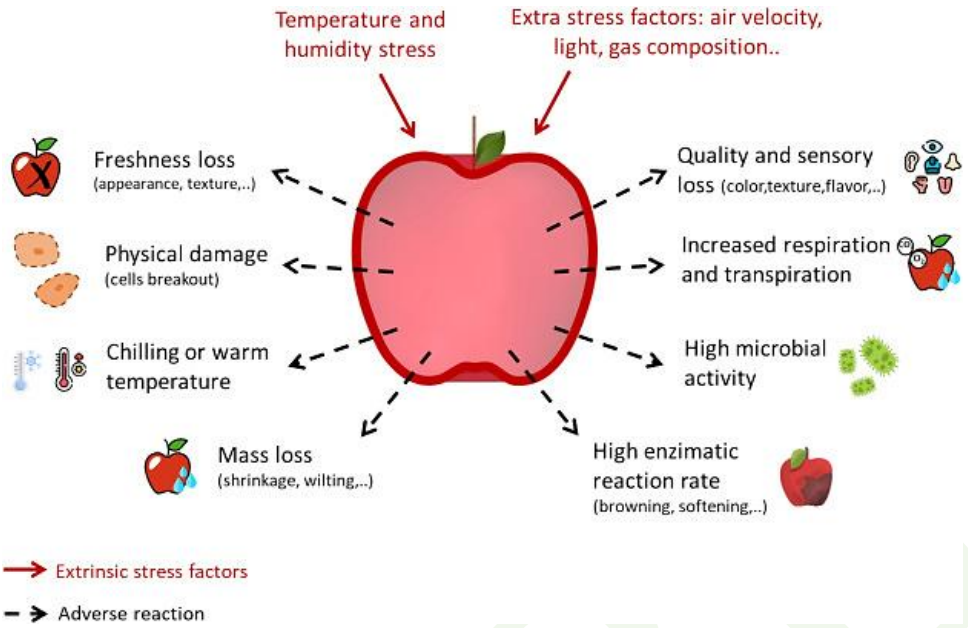

Figure 2: Air temperature and relative humidity stress (Source: Hoffmann et al., 2024)

2.0 OVERVIEW OF AGRICULTURAL POST-HARVEST PRODUCTS

Agricultural post-harvest products are the agricultural products that have been harvested and are undergoing food chain operations. These operations include handling, processing, refining, storage, transportation, and marketing operations (Rajapakshe et al., 2025). With respect to most of these products' intrinsic perishability, which tends to result from their divergent morphological and physiological characteristics, this has led to massive food spoilage (Idama and Uguru, 2021). The maximum post-harvest food spoilage tends to occur mostly in root crops, fruits and vegetables. The variety of agricultural commodities grown in various ecological zones, such as grains, legumes, tubers, fruits, vegetables, livestock products, and fisheries, is reflected in the variety of post-harvest products.

2.1 Cereals and Legumes

Cereals and legumes such as rice, maize, millet, wheat, cowpea, soybean, and groundnut (Figure 3), are rich in carbohydrates, protein, and vitamins. They are among the major staple foods in African and Asian countries (Vilakazi et al., 2025). Legumes contain bioactive compounds that play important roles in human health and productivity. These phytochemicals help prevent chronic illnesses and their associated risk factors, such as cardiovascular disease, diabetes, and cancer (Foyer et al., 2016; Kumar et al., 2022; Abushal et al., 2024). Legumes are now widely cultivated globally, even in regions with poor soils and little rainfall, due to the increasing demand for cereals and food insecurity (Adhikari et al., 2017). Despite typically having longer shelf lives than perishables, these goods are still susceptible to both quantitative and qualitative losses as a result of pest infestations, changes in moisture content, and inadequate storage conditions.

Figure 3: Cereal and legumes (source: Vilakazi et al., 2025).

