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Exploring post-harvest losses and waste in tomato supply chains: Insights from Kaduna State, Nigeria

A thesis submitted for the degree of Doctor of Philosophy in Environmental Geography

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Abstract

In recent years, academics from various disciplines, such as local and international organisations, have shown an increasing interest in food waste. Concerns over food security and environmental implications have heightened interest in the subject. While food waste happens at every stage of the food supply chain, researchers are yet to identify the primary generators of food waste as the evidence about the causes of food waste remains fragmentary. Reducing food losses and waste is one of the best ways to improve food security in the coming decades. This study aimed to investigate tomato waste along the supply chain in Kaduna state, Nigeria, using the mixed method approach for data collection. The mixed method approach allowed for a more comprehensive analysis of the complex factors contributing to tomato waste, providing valuable insights into the challenges faced by the tomato industry in the region. The research focuses on waste in the tomato supply chain using the "follow the thing" approach developed by Ian Cook.

The aim was to identify the waste that occurs at different supply chain stages. The study involved a survey of 64 farmers, 27 intermediaries, 47 traders and 38 consumers, and interviews with key stakeholders in the tomato industry. The data collection was analysed using both qualitative and quantitative methods. The results showed that the highest amount of tomato waste was generated by farmers, followed by intermediaries and traders. The waste is generated primarily due to overripe tomatoes, damaged tomatoes, and inadequate storage facilities. The study also identified several possible waste reduction techniques to improve the sustainability of the tomato supply chain in Kaduna State. The study highlights the need for effective waste management strategies and improvements in infrastructure and training for farmers to improve the sustainability and economic viability of the industry. The results of this research will be helpful for policymakers, agricultural practitioners, and other stakeholders in the agricultural sector to improve the efficiency and sustainability of the tomato supply chain in Nigeria.

CHAPTER 1: Introduction

This thesis provides a comprehensive examination of waste and losses of tomato along the supply chain in Nigeria. It aims to identify the stakeholders, actors and the major areas where losses and waste occur along the tomato supply chain before and after tomato produce gets to the consumer. A "follow the thing approach" (Wanasuk, 2019; Ugoh, 2018; Cook and Harrison, 2007; Cook, 2004) was the main framework used in the research. The 'Follow the thing approach' provided the research with a framework focused on PHL, revealing different perspectives to understand regional dynamics. A geographical 'Follow the thing approach' allowed the 'technical value chain' and showed how the commodity chain system engages with a series of actors or stakeholders. It was significant in providing an easy way of following a particular product within a geographical region, providing applied research deficient in its PHL literature.

1.1 Overview of the impact of food loss and waste

The volume of food loss and waste (FLW) generated globally may not be recorded accurately due to ambiguity, differing definitions and available data: estimates are sometimes criticised due to lack of actual measurement (Crist *et al*., 2017; Tendall *et al*., 2015; Parfitt *et al.,* 2010). There is research that focuses on commodity chain stakeholders from production to consumption (e.g. Clarke *et al*., 2011) and how these actors in the supply chain affect each other. However, the bulk of research relating to food is on meeting the demand of the growing global population, to set targets, for example "by 2050" (Bahar *et al*., 2020; Costello *et al*., 2020; Pastor *et al*., 2019; Berners-Lee *et al.,* 2018; Xie *et al*., 2018; Hunter *et al*., 2017; King *et al*., 2017; Van *et al*., 2016; Koo and Taylor., 2015; Mainuddin and Kirby., 2015; FAO, 2008). Sustainably feeding a population predicted to be 9.5 billion people by the year 2050 is predicted to be the big challenge of our time (King *et al*., 2017). This challenge encompasses agricultural production and its attendant environmental effects, population growth, natural resource scarcity (particularly soil), competing demands (e.g., biofuel production) and climate change (Mckenzie *et al.,* 2017; Koo and Taylor., 2015). However, waste and loss feature less prominently in such debates.

Despite the measurement problems mentioned above, there is evidence of substantial loss and waste of food every year. Estimates vary between 25-50% of global (approximately 1.3 billion tonnes) production (Nicastro and Carillo, 2021; Ananno *et al*., 2020; David *et al*., 2019;

Gustavsson *et al.,* 2011;). Food loss and waste is in part a substantial economic cost because of the waste of resources that are used up in producing something that does not deliver any nutrients or calories (Ananno *et al*., 2020). Production and distribution of food is today on a global scale, as food produced in Africa can end up being consumed - for example - in the United Kingdom (Garnett *et al*., 2020; Conway, 2019; Crist *et al*., 2017). The cassava grown in the soils of Africa can end up on the consumer's table in Asia.

The relationships between chain actors have been largely overlooked, causing misunderstanding of how the commodity system works and affects chain actors. As noted above, much of food-related research relates to production, distribution, and consumption (Sen *et al.,* 2021; Timiryanova *et al.,* 2020; Wanasuk, 2019; Erisman *et al.,* 2018; Gunawan, 2017). However, if the estimates of food waste and loss cited earlier are realistic, increasing agricultural productivity alone will be a sub-optimal approach to sustainably meeting the demands of a growing global population: there is also a need to reduce waste and losses in the food supply chain (FSC) (Bantoyehu *et al.,* 2019). Urbanisation is one reason for the expansion of the FSC, but this has also caused an increase in the amount of food loss and waste. Furthermore, the expansion of commerce and large-scale distribution has led to the replacement of traditional retailers with supermarkets. This has increased trends towards higher quality products that have also been associated with an increase in the amount of food waste (Nicastro and Carillo, 2021).

For example, expanding commerce and long-distance distribution networks to meet urban demand can introduce inefficiencies in the food supply chain. Delays, mishandling, or inadequate infrastructure can spoil and waste perishable products like meat and farm produce (Puram *et al*., 2022). Urban consumers seek fresh, high-quality food products. However, fresh fruits, vegetables, and bakery products typically have a shorter shelf life. The focus on quality and freshness can lead to higher levels of waste as these products have a limited window for consumption and are more likely to be discarded if not sold within a short time frame.

The terms "food waste" and "food loss" are often used together, but they have different meanings from the view of the Food and Agriculture Organization of the United Nations (FAO 2019). Food loss refers to reduced quantity or quality of food during production, post-harvest, and processing stages. This can occur due to poor harvesting methods, inadequate storage and transport, and spoilage during processing. In contrast, food waste refers to throwing away or

repurposing food that is still fit for human consumption, which typically happens during distribution and consumption (FAO 2019). Reducing food loss and waste is crucial for addressing global food insecurity and reducing the environmental impact of food production. The causes and impacts of food loss and waste vary depending on the location and stage of the food supply chain. In low-income countries, most food losses occur during the processing and post-harvest stages, while in low-income countries, most losses happen during the distribution and consumption stages. Different regions may need solutions, such as improved transportation systems or consumer education programmes (FAO 2019).

Food waste has considerable economic, social, and environmental effects. It leads to the inefficient use of resources, such as land, water, and generates greenhouse gas emissions contributing to climate change (FAO, 2019). Otherwise, food waste occurs when food is discarded at the retail, consumer, or institutional levels, such as households, restaurants, or schools, due to reasons like overproduction, expiration dates, or aesthetic imperfections. Therefore, it is essential to differentiate between food loss and food waste as they require different interventions and solutions. Addressing food loss requires reducing losses during production and post-harvest processing while tackling food waste requires minimising waste generation and promoting responsible consumption patterns.

According to FAO (2014) food loss before it reaches the consumer is significant and post-harvest losses in low-income countries can be up to 50 per cent of total production. In confirmation of these global trends, Mckenzie *et al.* (2017) and Parfitt *et al.* (2010) studied post-harvest losses between high income and low-income countries. The nature of food losses in developing countries changes as they grow economically and get better infrastructural techniques that improve their agriculture. In developing countries with poor post-harvest infrastructure, most of the food waste is found at harvest and post-harvest stages. In contrast, food waste occurs at retail and consumer levels in countries with more advanced infrastructure (Parfitt *et al.,* 2010). While consumer waste is higher in high and middle-income countries, post-harvest losses (PHL) are higher in low-income countries. Even advancing countries find it difficult to reduce food losses and waste because of changes in diet composition especially in economic transition countries such as Brazil, India, or Russia (Nicastro and Carillo, 2021). As educated and enlightened as the developed world is, it still wasted around 670 million tonnes of food (worth approximately US $ 680 billion, Save Food, 2015).

It is important to note that the impact of COVID-19 on food loss and waste has varied across regions and sectors (Iranmanesh *et al.*, 2022). While some areas experienced increased food waste due to the disruptions, others witnessed a renewed focus on reducing waste and implementing more sustainable practices. Panic buying at the beginning of the COVID-19 outbreak raised severe concerns about a potential rise in food waste levels and higher pressure on waste management systems. However, studies suggest that the COVID-19 pandemic has reduced household food waste in numerous countries. Changes in shopping behaviours, including improved planning and inventory management, increased focus on home cooking, and efficient utilisation of leftovers, have played a vital role in this reduction. These behavioural shifts highlight the adaptability of individuals in times of crisis and the potential for sustained positive changes in food consumption and waste management practices (Iranmanesh *et al.*, 2022).

Food loss and waste vary in different stages within the FSC, and the production stage is regarded as an essential point for food loss, especially during product processing. PHL occur from the point of production to retail and consumption points. PHL can be crop and region specific (Stathers *et al.,* 2020; Humble and Reneby, 2014) for example, fresh foods such as fruits and vegetables that are easily perishable are characterised by higher losses. The amount of loss will not be the same amongst tubers, roots, fruit and vegetables, and grains at different stages in the FSC, making the system complicated to explore (Ugoh 2018). The high climatic condition and humidity in developing countries negatively affect food preservation in the early stages of the FSC due to poor infrastructure and management, errors in processing, harvesting, and storage methods. Specific problems include a lack of transportation, improper handling, pests and disease, physical damage, microbial deterioration and lack of market networks (Joardder and Masud, 2019; Ugoh 2018; Humble and Reneby, 2014; Parfitt *et al.,* 2010).