2.2 Root and Tuber Crops

Root and tuber crops are rich in carbohydrates but have lower concentrations of proteins and vitamins. These crops include cassava, yam, cocoyam, potato, and sweet potato (Figure 4). These crops play a substantial role in the global food security structure, as they are major staple foods in the world, particularly in Latin America, Africa, and Asia (Akpokodje and Uguru, 2019; Otekunrin et al., 2021). Basically, these crops nutritional composition are influenced by their varieties, cropping pattern, and field practices. For example, yam and cassava are regarded mostly for their calorie content, whereas sweet potatoes provide significant levels of β-carotene (Ijabo et al., 2019). These crops are highly perishable after harvest due to their physiological traits and high moisture content. Thus, to increase shelf life of roots and tuber crops, and to reduce food wastage, appropriate handling and efficient transit are crucial (Tomlins et al., 2000; Kuyu et al., 2019; Tunde and Adeniyi, 2012).

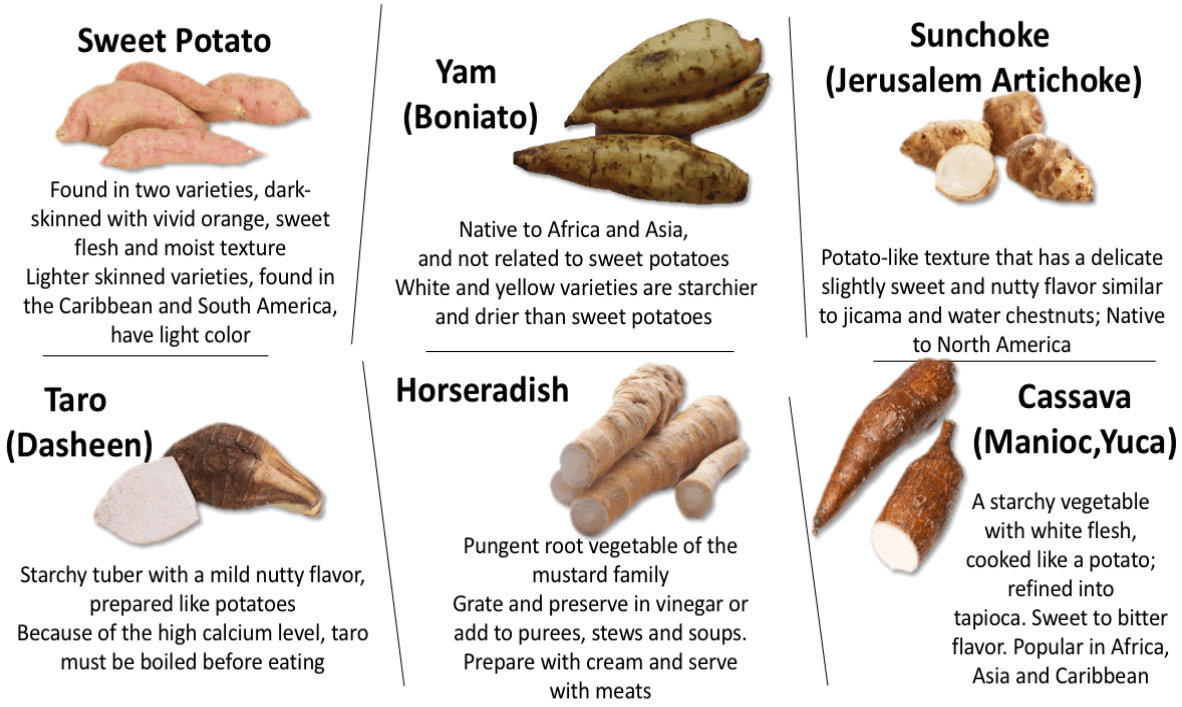

Figure 4: Roots and tuber crops (Source: Culinarypro, 2025)

2.3 Fruits and Vegetables

Fruits and vegetables, which consist of okra, mangoes, carrots, citrus, and leafy greens (Figure 1), are major sources of the human diet. These crops are rich in essential vitamins, antioxidants, and other bioactive compounds (Ekruyota et al., 2021; Ciccoritti et al., 2024). Phenolic acids, flavonoids, anthocyanins, and carotenoids are examples of phytochemical substances found in fruit and vegetable by-products that have drawn a lot of attention because of their potential health advantages. Their antioxidant, antibacterial, antidiabetic, anti-obesity, anti-inflammatory, and anti-carcinogenic qualities were shown in a number of in vitro and in vivo investigations (Banerjee et al., 2017; Coman et al., 2020; Rajeev et al., 2022).