The dearth of research in PHL in developing countries has left a gap in the PHL data collection systems (Ugoh 2018; Parfitt *et al.,* 2010), with available research using different methodologies. Understanding the dynamics of PHL requires a vital analysis of the production, handling, and supply chain of a particular product in a region at a given time or season. There is variation in the supply of products and variability in the quality of products due to the different seasons, climate conditions and technology used in growing products. Many small-scale farmers producing for local markets are dependent on intermediaries and traders for purchase (Humble and Reneby, 2014). In many developing countries the need to improve post-

harvest technology and to have reliable supply chain management is evident to further reduce PHL (Humble and Reneby, 2014).

1.2 Background to the study

Nigeria is a country with a potential irrigable land area of about 3.14 million hectares, with varied ecologies and climate conditions suitable to produce vegetables and fruits all year round (Adelodun, and Choi, 2018). Nigeria is the second-largest producer of tomato in the continent after Egypt and 14th largest tomato producer globally (Adigun *et al*., 2018; Babarinsa *et al*., 2018; Dandago *et al.*, 2017;). With a growing capacity of 2.3m tonnes annually, Nigeria contributed 1.2% of the world's output in 2016 (Babarinsa *et al*., 2018). Nigeria is a country where the tomato is widely consumed; however, about 1.3 million tonnes of locally produced tomato go to waste annually (Adenuga *et al*., 2013). After harvest, between 40% and 50% of domestic production goes to waste, with some cases experiencing more than 50% loss, as Adeoye *et al*. (2009) stated. According to a Federal Ministry of Agriculture and Rural Development report, Nigeria spends about $360 million annually importing tomato paste and puree and concentrates on meeting local demand (Kok *et al*., 2019). In 2017, the tomato supply chain caused a loss of around 45% of the local produce, according to Kok *et al*. (2019).

As with research globally, research on waste and loss of tomato has suffered neglect in Nigeria when compared to the study of its production. Research on the PHL of tomatoes in Nigeria is limited, despite the country's status as a major producer in Africa. Ashinya *et al*. (2021) identified a significant gap in knowledge regarding the measurement and characterization of tomato PHL in Nigeria. They emphasized the need for further research to develop effective strategies for reducing waste. Similarly, Korie *et al*. (2022) highlighted the need for more research on the causes of PHL in Nigerian tomatoes, particularly concerning transportation and storage, which hampers developing and implementing effective waste reduction measures. Ibrahim *et al*. (2022) and Ali *et al*. (2021) also stressed the need for more research on the economic impact of PHL on smallholder tomato farmers and other stakeholders in Nigeria, given the limited attention given to this issue (Korie *et al*., 2022). The limited research on PHL in Nigeria has significant implications for the country's agricultural industry, the environment, and the economy. Efforts to reduce PHL in the tomato sector can increase the availability of fresh produce, enhance farmers' livelihoods, and reduce greenhouse gas emissions associated with food waste. Therefore, there is a pressing need for more research on PHL in Nigerian

tomatoes to facilitate the development of effective strategies for reducing waste and promoting sustainable agricultural practices.

1.3 Research problem

As Nigeria's population is growing, so is the need for food. Much is done to provide the people with their needs by increasing yield, production, and food supply (Lopez *et al*., 2019). Nevertheless, little has been done to trace how these food supplies end up on consumers' tables and research on post-harvest waste and loss is lacking (Adekalu *et al*., 2019). Most of the available research refers to generalised farming issues and does not give attention to the specific problems of a particular region or area (Stathers *et al.,* 2020). The solution for food security is not just to increase agricultural yield. Reduction of food waste and loss is also essential. Nigeria has not addressed the problem of food waste and loss to any great extent (Adesina 2012). Most of the intervention programmes organised by both local and international organisations are focused on grains, roots and tubers and not perishable products. The emphasis on grains, roots and tubers in intervention programmes by local and international organizations can significantly impact food loss and waste in Nigeria (Adesina 2012).

These crops are commonly considered staple foods in Nigeria. Their shelf life is more protracted than perishable products like fruits and vegetables, making them less susceptible to spoilage and easier to store for extended periods. However, perishable products have a shorter shelf life. They are more prone to spoilage and waste, particularly in Nigeria, where inadequate storage and transportation infrastructure often result in post-harvest losses. By focusing solely on grains, roots, and tubers, local and international organizations may neglect the issue of food loss and waste in Nigeria's perishable product supply chain, which could lead to economic losses for farmers and traders and a missed opportunity to improve food security and nutrition. Organizations must include perishable products in their intervention programmes to address this issue and provide training and resources to farmers and traders on proper storage, transportation, and processing techniques. This approach can help to reduce food loss and waste in the perishable product supply chain and enhance the sustainability of Nigeria's food system.

Illustrative of the problem are comments to the author made by the Chairman of Horticulture at the Federal Ministry of Agriculture, Abuja. He testified that there is no record relating to any vegetable or fruit PHL across the country in his office. Institutions such as the Nigerian Defence Academy, Kaduna State Polytechnic, Kaduna State University were also visited and staff had

similar perspectives: for example, they had no records of undergraduate theses on PHL of any fruit or vegetable. The lack of data in this field shows a lack of awareness of the problems food waste and PHL impose.

1.4 Aims and Objectives

The research aims to examine the tomato supply chain in Nigeria to identify causes of waste and post-harvest loss. This will be achieved through the following objectives.

- Critically review the supply value chain in Nigeria and identify the main actors.
- Examine key points along the value chain where losses and waste occur.
- Explore the challenges and causes of tomato waste at different points in the supply chain, as well as its impact on the environment.
- Identify approaches to reduce post-harvest losses and waste in the tomato supply chain in Nigeria.

1.5 Justification of the research and methodological approach

Waste represents a financial loss to farmers and other actors in the supply chain and an economic loss through wasted resources used in production. With respect to Nigerian tomatoes, actors through the chain are often small-scale (farmers and traders) and thus waste has a particularly negative impact on their livelihoods. As argued, there is a lack of research on waste; this does not imply that it is not important. Despite the lack of research, waste and loss have seen some attention in recent years: scholars such as Kirgeir *et al*., (2020); Elik *et al*., (2019); Porat *et al*., (2018) and Kumar and Kalita (2017) have pointed out problems of post-harvest losses and identified ways to reduce waste, such as through proper handling and better storage. Organisations such the FAO have emphasised the importance of food waste in developing countries (Levernz *et al*., 2019; Maestre *et al*., 2017).

This study involves following the tomato from the point of harvest to the consumer. It adopted a commodity centred approach to research as used by Ian Cook to study the papaya (Cook *et al*., 2004). The ‘Follow the thing approach’ provides the research with a framework focused on PHL, revealing different perspectives to understand regional dynamics. The 'Follow the thing approach' is a research framework that focuses on tracing and analysing the supply chain of a particular product, from its origin to the final consumer, to uncover the various actors, relationships, and power dynamics involved in its production and consumption (Goodman *et*

al., 2010). This approach is beneficial for investigating food loss and waste issues because it can reveal where and how waste occurs within the supply chain.

In the context of the tomato supply chain in Kaduna, Nigeria, the 'Follow the thing approach' could be used to trace the journey of tomatoes from the farms to the markets and investigate the various actors and power dynamics involved at each stage. For example, the approach could be used to understand how tomatoes are harvested, transported, and stored and identify any inefficiencies or waste at each stage. Using the 'Follow the thing approach,' researchers can gain different perspectives on the tomato supply chain in Kaduna, which can help reveal the regional dynamics of food loss and waste (Bammann 2019). For instance, they may discover that farmers need access to proper storage facilities or that there is a need for refrigerated transportation to preserve the quality of the tomatoes during transit. Alternatively, they may uncover the influence of powerful intermediaries in the supply chain who control prices and create a situation where farmers are forced to sell their produce at low prices, leading to financial losses and waste.

Overall, the 'Follow the thing approach' provides a valuable framework for investigating food loss and waste issues in the tomato supply chain in Kaduna and can reveal different perspectives on the regional dynamics of this supply chain. By better understanding the actors, relationships, and power dynamics involved in the supply chain, researchers can develop more targeted and effective interventions to reduce food loss and waste and support the sustainability of the tomato supply chain. The Nigerian food supply chain is not all that complicated, as most of the food and fruit items are sold within local markets, which makes tracing the chain simple. The supply chain stakeholders are the farmers, intermediaries, traders and consumers. This research studies the supply chain as a complete system, pointing out the underlying operational dynamics and where PHL occur. The value chain does not reveal the operations that occur concurrently, but it is a way of understanding the social interactions between actors and PHL along the supply chain. The approach is suitable because it shows the relationship between actors and how tomatoes are transported from one stakeholder to another.

Drawing from interviews conducted in this research, the presence of Africa’s largest tomato processing factory did not stop local farmers in the study area from losing 30-40% of their products annually. The factory has since closed due to government restrictions on food importation, among other problems. The 1200 tons per day processing factory was only able

to run at 20% due to inadequate supply of tomatoes from local farmers (Fresh Plaza 2021). Interviews with respondents in this research indicate that the government has yet to provide a lasting solution to post-harvest losses. The study reveals the waste beyond the farm to the consumer in order to provide a complete picture of waste generated throughout the supply chain. Food waste research should include consumers, especially in developing countries, to get a sense of the entire waste generated after harvest. This study of PHL in Nigeria provides applied on a specific fruit in a particular geographical region. The research reveals the realities of tomato losses in Nigeria, their impact on the environment and actors, highlighting commonly ignored problems and contributing to the pool of knowledge on tomato post-harvest losses. It is hoped that it will help to bring about a better relationship within the immediate actors and bridge the gap that has been existing for a long time.

1.6 Structure of the thesis

This PhD thesis is structured into ten chapters, with a clear introduction and conclusion. The first chapter introduces the research concept, providing an overview of the study's context and research issues. The second chapter presents an in-depth literature review, clarifying the definitions of food waste and food losses and identifying the difficulties and challenges in the agricultural environment. The third chapter examines the research's theoretical framework and the conceptualisation of commodity networks, exploring qualitative, quantitative, and mixed research approaches, ontology, and epistemology. Ian Cook's global commodities chain and follow-the-thing approach are also explained. The fourth chapter discusses the research methodology, sample technique, study region, and data collection, including questionnaire administration, data analysis, data validity, and data reliability. Ethical considerations, challenges, and limitations are also examined.

Chapter five provides an overview of the benefits of tomatoes to the body, how tomato nutrients can benefit humans, and the difficulties associated with planting, storing, and harvesting tomatoes. The sixth chapter presents the farmers' statistics, examining the outcomes of farmers in various regions and seasons and identifying the sources of post-harvest losses and waste generated by farmers in Kaduna state, the research area, across seasons and regions. Chapter seven explores the findings from the perspective of intermediaries, explaining how farm gate activities and transactions affect the price and transit of tomatoes from the farms to the markets, with intermediaries identifying the most significant causes of tomato post-harvest losses. Chapter eight examines the traders and how they sell tomatoes in the research region,

identifying distinct groups of traders and highlighting financial, security, and market issues. The customer survey outcomes are presented in chapter nine, focusing on consumer satisfaction and consumers' waste and losses of tomatoes. Finally, chapter ten summarises all findings and explores the thesis' contribution to the pool of knowledge and its limitations. Research gaps are identified, and opportunities for further study are highlighted.

CHAPTER 2: Review of related literature

2.1 Introduction

This chapter delves into food waste, building upon the concepts introduced in Chapter 1. It examines the global scale of food waste generation and highlights the difficulties in accurately documenting it due to the various definitions employed. The chapter also elucidates the distinction between food loss and waste, shedding light on their implications. Furthermore, it explores food and agriculture challenges, particularly within the supply chain context, and introduces the concept of post-harvest losses. The chapter analyses the historical and current state of post-harvest losses, along with implementing policies to reduce food waste.

2.2 Exploring food waste

Food can be thought of as any product or substance- whether processed, unprocessed, or partially processed - that is expected to be consumed by humans. (Stenmarch *et al*., 2016). Due to ambiguity in food waste definitions and the lack of readily available food waste data, it is possible that the total volume of food waste generated worldwide will not be accurately documented (Crist *et al*., 2017; Tendall *et al*., 2015). According to the Food and Agriculture Organization of the United Nations (FAO), around 1.3 billion tonnes of food are wasted each year, accounting for approximately one-third of all food produced for human use worldwide (FAO, 2011). Food waste may be caused by various circumstances, including insufficient packaging, improper handling, and other actions across the supply chain (e.g transportation and distribution). Further, waste has environmental implications and can place a financial burden on consumers and producers.

According to various studies, food waste is a significant global problem, with developed countries estimated to waste $680 billion and developing countries wasting $310 billion of food annually (Jribi *et al.*, 2020; Berjan *et al*., 2018; Finn, 2013). While both worlds waste similar amounts of food per capita, consumers in Europe and North America generate much more food waste than those in Sub-Saharan Africa, South Asia, and Southeast Asia (FAO, 2019; Lipinski *et al*., 2013). Fruits, vegetables, tubers, and roots are the most wasted food groups globally, with cereals wasting around 30%, root crops and fruits and vegetables wasting between 40-50%, oilseeds, meat, and dairy products wasting 20%, and seafood wasting 35%. The economic impact of food waste is significant, with the global economy predicted to have lost $750 billion in 2007 due to food waste (FAO, 2013). In the UK, household food waste has a retail value of around £12 billion, with each household wasting between £4.80 and £7.70

worth of food per week, equivalent to £250-£400 per year or £15,000-£24,000 over a lifetime (Quested *et al*., 2011; WRAP, 2007).

For restaurants in the UK, food waste costs around 2-3% of their revenue (Sustainable Restaurant Association, 2010). Preventable food losses have a direct and detrimental effect on farmers' and consumers' incomes, particularly smallholders living on the edge of food poverty. Therefore, reducing food waste could immediately and considerably impact their lives. In total, the amount of food wasted globally is equal to half of the world's crop production, which is approximately 2.3 billion tonnes per year (Berjan *et al*., 2018; Finn, 2013; Gustavsson *et al*., 2011; Lundqvist *et al*., 2008)

> *"Food loss is defined as losses in the course of preparation and post-harvest processing, while food waste refers to wastage during distribution and consumption stages"* (Mak *et al*., 2020:3).

Food loss refers to a decrease in the quantity or quality of food due to decisions and actions taken by food suppliers across the supply chain, omitting retailers, food service providers, and consumers. Food waste is defined as the quantity or quality of food due to retailers, food service providers, and consumer decisions and behaviours. The terms "food loss" and "food waste" have been used interchangeably in some cases; however, specific definitions exist; these differentiate between different stages of the Food Supply Chain (FSC). The FSC is the route food follows from the point of production to end consumers, A supply chain is comprised of buyers, sellers, storage, transportation, processing, standardisation (e.g., size, quality marks), financing (e.g., money for a pick-up), risk bearers (the agent who puts up the money for the pick-up), and market intelligence (e.g., price forecasts for tomatoes next season). Where these are lacking, the market will be less effective, increasing the likelihood of loss. The likelihood of waste may grow or decrease - more affordable food may mean that consumers are more prone to waste it.

According to Berners-Lee, *et al*., (2018) transition to an ecological global food system will be more challenging as the world's population grows. A widespread belief is that the global food supply is enough to feed the world's populace now, with timely distribution necessary to avoid hunger (World Hunger Organization, 2016), but that food production must significantly improve in the coming decades (Röös *et al*., 2017; Food and Agriculture Organization of the United Nations, 2009) as the global population grows to 9.7 billion in 2050 (United Nations

Department of Economic and Social Affairs, 2015). However, increasing production will not necessarily solve the challenge of sustainably producing enough food for the world's growing population, as there is a border to the potential for efficiency gains, and many of these come with increased environmental costs, and increasing agricultural area through land-use change almost always results in biodiversity loss. Changes in consumption patterns may also have negative environmental consequences, such as increased worldwide meat consumption (Röös *et al*., 2017). In both the developed and developing countries, food waste has been linked to global challenges: as agriculture and fisheries extend, the result is overexploited natural resources, forest and marine habitats and a loss of biodiversity.

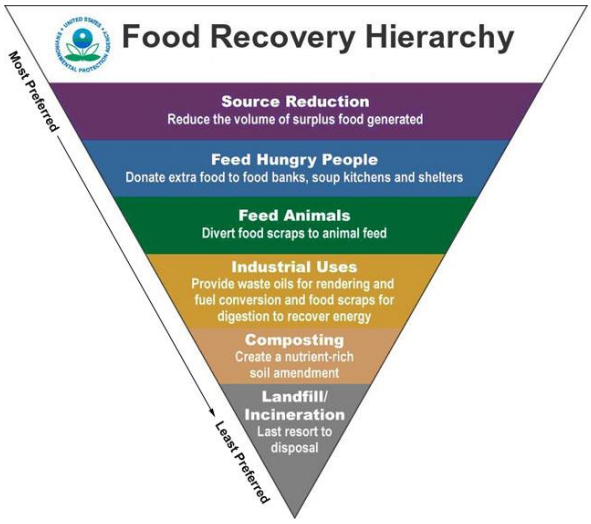

Figure 2.1: The food recovery hierarchy

Source: (Gusinja, B., 2018)

The food recovery hierarchy outlines the preferred methods of managing and reducing food waste. It is divided into six stages, with source reduction being the most preferred and landfill/incineration being the least preferred (Gusinja 2018). Prevention at the source is prioritized by reducing overproduction or improving storage and transportation. Donating to food banks or using waste for compost are options only after source reduction. While feeding hungry people is desirable, source reduction is still a better option than relying on food donations to address food waste issues (Gusinja 2018).

2.2.1 Waste

Descriptions from different research organizations have described waste in different ways. The definition of waste can commonly be found in dictionaries (e.g., Collins Dictionary, Oxford English Dictionary and American Heritage Dictionary), government and organization reports,

encyclopedias and others to mention but a few. The European Union (EU) Waste Framework Directive (WFD) of 1975 defines waste as "anything the people get rid of and is no longer useful to their livelihood" (Malinauskaite *et al*., 2017). The scope of waste processes is essential because a lot has been said and discussed as to what constitutes waste. Arah *et al*., (2015) suggest that all economically unusable by-products that are no longer needed at any time or place or anything that is rejected intentionally or accidentally in the environment is regarded as waste. Malinauskaite *et al*., (2017) stated that the primary definition of waste by the WFD has not changed from as far back as 1975.

The EU waste directive also states that something may be excluded in the definition of what constitutes waste, and some examples of such exceptions are radioactive waste, gaseous emissions, wastewater, decommissioned explosives, and specific natural non-dangerous items. They argue that such substances belong to a different legal definition. The Longman dictionary of contemporary English defines waste as the substance that is left over or unwanted material that was used for something (Arabs *et al*. 2015). Food, housing, and transportation are the three sectors within the EU that account for approximately 70% of the total environmental effect of human consumption and production (Cakar *et al*., 2020; Conrad *et al*., 2018; Tukker *et al*., 2010).

2.2.2 Definitions of food waste

The literature contains some distinct definitions of food waste. To begin, the Food and Agriculture Organization (FAO) defines food waste as nutritious edible material meant for human use that is thrown, lost, degraded, or devoured by pests at any point along the FSC (FAO, 1981). Second, Stuart (2009) expands the FAO's definition of food waste by arguing that it should consist of edible stuff that is purposely fed to animals or that is a by-product of food processing that is diverted away from the human food chain. Thirdly, Smil (2002) proposes that food waste encompasses the preceding definitions but also includes overnutrition, the difference between the energy value of food consumed per capita and the energy value of food required per capita. The EU food waste term stands for all food products and content that is being discarded instead of being used for human consumption. A food supply chain (FSC) is made up of all the parties involved in the coordinated manufacturing and value-adding activities required to manufacture food products (FAO, 2022).