However, most fruits and vegetables are very susceptible to spoilage, primarily due to their high respiration rates, sensitivity to mechanical damage, and vulnerability to microbial putrefaction (Lorenzo et al., 2018). Typically, bruises, cuts, punctures, compression, and tension that crops undergo during harvesting or transportation operations tend to cause rupture of fruit and vegetable cells, leading to rapid microbial growth and hastening decay (Balali et al., 2020; Hussein et al., 2020; Uguru et al., 2022). The relevance of cold chain systems in contemporary supply chains is highlighted by the fact that poor transportation methods frequently hasten ripening and degradation since temperature, humidity, and ventilation are critical factors in maintaining their freshness (Skawińska and Zalewski, 2022). This explains why great losses are recorded when fruits and vegetables like tomatoes, mangoes, avocado, watermelon, etc. are transported from one part of the Nigeria to another.

Figure 5: Fruits and vegetables (source: Ciccoritti et al., 2024)

2.4 Livestock and Fisheries Products

Animals and their products provide essential nutrients that are difficult to obtain from plants and plant-derived foods in human diets (Abdulfattah et al., 2025). Livestock and fish products, such as meat and fish (Figure 6), are highly perishable because of their high levels of moisture content and protein, which provide a suitable environment for microbial activity. Blood, viscera, and muscle tissue are all considered parts of the animal that make up meat. In terms of cultural food, marine mammals are likewise regarded as meat (Speranza et al., 2021; Cuchillo-Hilario et al., 2024; Alharthi et al., 2025). In many low and middle-income countries, insufficient preservation and transportation systems have resulted in rapid food spoilage, decreased nutritional value, and complimented health issues (Fanzo et al., 2023).

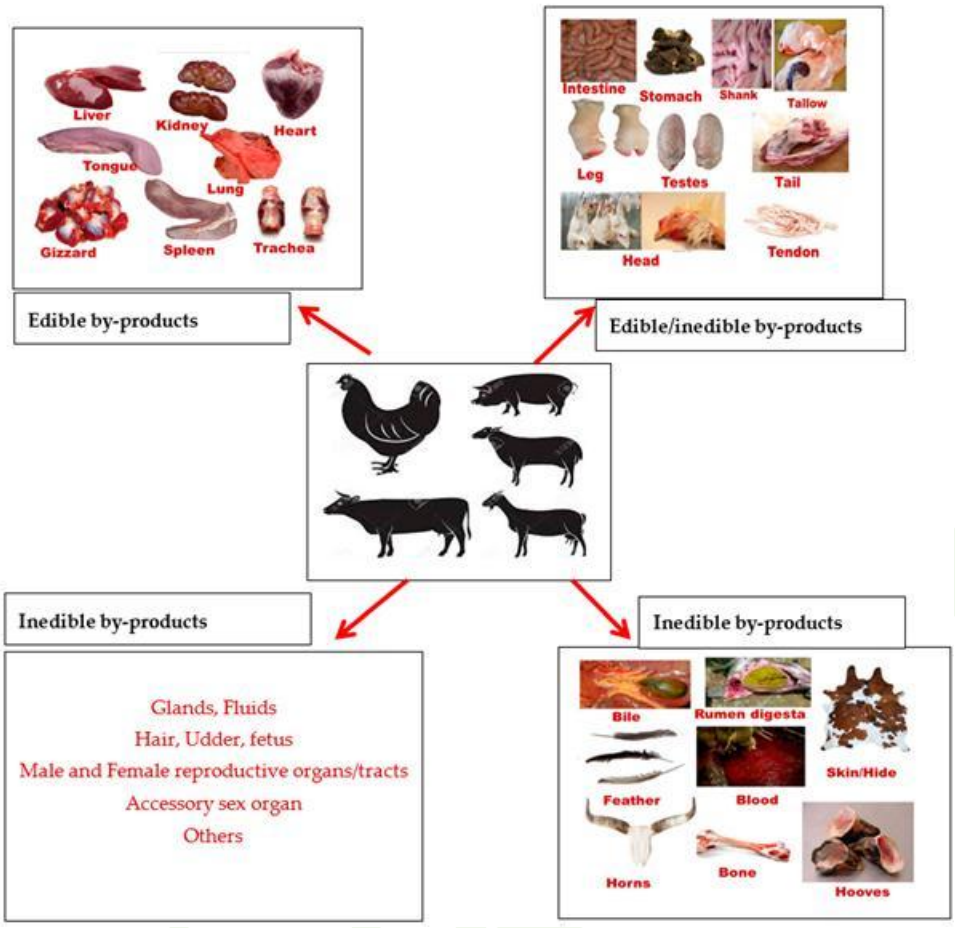

Figure 6: Animal and its products (Source: Alao et al. 2017)

3.0 TRANSPORTATION IN AGRICULTURAL SUPPLY CHAIN AND FACTORS AFFECTING IT

Adequate rural-urban road transportation system is very crucial for the functionality of agricultural business, particularly in developing and underdeveloped countries with poor storage and processing facilities (Kaiser and Barstow, 2022). According to Ajiboye and Afolayan (2019), farmers' socioeconomic status can be improved by adequate transportation system, as this can boost economic focus, facilitates contact between geographical and economic regions, and widens the agricultural produce market net. This is because a proper transportation network simplifies the movement of workers and farm inputs/outputs; hence, it encourages farmers to work harder in rural areas, leading to increased productivity, improved consumer preference for their products, decreased spoilage and waste, and a positive impact on their income and poverty reduction (Yusuf, 2020; Ako and Wanie, 2022). The bad conditions of Nigeria roads are affecting crops production and smooth running of the marketing channel (Figure 7 and 8). Most significantly, farmers can easily convey their raw agricultural materials from their farms, to the processing factories and enterprises, with access to affordable road transportation system (Chakwizira et al., 2010; Zakaree, 2022; Erokare et al., 2024).

Figure 7: Nigeria bad roads (source: ThisDay, 2023)

Figure 8: Nigeria bad roads (source: Independent, 2025)

Additionally, apart from bad roads, the transportation of agricultural products in Nigeria is currently facing several challenges such as poor logistics systems, human errors and high fuel costs (Ugwu et al., 2025). However, there are a number of issues with Nigeria's road infrastructure, such as inadequate maintenance, bad road conditions, and inadequate financial commitment (Bwanbale, 2024). Perishable farm produces such as tomatoes, fish, fruits, vegetables, and dairy products are particularly susceptible to this transportation problem (Figure 9), since they quickly decay if they are delayed or subjected to adverse transit circumstances. In addition to restricting farmers' access to markets, the absence of dependable and reasonably priced transportation choices lowers their earning potential and deters large-scale production (Khalid et al., 2024).