The FUSION definitional framework states that food waste refers to any food or inedible portion of food that has been taken from the food supply chain to be recovered or discarded (Cerciello *et al*., 2019). However, many researchers argue that this definition may exclude food loss at on-farm pre-harvest, processing, storage, and post-harvest levels. Stuart's (2009) definition encompasses additional potential for food surplus and waste management, as it comprises food losses due to animal nurturing and the diversion of food industry by-products. Food waste relate to the loss of edible food mass during in the human FSC (Gustavsson *et al*., 2011). Food waste can be a result of many factors and behaviours connected to numerous aspects of the FSC: it does not have to be an 'unusual' activity. As such finding a theoretical framework that fits all the elements may be impossible (Secondi *et al*., 2015).

Food waste can occur during and after harvest, marketing of the food produced, or limitations in packaging that results in exposure of the goods at different points along the FSC. Food waste can also be a result of an individual's actions such as discarding eatable food for consumption or not minding the implications of discarding waste into the environment. Farm resources are also used to produce feed for animals and, increasingly, bioenergy crops: it has been argued that these also constitute 'waste' given that they are not consumed directly by humans (Kennard 2019; Diaz Ruiz., 2018; Girotto *et al*., 2015). The problem of food waste is growing, and it affects everyone involved in the food supply chain, from farmers and manufacturers to retailers and end-users. Sustainable solutions need to be found for all these people. Several solutions can be used to make sure that food waste is properly managed, and they can be ranked in a similar way to waste management (Diaz Ruiz., 2018; Girotto *et al*., 2015).

Eliminating all food waste may be unachievable and reducing the food waste beyond a certain level will incur more cost and may not be sustainable (Diaz Ruiz., 2018). Food waste problems have been acknowledged globally Garrone *et al*., (2014) and the available scientific literature on the subject demonstrates that researchers and policymakers frequently use and define the same phrases differently ("possibly avoidable food waste," "preventable food waste," "food loss," "unavoidable food waste," and "food waste," for example). Additionally, the definition of food waste influences how policies are created and how food waste is quantified across the many sectors of the food supply chain. (Fusions 2014). Food waste research is loaded with several definitions.

Food losses are generally generated due to lapses and problems found within agricultural and technological processes; it is the reduction of food in quantity in the supply chain after harvest

before the food is presentable to the consumer. The losses happen at post-harvest stages in the supply chain during activities such as processing, distribution, handling, storage, and transportation (Kennard 2019; Parfitt *et al*., 2010; Parfill 2010; Lundwsit *et al*, 2008). Food waste is largely seen to be caused by the final consumer or the retail operations. This is food of the right quality to be eaten but discarded for one reason or the other (Parfitt *et al*., 2010). The term potential food loss and waste can be said to be crops or food items that have been left in the field and not harvested for some reason, they are left there to rot either on purpose, through lack of good management or lack of a market. This can also include loss of crops because of pests and diseases and other post-harvest problems that lead to e.g., rotting, unsatisfactory appearance, or reduction in yield (Kannard 2019).

2.3 Issues and challenges for food and agriculture

The global food system has a significant impact on the environment, through water abstraction, biodiversity loss, water and air pollution, soil degradation, land use change, and greenhouse gas emissions (Cameira and Santos, 2019; Pereira 2017). Agriculture's primary challenge is to produce enough food to feed a growing population while addressing environmental issues such as a decline in critical ecosystems services; it must do this within a wider environment characterised by, droughts, climate uncertainty, urbanization, poverty, variable supply, and growing competition for water and land (Cameira and Santos, 2019; Pereira 2017).

2.3.1 Agriculture and climate

Agriculture is responsible for approximately 22% of global greenhouse gas (GHG) emissions, with animal production contributing about 18% (FAO., 2022; Parker *et al*., 2018; Froemelt *et al*., 2018; Balafoutiset *et al*., 2017; Lundqvist *et al*., 2008; McMichael *et al*., 2007; Steinfeld *et al*., 2006). Reducing food waste can lead to a significant reduction in GHG emissions, as Barrett and Scott (2012) estimate a potential decrease of 456 million tonnes by 2050 in the UK alone. The Waste and Resource Action Programme (WRAP) reported that unnecessary food waste generated 17 million tonnes of CO2 equivalent emissions in 2010, equivalent to the emissions of one in every five cars on UK roads (WRAP, 2011). WRAP, a registered charity established in 2000, aims to promote and accelerate the transition to a resource-efficient economy while protecting natural resources.

Food products in Germany are ranked second regarding resource use and potential environmental impact across the manufacturing cycle (Moll and Jose, 2006). The food sector

in the EU is projected to contribute to around 22% of the region's global warming potential (Slorach *et al*., 2020; Salemdeeb *et al*., 2017). The MENA region, vulnerable to climate change, water scarcity, and food shortages, requires special attention. The local economy in MENA relies heavily on oil and gas production and agricultural activities sensitive to climate change (Mahlooji *et al*., 2020). Furthermore, the region's economic hubs are located along the coastlines, which are susceptible to rising sea levels. The anticipated consequences of global warming in the MENA region are expected to have significant social, economic, and ecological implications, leading to greater energy insecurity (Mahlooji *et al*., 2020).

The Middle East and North Africa (MENA) region makes a significant contribution to global greenhouse gas (GHG) emissions (Mahlooji *et al.*, 2020). Food waste has several environmental impacts, including the depletion of natural resources such as energy, water, and soil nutrients, as well as the disruption of biogenic nitrogen and phosphorus cycles associated with using fertilizers in agriculture (Rockström *et al*., 2009; Smil, 2002). Additionally, food waste can lead to environmental pollution throughout the food supply chain, mainly through waste disposal (FAO, 2014; Lundqvist *et al*., 2008; Lundie and Peters, 2005). Food waste also has social consequences that revolve around ethical and moral considerations, particularly regarding the discrepancy between wasteful practices and food poverty (Evans, 2011; Stuart, 2009; Wrigley, 2002) and are well documented in the literature.

As the issue of global food security gains more attention, reducing food loss and waste in the food supply chain and exploring alternative diets are seen as essential steps towards achieving food security. Edwards and Mercer (2007) examine the ethics of food waste and discuss the emergence of "freeganism" and "gleaning" movements in Australia as alternatives to current consumption patterns. These movements consume discarded food to reduce environmental impact and address food insecurity. Gregson et al. (2007) highlight the tension between social values associated with frugality and environmental values linked to reuse and the implications for waste generation and avoidance. Haberl *et al*. (2011), Schönhart *et al*. (2009), and Engström and Carlsson-Kanyama (2004) also emphasize the value of lowering food loss and waste and developing alternative diets in achieving global food security.

According to Evans (2011), frugality is the practice of consuming resources, products, and money carefully and sparingly, emphasising waste prevention and prudent consumption. Evans argues that frugality is associated with sustainable consumption practices and has a moral dimension. In particular, frugality is associated with preventing food waste and the belief that

wasting food is morally wrong (Parfitt *et al*., 2010). Evans (2012) identifies the specific material culture of food waste as a challenge to its reuse and recycling. Gregson *et al*. (2013) highlight the importance of social context in transforming surplus into waste.

2.3.2 Environmental, economic and social implication to food waste

In recent decades, food waste has become a significant concern for environmental organizations, policymakers, analysts, and researchers (FAO, 2014). According to the US Environmental Protection Agency (EPA), it is the most significant single type of waste which ends up in landfills, according to the US Environmental Protection Agency (EPA), and reducing and diverting it has become a priority due to its negative impact on global climate change and other environmental issues. Food waste's economic, environmental, and social impacts are significant (Evans, 2011; WRAP, 2011; Morrissey and Browne, 2004). Overproduction of food leads to excessive use of natural resources, including land, water, and fossil fuels, resulting in unwarranted depletion. Food waste also releases methane and carbon dioxide during the natural decomposition process in landfills, which increases greenhouse gas (GHG) emissions and exacerbates climate change (Morone *et al*., 2019).

For consumers experiencing food poverty, the aim is to have access to nutritious, safe, and affordable food products. Food insecurity is often an access issue related to purchasing power and food prices rather than a supply issue. Improving the efficiency of the food supply chain (FSC) could reduce the cost of food for consumers and increase access. Investment in loss reduction could be a way to reduce food costs, given the scale of food losses. The EPA urges food producers, retailers, and the food service industry to reduce food waste to achieve significant cost savings in purchasing costs and final waste disposal costs (EPA, 2003, 2012). The UNEP stresses the economic benefits of resource efficiency and waste reduction, as it can lead to cost savings, new business opportunities, and increased employment and competitiveness (UNEP, 2011). Food waste's final disposal in landfills is a significant environmental consequence, as it produces methane and carbon dioxide during natural decomposition. Methane is more potent than carbon dioxide, trapping 21 times more heat (Adhikari *et al*., 2006).

The waste sector is projected to contribute approximately 3% of global GHG emissions, with the same percentage applying to the UK (Defra, 2011; UNEP, 2010; Stern, 2006). According to Defra, food waste is a priority waste stream for intervention, accounting for nearly half of all CO2 emissions linked with waste in the UK (Defra, 2011). Food waste also has an

environmental impact due to the carbon incorporated in the food during its life cycle stages before becoming waste. Agriculture (including land use change), processing, manufacturing, shipping, storage, refrigeration, distribution, and retail all have an inherent GHG impact (Padfield *et al*., 2012; Tuncer and Schroeder, 2011; Lundqvist *et al*., 2008).