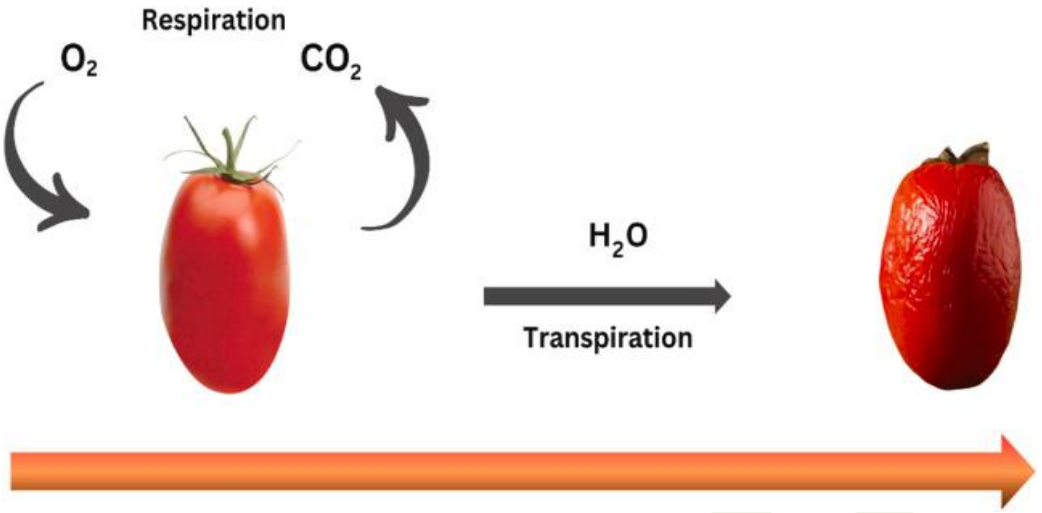

Figure 9: The process of tomato degradation (Source: Bwanbale, 2024).

The main obstacle to the efficient distribution and marketing of agricultural products has been found to be inadequate road infrastructure, which increases post-harvest losses, raises transportation expenses, and limits farmers' access to markets. Nigeria's ineffective transportation system hinders the competitiveness of locally produced goods and raises operating expenses, which have an impact on agro-industrial growth (Tunde and Adeniyi, 2012). Farm inputs such as labor and other equipment can be easily transported to rural farms where they can be utilized to increase productivity with the help of an efficient transportation system. Additionally, in order to achieve the demands of industry and households, farm produce - some of which are perishable, must be transported in big quantities at a reasonable cost and on time (Zakaree, 2022). The implementation of rail cargo services, refrigerated vehicles, and cooperative transport systems can all help to lessen these problems by lowering expenses and losses (Figure 10).

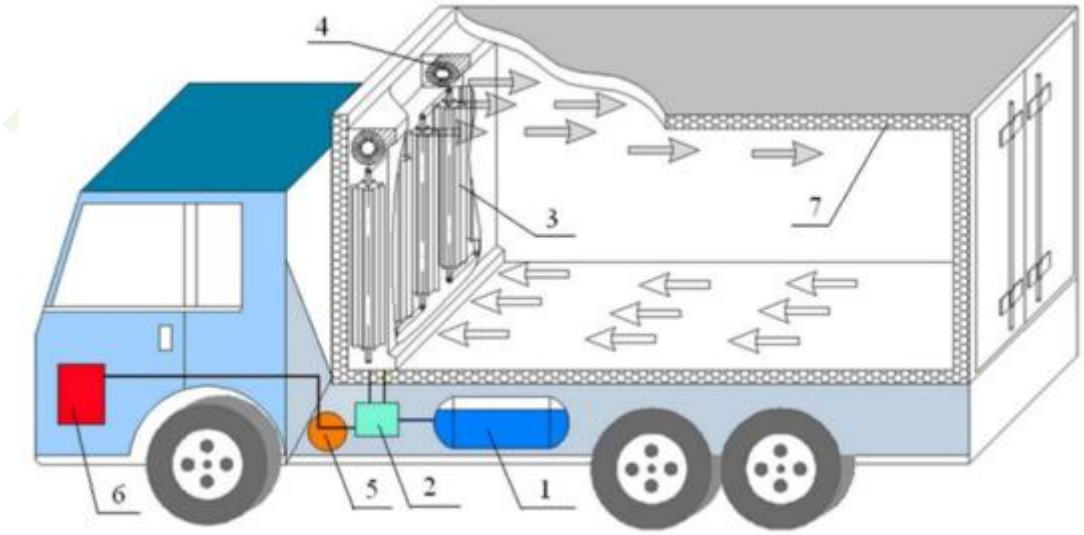

Figure 10: The schematic diagram of a light-duty LNG-chilled refrigerated vehicle (source: Maiorino et al., 2021).

4.0 FACTORS AFFECTING POST-HARVEST QUALITY DURING TRANSPORTATION

A substantial challenge in developing countries like Nigeria, where poor handling and insufficient infrastructure are common, is the post-harvest quality degradation of agricultural products during transportation. Agricultural produces spoilage is usually exacerbated by poor packaging, microbial contamination, humidity, mechanical damage, and temperature swings. Temperature and humidity are critical environmental conditions that play essential roles in preserving the produces nutritional quality and freshness, mainly of perishable farm produce. Prolong elevated temperatures and lower relative humidity, which are usually associated with poor transportation network, tend to hasten respiration, moisture loss, and enzymatic reactions of the produce (Figure 11). This results in wilting, shriveling, microbial invasion and spoilage of the farm products (Gidado et al., 2024). Additionally, higher relative humidity levels have the ability of enhancing fungal growth and microbial activity in mainly farm products. These issues are made worse by Nigeria's transportation system's absence of cold-chain amenities like refrigerated vehicles, particularly for goods that are sensitive to temperature (Zhou et al., 2024).

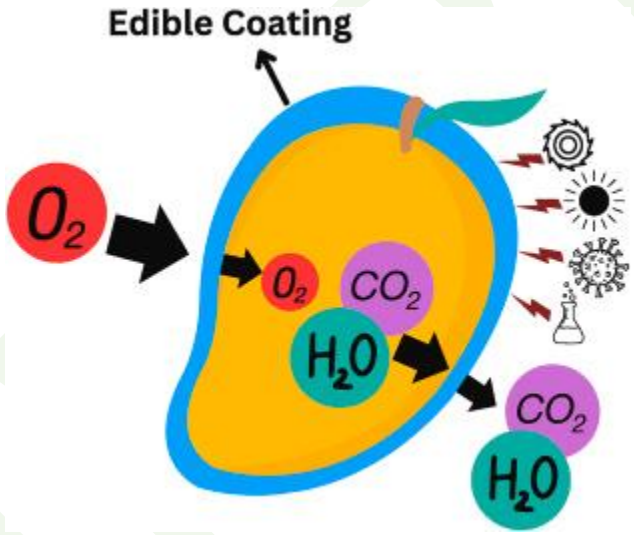

Figure 11: Biochemical changes on fruit due to environmental conditions (source: Gidado et al., 2024).

Furthermore, mechanical damage is another substantial factor that influences farm products durability during storage. Serious vibration which is usually associated with poor transportation networks; tend to cause bruises, cuts, and crushes of fragile farm products. These mechanical damages lower the visual appearance of farm products and create entry points for microbial invasion, leading to lower nutritional quality. Additionally, post-harvest quality can be further compromised by extended transportation times and delays brought on by traffic, bad vehicle maintenance, or insufficient logistics planning, which can result in biochemical changes and a decline in market value. Bulk transportation of grains and tubers leads to excessive vibration that usually results in compaction, segregation, mechanical damage and packaging failure. When the engineering properties of agricultural products are not known or applied in handling the products, the resultant effect is postharvest losses. Consequently, many authors have argued in favour of the determination of engineering properties of agricultural products to understand the best way to

handle the product without causing damage (Benestante et al., 2023; Dickson et al., 2023; Zhu et al., 2023; Chandio et al., 2021; Sheikh et al., 2021; Fayed et al., 2020; Jahanbakhshi et al., 2020; Ndukwu et al., 2019; Abodenyi et al., 2018; Davies, 2018; Igbozulike & Aremu; 2009; Aydin, 2007). These properties such as porosity, true and bulk densities, coefficient of friction, hardness, compressive strength, shear strength, rupture force, modulus, size and shape, angle of repose have great influence on the design of equipment for efficient handling of agricultural materials.