2.3.3 Food safety and related issues

Improper use of agricultural pesticides and antibiotics and contamination of land and water can also contribute to food waste (Franz *et al*., 2018). For example, crops may be rejected for sale or consumption due to excessive pesticide residue or other contaminants, leading to unnecessary food waste. Additionally, food products contaminated with harmful bacteria or other pathogens may need to be discarded to avoid the risk of foodborne illness, resulting in further food waste. Therefore, addressing issues related to food safety can also help reduce food waste and improve the overall sustainability of food production. Each year, approximately 351,000 people die from food poisoning, and over 582 million cases are documented globally. Food production can result in dangerous food if agricultural pesticides and antibiotics are used improperly or excessively, or if the land or water used is contaminated. Food safety issues have increased as food production has become more industrialised and integrated into globalised networks (Aworh, 2021; Franz *et al*., 2018).

Due to increasing consumer concerns about food safety, analytical chemists strive to ensure that food is safe for consumption. The presence of harmful compounds in food can result from their use or misuse during food production or their formation during food processing or storage. Consequently, food safety laboratories face the challenge of detecting a diverse array of chemical compounds in complex matrices of both plant and animal origin, which require high levels of concentration sensitivity and selectivity (Hernández-Mesa *et al*., 2017). All foods are subject to general food labelling regulations, and any labelling must be accurate and not misleading (Food Standards Agency, 2022). According to the Food Standards Agency, pre-packaged food products must have a mandatory food label that includes specific information. Food labels must also indicate a "best before" or "use-by" date to show how long the food can be stored and how to preserve it properly. Use-by dates are a significant contributor to food waste.

Food makers use use-by dates to indicate when a product is no longer safe for human consumption. Even though the item is still safe to eat, consumers are sometimes cautious about consuming food beyond their use-by dates. This causes perfectly edible food to be discarded,

contributing to the problem of food waste (Food Standards Agency. 2022). Also, some consumers may need to comprehend the distinction between use-by and best-before dates. Best-before dates indicate when a product's quality has diminished, but it is still safe to consume. However, many people discard food products after their best-before dates, even though the food may still be edible (Food Standards Agency. 2022).
In addition, businesses may contribute to food waste by throwing food products past their expiration dates, even if they are still safe to consume. This may occur due to liability worries or a desire to maintain a high-quality standard. Hence, perfectly edible food may be discarded, contributing to the problem of food waste.

2.3.4 Animal welfare, livestock production and food waste

Animal welfare and animal rights perspectives also relate to food waste. In meat production, animal welfare advocates argue that the high mortality rate in concentrated feeding lots and the stress of transport and slaughter negatively affect animal welfare (Lionch *et al*., 2017; Dawkins, 2016). They propose reducing meat consumption, improving animal welfare standards, and increasing the use of alternative protein sources to reduce animal suffering. On the other hand, animal rights advocates oppose using animals for any purpose, including food production, and argue that reducing meat consumption is not enough. They promote a vegan or plant-based diet as the only solution to ending animal exploitation (Joy, 2020; Lionch *et al*., 2017).

Food waste is a significant concern in meat production, with estimates suggesting that up to one-third of all food produced for consumption is lost or wasted globally (FAO, 2011). Animal welfare and animal rights advocates argue that reducing meat consumption can help address food waste by decreasing the resources used to produce meat. Additionally, animal welfare advocates suggest improving meat production practices to reduce the number of animals raised and slaughtered unnecessarily. Animal rights advocates propose a shift towards plant-based diets, arguing that reducing the demand for animal products would lead to fewer animals being raised and slaughtered. Animal welfare and animal rights perspectives have significant implications for meat production and consumption, including their impact on food waste (Firdaus and Mclean., 2022; Lionch *et al*., 2017; Dawkins, 2016). Both perspectives propose reducing meat consumption and improving animal welfare standards. However, animal rights advocate further promote a vegan or plant-based diet as the only solution to ending animal exploitation. Addressing food waste in meat production will require considering these

perspectives and exploring alternative protein sources that are both sustainable and humane (Firdaus and Mclean., 2022).

The animal welfare perspective advocates for humane treatment of animals so that their welfare is not jeopardised, and no needless pain or suffering is inflicted. Some members of society are opposed to humane treatment of animals (Madzingira, 2018). They believe that animals should be granted basic rights to protect them from human abuse. These are animal rights activists who see animals on an equal footing with humans and are opposed to any type of animal exploitation. An animal rights perspective is an ethical approach that recognises non-human animals as having rights in addition to the animal welfare considerations. Some of these rights are equivalent to those accorded to humans (Madzingira, 2018).

2.3.5 Climate change

Climate change exacerbates pre-existing obstacles and issues in food production. Increased frequency, duration, and severity of extreme weather events, rising sea levels, and variations in temperature, evaporation, humidity, and rainfall will all influence the amount of food produced, as well as its affordability and physical accessibility. The increase in droughts and dry spells, which damage both crop and livestock output, is of special concern. Areas with existing high levels of food insecurity are projected to be disproportionately affected by such developments (Ali *et al*., 2017). Additionally, the crops that may be cultivated in specific places, the way ecosystems function, and the types of pests and diseases that exist may change. Desertification is expected to result in a loss of agricultural land. Even small changes in temperature can have a significant effect on crop production. As a result, the variety of meals available to meet various micronutrient requirements and the food's safety may decline. Simultaneously, the effects may benefit plant development because of the increase in atmospheric carbon (Ali *et al*., 2017).

2.3.6 Population growth and urbanisation

By 2050, the world's population of 7.3 billion is predicted to reach 9.6 billion, and a growth of one billion is projected during the next 15 years. Most population growth will occur in emerging countries, most notably in Sub-Saharan Africa. Urbanisation is anticipated to accelerate to the point where 70% of the world's population will live in cities, up from 49% currently. Rural populations, particularly agricultural villages, are predicted to dwindle. Urbanization is displacing agricultural land uses. All these causes will contribute to an increase

in food demand and the FAO estimates that food production must increase by 70% between 2007 and 2050 and that present production levels in developing nations must nearly double (Tripathi *et al*., 2019). By reducing food waste, we can increase food availability, thereby reducing the number of people who go hungry. According to the FAO (2011), if global food waste were reduced by just one-fourth, it could feed an additional 870 million people.

2.3.7 Volatile food prices

According to a United Nations Food and Agriculture Organization report, volatile food prices can significantly impact food waste (FAO, 2018). Food prices are volatile and there are indications that this volatility is increasing, increasing food poverty and civil instability. Prices are projected to be highly volatile and elevated not just in the near term, but also in the medium to long term, because of climate change. Food prices are out of reach for lower socioeconomic classes. Food prices are always volatile due to supply shocks (Ukraine) and price inelastic demand for food (people want food even though there is a shortage and thus will pay a lot to obtain it as there are no substitutes for food, unlike other goods). When food prices are high and unstable, it becomes more difficult for people to afford the food they need, leading to increased food insecurity and malnutrition. Conversely, when food prices are low and stable, it can lead to overproduction and waste, as farmers may need help finding it financially viable to harvest or transport their crops to market (FAO, 2018).

When food prices are high and unstable, consumers may opt for cheaper, less nutritious foods or reduce the amount of food they purchase and consume, leading to malnutrition. Retailers and food service providers may also overestimate demand and order more food than they can sell, resulting in unsold food that goes to waste. Similarly, when food prices are low and stable, farmers and retailers may produce or order more food than they can sell, resulting in food waste. This can happen when farmers have excess crops because they are confident, they can sell them or when retailers order more food than they need to take advantage of low prices. Overall, volatile food prices can contribute to food waste by creating imbalances in supply and demand that result in excess food that is either not sold or not consumed. Recent, substantial spikes in food costs were caused by a variety of variables, including growing biofuel markets, increased investor speculation about the price of agricultural commodities, macroeconomic issues, and inadequate emergency and price stabilisation food stocks (Hunt *et al*., 2021).

In June 2010, a "flash drought" began, and it quickly got worse and spread across a large part of western Russia. By early July, almost all of Russia's major wheat-growing areas were under a lot of water stress. The timing of the flash drought was terrible because it happened at the same time as both winter and spring wheat crops were beginning to bloom. As a result, the top wheat-producing areas saw their yields fall by almost 70%, and total wheat production fell by 20 million metric tonnes because of the drought (MT). Russia limited wheat exports in early August 2010 because of its new Food Security Doctrine. Russia had a significant drop in wheat production, which led to a big drop in world wheat stocks. The world's wheat stocks fell quickly, which led to a rise in wheat prices worldwide. Wheat prices rose quickly because of the worsening of the drought in Russia (Hunt *et al*., 2021).

As a result of volatile food prices, Kalkuhl *et al*., (2016) argued that volatility must take into account the policy situation. When food prices rise, political leaders' influence may be questioned. In India, rising onion costs influenced election results. Thousands of people took to the streets of Port au Prince and Algiers in 2008 to protest rising food prices. In April 2008, rising food prices prompted Haiti's prime minister to resign, while protests for political change erupted in numerous Arab countries. Bangladesh, Côte d'Ivoire, Egypt, Indonesia, Uzbekistan, and Yemen all experienced societal and political unrest due to the 2007/2008 crisis. As a result of increased food costs, several other countries have seen violent food riots, rallies, or societal unrest (Kalkuhl *et al*., 2016).

2.3.8 Resource scarcity and pollution

Resource scarcity and pollution are significant global challenges that are closely linked to the issue of food waste. The scarcity of resources, particularly land, freshwater, energy, and genetic materials, significantly constrains food production. Inefficient food production and consumption practices deplete natural resources and increase the environmental impact of agriculture, resulting in resource scarcity and pollution (FAO, 2019). This, in turn, intensifies the demand for freshwater, energy, and land, further exacerbating the issue of resource scarcity. Additionally, food waste in landfills contributes to greenhouse gas emissions, aggravating pollution. Agriculture is the largest consumer of freshwater and a significant contributor to the degradation of surface and groundwater. It is also the primary land use on the planet, contributing significantly to soil degradation and deforestation (FAO, 2019).