In sum, transportation-related postharvest losses are influenced by multiple interacting factors such as road conditions, travel distance, vehicle roadworthiness, mode of loading, produce maturity, sorting practices, and the engineering properties of produce. Figure 12 provides a conceptual visualization of the relative influence of these factors, based on widely reported postharvest handling principles.

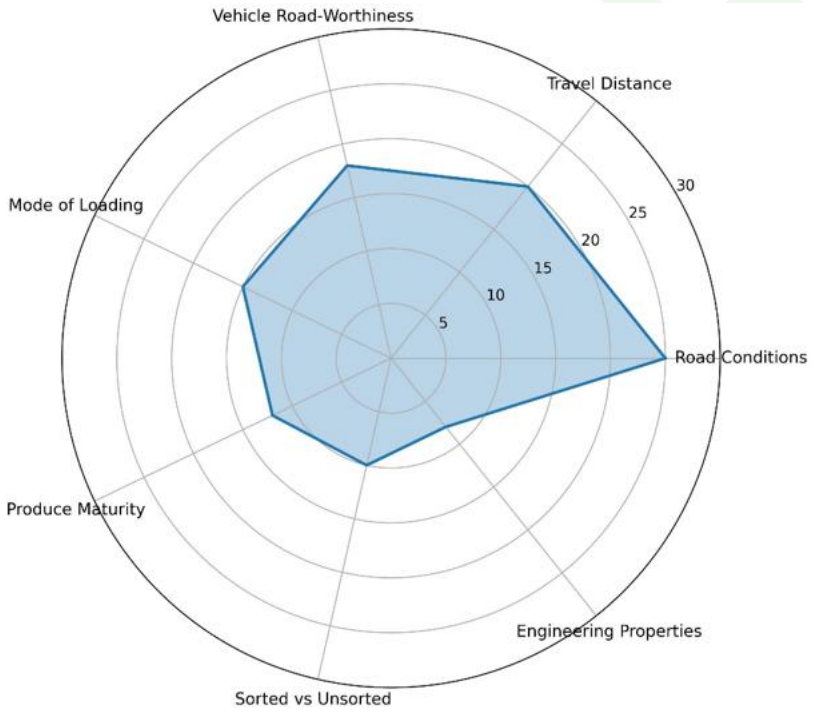

Figure 12: Hypothetical radar chart illustrating the relative contribution of transportation-related broad factors to postharvest losses in fresh agricultural produce.

5.0 CONCLUSION

Agricultural products are inelastic, and when excessive forces beyond their yield point are exerted on them during transportation, their internal and/or external structure are ruptured. Often, the internal structure rupture is invisible to the eyes but serves as the starting point for deterioration and eventual postharvest loss. Transportation plays an essential role in evaluating the post-harvest nutritional quality, market worth, and general profitability of agricultural products. Ineffective transport systems can contribute immensely to the mechanical damage, food wastage, and nutrients deterioration of farm products, mostly the delicate and perishable ones. These problems are predominantly serious in under-developed nations including Nigeria, where infrastructural and logistical restraints hamper the smooth flow

farm products from the farm settlements to the markets. Poor rural roads and logistics inefficiencies are specifically identified as key contributors to 30 – 40 metric tonnes of postharvest losses in Nigeria that is estimated to about 3.5-5 trillion Naira in 2025 alone (Abuh, 2025; Adigun, 2025; Essiet, 2025).

Enhancing the transport system, utilization of refrigerated vehicles, as well as adopting modern handling and packaging technologies, are very crucial in reducing post-harvest losses. Thus, improving the agricultural value chain, guaranteeing food security, lowering financial losses, and fostering the general expansion and competitiveness of the agricultural industry all depend on efficient and ecological transportation systems.

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