Human activities such as population growth and land use competition have led to land scarcity and the conversion of wildlands to agriculture, resulting in land use and cover changes. This intensified during the Anthropocene Age, with agriculture significantly contributing to the intensification of human impacts on land and natural resources (Kanianska, 2016). The use of agricultural pesticides and other synthetic inputs has significant environmental and public health consequences, including water and air contamination (Dinar *et al*., 2019). Agriculture is a major contributor to greenhouse gas emissions, with emissions from the farm gate and land use changes totalling 9.3 billion tonnes of CO2eq in 2018, primarily due to enteric fermentation, manure deposition, and deforestation (FAO, 2022).

Climate change has implications for agricultural productivity, with farmers facing increased risks and unpredictability from warming, shifting rainfall patterns, and extreme weather events. However, agriculture also has significant potential for greenhouse gas reduction, using agricultural leftovers in biorefineries as a promising alternative to fossil fuels (Kanianska, 2016). While emissions associated with deforestation have declined, those associated with the drainage and burning of organic soils have increased globally by roughly 35% since 2000 (FAO, 2022). In Africa, farm-gate and land use-related emissions have increased by 38% and 20%, respectively, over the same period. Given the significant impact of agriculture on the environment and public health, it is essential to prioritize this sector in economic and environmental policy (Kanianska, 2016).

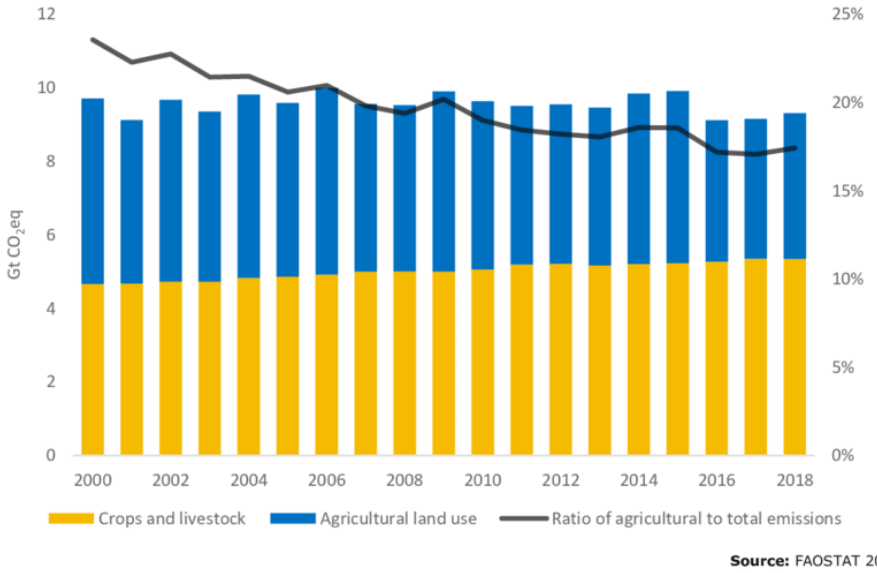

Figure 2.2: Yearly emissions from crops and livestock and related land use and share of agriculture in global GHG emissions from all sectors, 2000–2018

Source: (FAO., 2022)

2.3.9 Corporate concentration

Corporate concentration in the food industry is a significant issue related to food waste. According to a report by the Institution for Agriculture and Trade Policy (IATP), a small number of large food corporations dominate the food industry, controlling most of the global food supply chain (IATP, 2019). This concentration of power can lead to practices prioritising profit over sustainability and contributing to food waste. For example, supermarkets often reject perfectly edible produce that does not meet strict cosmetic standards, leading to unnecessary food waste (IATP, 2019). Additionally, large food manufacturers may prioritise the production of highly processed, packaged foods that have a long shelf life but are not necessarily nutritious, leading to a waste of resources and contributing to the problem of obesity and other diet-related health issues. Food production on a global scale, and indeed food chains in general, are dominated by a few transnational firms. Chemical businesses have surpassed seed companies as the primary purchasers of agricultural commodities, and the same companies that purchase agricultural commodities also mill, ship, and sell them as livestock feed or cereal. This is a concern for farmers and consumers alike, as it may - and possibly already has - resulted in competition concerns with the result that farmers may receive less than free market prices for their outputs and pay more than free market prices for their inputs (Van, 2018).

2.3.10 Biodiversity loss

Biodiversity loss refers to reducing the variety and number of species in an ecosystem, which can have significant ecological and economic impacts. Agriculture, including food production, is a leading cause of biodiversity loss. The conversion of natural habitats to agricultural land, using pesticides and other inputs and cultivating monoculture crops all contribute to the problem (FAO, 2019). Food waste exacerbates the problem of biodiversity loss by increasing the demand for more food production. As more food is produced to meet demand, more natural habitats are converted to agricultural land, further contributing to biodiversity loss. Additionally, using pesticides and other synthetic inputs to increase food production can significantly impact non-target species, including pollinators and other beneficial insects, leading to further biodiversity loss.

Diversification of agricultural ecosystem components is crucial for food supply, variety creation, and climate change adaptation. Only thirty of the thirty thousand edible plant species

are used to feed the world, implying that indigenous or traditional variations are significantly underutilised and underdeveloped (Dwivedi *et al*., 2017). Food production is the primary cause of biodiversity loss on a global scale. Land used for farming, particularly intensive farming, degrades the quality and quantity of habitat. Ecosystems have altered faster in the last 50 years than at any other period in history, and this epoch is tied to a lot of farming in many places across the world. In terrestrial ecosystems, changes in land use are a significant source of biodiversity loss. Additionally, food production has a detrimental effect on freshwater wildlife (through water extraction and the reduction in water quality resulting from soil and farm chemical run-off).

Downstream contamination, particularly from fertilisers, also has a detrimental effect on marine systems. Fishing and various fish and shellfish cultivation also significantly impact marine biodiversity (Kanianska, 2016). All long-term historical land-use changes that resulted in converting natural ecosystems to seminatural ecosystems or artificial systems resulted in significant changes in the composition of biodiversity and ecological processes.

2.3.11 Nutrition and food waste

Nutrition plays a significant role in the production and consumption of food, and it also contributes to the problem of food waste. According to a study by Quested *et al*. (2013), consumers often waste food due to food safety and nutrition concerns. Consumers may discard food that is approaching or past its expiration date, even if it is still safe to eat, due to concerns about food safety. Additionally, consumers may waste food that they perceive to be unhealthy or not nutritious, such as fruits and vegetables that are deemed too high in calories or sugar (Quested *et al*., 2013). On the production side, the emphasis on producing food that meets specific nutritional standards can contribute to food waste. For example, farmers may discard produce that does not meet specific cosmetic standards, such as perfectly edible fruits and vegetables that are misshapen or discoloured, leading to unnecessary waste (Stuart, 2019).

To achieve nutrition security, it is crucial to change the behaviour of both consumers and producers in reducing food waste. Nutrition security is a nutritionally adequate diet supporting growth, disease prevention, recovery, childbirth, and physical activity (FAO 2015). The Sustainable Development Goals (SDGs) set by the post-2015 development agenda prioritize food and nutrition security. Nevertheless, 780 million people remain undernourished, and two billion are malnourished despite government and international efforts (Kalkuhl *et al*., 2016; FAO 2015). The nutrition transition demonstrates the link between food production and

consumption. Changes in demographics and disease patterns have led to a diet high in saturated fats, sugar, and refined foods and low in fibre, commonly known as the "Western diet" (Peters 2020).

2.4 Food waste in the supply chain

One of the mandates of the Food and Agriculture Organization of the United Nations (FAO) established in 1945 was to reduce food losses. The FAO identified a reduction of post-harvest losses during the first World Conference in 1974 to solve food losses and address hunger. Accordingly, the FAO designed a programme to prevent food loss which was called the *Special Action Programme*. The programme aimed at reducing food losses by 50% by 1985 with its primary focus on durable grain. However, in early 1990 the programme expanded its scope to include vegetables, fresh fruits and tubers (FAO, 2019). The post-harvest losses reduction target of 1985 had no account of the progress and recently Lundqvist *et al*., (2008) advocated that a 50 percent reduction in post-harvest losses can be achieved by the year 2025.

More recently, it has been estimated that between 1.6 to 2 billion metric tonnes, which is about 40-50% of food produced for human consumption, is wasted before or after it gets to the consumer at different stages of the Food Supply Chain (FSC) (Crist *et al*., 2017; Lundqvist *et al*., 2008). This scale of loss has been estimated to be the equivalent of the total food produced in Sub Saharan Africa (Affognon *et al*., 2015). The scale of waste may not be accurate due to a lack of accurate measurement standards for post-harvest losses (Parfitt *et al*., 2010, Affognon *et al*., 2015). A lack of standards and clear methodology has prompted researchers to investigate and understand reasons for the magnitude of the loss of food that was meant for human consumption (Lipinski *et al*., 2013). It has become a priority and a global concern to confront the problem of food waste, in part to address the environmental concerns mentioned earlier (Filimonau and Delysia, 2019; Schanes *et al*., 2018).

Although the demand for food will increase as the population increases, the task is to balance food supply by reducing inadequacies and waste across the entire food supply chain. (Lundqvist *et al*., 2008). While organizations like the FAO, Food Standard Agency (FSA) and many others are trying to reduce food waste, it remains a severe problem. (Conrad *et al*., 2018). There is a need to increase awareness of the issues surrounding food waste to make people see reasons to change their attitudes; however, there may also be policy interventions that government can introduce (e.g., charging for plastic bags in supermarkets in the UK has

reduced the amount of ‘wasted’ shopping bags). Without putting a stop or reducing the rate at which food waste is accumulated, the needs of present and future generations is in jeopardy. Food waste poses a significant threat to present and future generations, leading to the unnecessary depletion of natural resources, contributing to greenhouse gas emissions, and undermining food security. There is a need to increase awareness among consumers and policymakers. For example, campaigns that raise awareness of food waste's environmental and economic consequences can encourage individuals to change their behaviour and reduce waste.

Similarly, policy interventions, such as taxes or bans on single-use plastic bags or incentivizing food donations, can help reduce food waste at the institutional and systemic levels (Parfitt *et al.*, 2010). Studies have shown that policy interventions can be effective in reducing food waste. For example, introducing a charge for plastic bags in supermarkets in the UK led to an 85% reduction in the number of bags used, demonstrating that even small policy interventions can significantly impact behaviour change (WRAP, 2021). Most of the food waste and loss differ by region, developed and developing countries and the process that food go through in the FSC (Lipinski *et al*., 2013). In developed countries most of the food waste is generated at retail and consumer stages, while in developing countries the majority of the food loss occurs at the processing or production stages of the FSC before it reaches the consumer (FAO 2011). According to the FAO (2011) estimates of food waste in developed countries at consumer level is an estimate of 222 million (230 million tons). There is a clear distinction between the developed and developing nations regarding who generates the most food waste and which stage of the food supply chain constitutes the highest amount of food waste (Figure 2.3).

High income countries like the UK and US have high food wastage at the retailer and consumer household stage, their supply chain is efficient and effective in that it tackles the issues encountered during agricultural processes such as pre-harvest, post-harvest, storage, processing, distribution and delivers abundant cheap food. This ‘low cost’ makes some people buy more than they need (Kok *et al*., 2019; Gunders *et al*., 2017; Parfit *et al*., 2010) Bernstad (2014) argues that individuals buy more than they need because do not measure what they buy in their offices and homes, and that leads to putting much food to waste. Even though they have refrigerators and proper storage facilities, they throw the food away intending to replace them with fresher ones. In the UK for example, the government has made the nearly free weekly waste collection available to every household as part of an effective government plan to address the waste situation (Bawden, 2022). This, in some way, allows the people to waste more food

because they have no idea the amount of food they waste. At the moment, almost a third of local authorities collect food trash separately - although UK households discard over 7 million pounds of food each year, the majority of which is edible (Bawden, 2022).

> *"In countries with higher gross domestic product (GDP) per capita nominal such as Switzerland (USD$82,839) and Singapore (USD $64,582), food distribution and consumption accounted for the highest wastage in household food waste"* (Mak *et al*., 2020:2).

The increase in food wastage in developed counties is encouraged using 'best food' labels, according to the Natural Resource Defence Council (NRDC). These labels are sometimes not accurate, they serve to attract sales, and many people fall victim to it buying more than what they need (Gentil and Poulsen 2012). Grocery stores and supermarkets are another reason for food waste in developed countries. They gave rise to competition and reduction of the price of food items amongst stores which encourages clients to buy more (Filimonau *et al*., 2019). Due to aesthetic perfection and freshness of the commodities, individuals overstock their household with fresh farm produce only to discard them after some time, to be replaced by fresh ones. The stores are also known for throwing away eatable food that is no longer attractive for individuals to purchase.

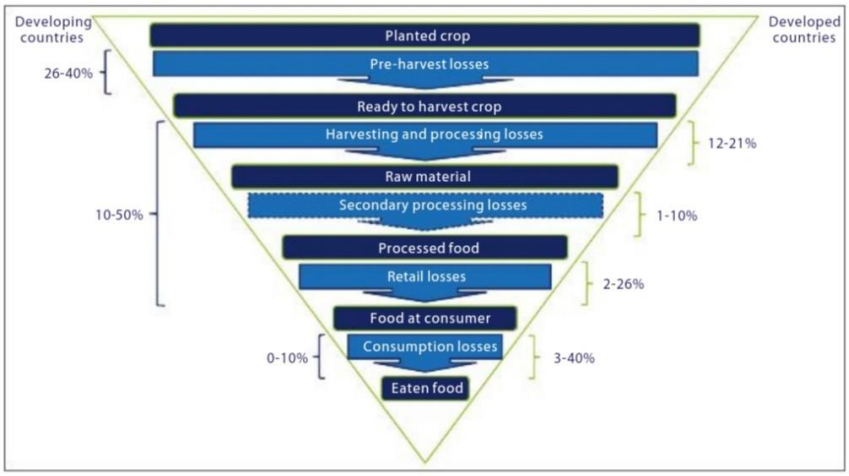

Figure 2.3: Wastage of food products along the supply chain.

Source: (Oguntade, 2013)

In low and middle income countries, most of the food produced is lost before it gets to the consumer (Graham-Rowe *et al*., 2014). Significant wastage occurs at post-harvest, storage,

and transportation stages due to a lack of effective and efficient technology within Food Supply Chain (FSC) management that prevents proper storage, preservation, processing and distribution of food items (Verma *et al*., 2019; Gunders *et al*., 2017; Poins *et al*., 2017; Vanham *et al*., 2015).

The waste along the supply chain also affects the quantity of the products available for sale, making the prices of such goods fluctuate. Furthermore, food losses are taken directly to landfills in most developing countries because they do not have a recovery system or a policy that will encourage and guide people to recycle food items (Thi *et al*., 2015). Countries like Brazil, Nigeria, and Mexico have a weak recycling system due to their legislative framework. Waste collection is not constant, and waste separation is also not implemented. The educational system is inadequate to enlighten people on programmes that will encourage waste separation to quickly identify food waste from general waste (Thi *et al*., 2015).

The case is also the same in India where a significant amount of waste is disposed of in landfills, open dumpsites, and other unsanitary conditions, leading to environmental pollution and health hazards (Sharholy *et al*., 2008). One of the significant components of the waste generated in India is organic waste, including food waste, which is often disposed of without proper treatment due to the lack of infrastructure for collection and treatment facilities. The improper disposal of organic waste has several public health and environmental impacts. When organic waste decomposes in landfills or open dumpsites, it produces methane, a potent greenhouse gas contributes to global warming (Thi *et al*., 2015; Sharholy *et al*., 2008). Similarly, China's recycling system is weak, and the massive amount of food waste generated has made places like Shanghai and Beijing implement waste separation and home collection to encourage food waste reduction.

In Nigeria, a lack of regulations and waste management policies paved the way for Non-Governmental Organizations (NGOs) to take over the affairs of waste collection (Igbinomwanhia, and Ohwovoriole, 2012; Amarachi *et al*., 2016). The cumulative volume of general household waste, encompassing food waste, remnants, paper, metal, and textiles, reaches an estimated annual 25 million tons. Regrettably, 8% of this waste is effectively recycled and repurposed for compost each year. (Orhorhoro *et al*., 2017; Amarachi *et al*., 2016; Igbinomwanhia, and Ohwovoriole, 2012). While there is debate as to what constitutes food waste, the issue remains critical and unacceptably high worldwide (Kiaya 2014; Papargyropoulou *et al*., 2014). A considerable amount of food is rendered waste as a result of

spoilage along the supply chain before it gets to the consumer. This considerable amount of food waste is often the case in many developing countries. For example, in Nigeria, it is a well-known fact that tropical weather and poorly designed infrastructure are significant contributors to food waste and as much as 40-50% of food go to waste annually (Kok *et al*., 2019; Schuster *et al*., 2016). Post-harvest handling is a critical area where attention is needed (Kok *et al*., 2019; Crist *et al*., 2017).

Post-harvest losses (PHL) vary between regions due to the different characteristics they portray. Factors such as social, cultural, biological, economical, natural and political can influence and contribute to food loss or waste generated in a particular region (Kader *et al*., 2015, Hodges 2010). As such, the losses of grain, vegetables and fruits will not be the same at each stage of the FSC which makes the analysis of PHL different across regions. The inefficiency in harvesting methods, processing technology, storage, transportation and proper handling of farm produce in developing and underdeveloped countries are notable causes of post-harvest losses. The scarcity of PHL research has produced little data or information that will enrich people's awareness of how big the problem is and can be for the next generation (Parfitt *et al*., 2010).

There is a series of activities that take place before the food gets to the consumer. It involves concerted actions that take place from harvest through processing, sorting, packaging, storage, transport, distribution and food preparation which are different in nature as the regions differ in weather and other conditions (Kok *et al*., 2019; Poins *et al*., 2017; Papargyropoulou *et al*., 2014). However, the chain may be different in some instances where the farms and factories are in the same place. Nonetheless, the final destination is the consumer who decides to either eat the food or waste it. Figure 2 below illustrates the flow of the food in tiers, as it goes through the supply chain (Poins *et al*., 2017).

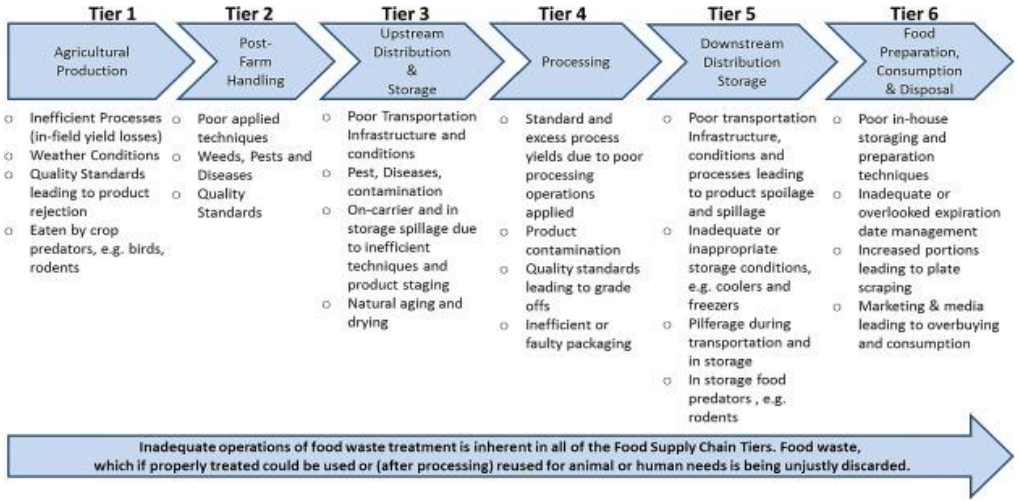

Figure 2.4: Food supply chain and the key sources of waste creation per tier

Source: (Poins *et al*., 2017, p 1269)

There is a growing realisation of the dangers that post-harvest losses of food items are leading the world to; and interventions in PHL reduction have since commenced to reduce food scarcity and improve food security (Poins *et al*., 2017; Papargyropoulou *et al*., 2014).

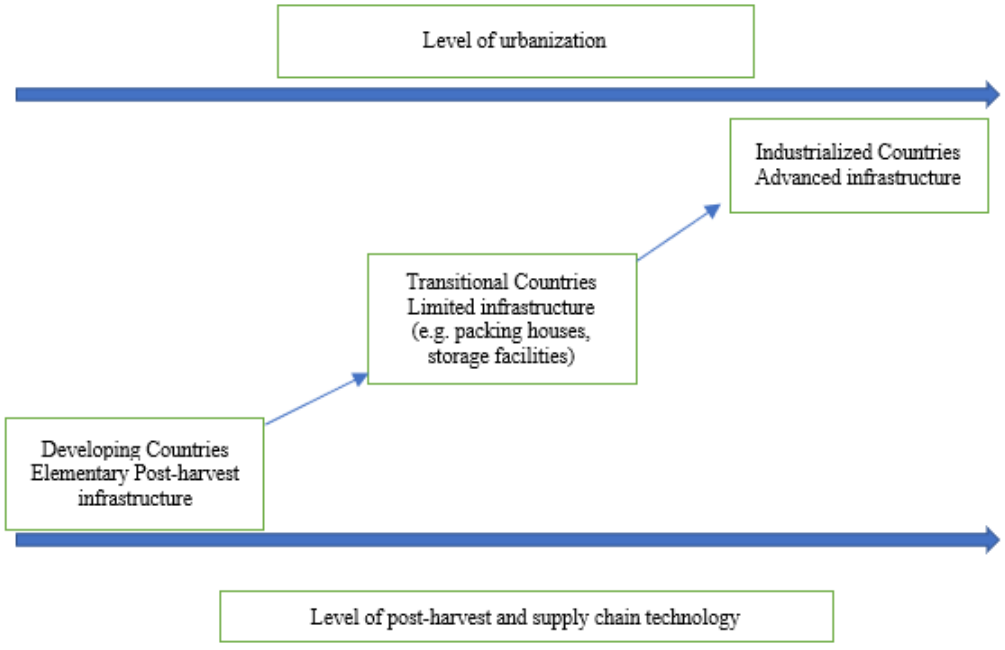

Figure 2.5: Development of FSC in relation to post-harvest infrastructure. Source (Poins *et al*., 2017)

Post-harvest losses can be considered along economic and technological gradients (Figure 2.5). The line shows how industrialized countries compare with developing and intermediate countries. The extent to which markets have developed for agricultural produce is a determinant of the amount of PHL generation and technology is a crucial factor in reducing

PHL (Parfitt *et al*., 2010). Most farmers in developing countries rely on a short food supply chain which requires limited post-harvest infrastructure and technology. Moreover, extended FSC that feeds the urban population will involve some intermediaries between the farmers and consumers. Hassan *et al*., (2021) argues that intermediaries play a vital role in providing and organizing transportation of product by an appropriate means from the farmer to the consumer. They strive to ensure that fruits and vegetables get to the consumer in good condition. They are the source that reduces the gap and uncertainty of the supply chain because they absorb some of the risk attached to buying and selling in the supply chain (Hassan *et al*., 2021; Ashraf *et al*., 2020).

However, the lack of market structure results in a poor return to the farmers (Ashraf *et al.,* 2020). Similarly, inefficiency in market management spoils the fruits before it gets to the consumer. Literature shows that in most developing nations the transport infrastructure is poor which makes it difficult to comfortably transport fresh fruits and vegetables from one point to another making the work of intermediaries more difficult (Hassan *et al*., 2021). Moreover, due to lack of knowledge, challenges and insufficient storage facilities that intermediaries confront, they are forced to use traditional technologies such as bamboo (or raffia) baskets and under shade storage for their produce. However, upgrading, and technical training to minimize food losses is the focus of the intervention within these systems (FAO 2008).

To promote the role of intermediaries in value addition and quality improvement, various stakeholders have implemented several initiatives, including the creation of relevant organizations such as the Small Industries Development Organization (SIDO) under the Ministry of Industry and Trade (MIT) (Hassan *et al*., 2021). Additionally, policies such as the Trade Act, agricultural development policy, SMEs policy, and the national horticultural policy have been enacted to address challenges in the horticultural industry. However, despite these efforts, value addition and quality improvement for urban fresh fruits and vegetables still need to be utilized, leading to food waste and losses instead of business promotion and improvement (Hassan *et al*., 2021).

Similarly, there are limitations with food waste and study of commodity value chain concerning perishable food items in developing countries, because most of the food items end up consumed within the production region or sub-region. Furthermore, the study of commodity chains as revealed by works of literature indicates that emphasis is more on commodities that move across international borders (Cook *et al*., 2004; Busch and Juska 1997). Researchers and

studies from around the world have attempted to quantify the amount of food waste over a long period, to value the scale of waste and compare it with global malnutrition. Up to date the interpretation and calculations are based upon the limited database collected across the food supply chain (Parfitt *et al.,* 2010). As scrutinizing such results may be difficult, researchers need to cut across all the stages of the FSC for a better understanding of where waste is occurring.

2.5 History of post-harvest Losses

From as far back as 1940, various loss estimates have been established from various parts of the world. They had ranges of losses from very little up to 50 per cent in both developed and developing countries. Data on pre- and post-harvest losses were fundamental because they were needed to implement policies that would help reduce food losses in the supply chain (AOUN 1980; Saunders *et al*., 1980). At that point, such data were not available, and those available were intelligent guesses by experts in the farm industry. Fungi, insects, or rodents commonly caused these food losses in perishable goods or due to microbial spoilage. Several studies on PHL on food items assumed that the farmers make the highest losses (Akarawetsaphong *et al*., 1980). The statement may be wrong: Pedersen (1978) in a review on literature shows that farmers take good care of their products and have an excellent zeal to ensure that their product reaches the final consumer.

Agricultural production has expanded rapidly over the previous twenty to thirty years, but interest in crop protection against post-harvest losses has not been considered in a similar tempo (Boxall *et al*., 1979). However, the problem of PHL has been examined at several conferences, meetings at both national and international levels. Global food shortages emphasise the importance of decreasing PHL and improving mechanisms for distributing and transporting food to places experiencing food shortages (Harvey, 1978). Hence, the critical nature of PHL management was discussed during the 7th Special Session of the United Nations (UN) General Assembly and the 1974 and 1975 World Food Conferences (Grolleaud, 2002). In the meeting, intentions were declared to reduce PHL by 50% by the year 1985, but the assembly failed to declare what type of food waste to reduce, as they lacked a reliable estimate of losses and how to base their intentions (Saunders *et al*., 1980; Boxall *et al*., 1979).

Although the decision to reduce PHL was timely, they devoted attention to the subject of PHL in the conference as they recognised the damage pests cause grains and cereals. It was difficult

to quantify the damage realistically in terms of losses, so they had three objectives: To consider data on PHL and its relevance, to look into the problems of estimating losses (e.g. agreed definition, losses and methodology) and finally, how to use loss assessment to obtain and evaluate loss reduction programmes (Boxall *et al*., 1979; Harris and Lindblad 1978). To achieve the above objectives, work done by agencies and experts in the field of PHL had to be identified to get a suitable and appropriate methodology that will befit conditions in different regions, particularly third world countries (AOUN 1980). The FAO council discussed the problem of PHL in the seventy-first session held on the 6th and 7th June 1977 and identified the lack of definitive loss data in many countries, and also recommended the need to conduct a loss reduction programme (AOUN 1980).

The approach for collecting data on PHL is complex, as multiple causes of loss must be addressed at each point of the supply chain. Definitions of losses vary considerably in their interpretations of what constitutes a loss. In some instances, the terms "loss" and "damage" are used interchangeably, which is not supported by many experts. Losses are quantifiable in terms of reduced amount and quality of food, whereas damages are viewed as a complete waste. According to Boxall *et al*. (1979), there are several types of losses. These include weight loss which results from a decrease in moisture content of the perishable food item, which may cause quality loss. Food items may be graded according to their shape, size, and appearance, or what traders and consumers consider essential, and nutritional loss. According to Bowxall *et al*., (1979) this can include commercial, nutritional and seed viability losses. The lack of a suitable methodology to estimate losses due to various causes and different definitions and types of losses was a significant problem (AOUN 1980).

The FAO asked the Indian Agricultural statistical research institute in New Delhi to review the available literature on PHL and suggest an acceptable methodology for collecting data on PHL, giving cognisance to developing countries and their peculiarities (AOUN 1980). In low-income countries, at least 10% of grain crops are lost after harvest and only 40% of food losses are documented. Reduce these losses by half and it was estimated that this might meet over 50% of developing countries' food grain import demand by 1985, at the cost of roughly $US 8 billion (Gorgatti-Netto., 1979). Farmers were organised into associations and groups to educate them about the value of quality and proper post-harvest management. To improve the value and quality of the product, facilities such as knives, shredders, packing sheds and drinkable water (for prepared pre-packed vegetables), packaging materials, and labels became necessary to add

value to products (Saunders *et al*., 1980). Identified also was the need to improve the distribution of food items in terms of logistics by improving infrastructure such as roads, rural markets and better electricity to improve on refrigerating fragile fruits and vegetables (Pedersen., 1978). Significant improvements should be made by providing potable water, sanitary facilities and concrete surfaces with covering to shelter produce from the sun.

Reducing post-harvest losses has the potential to provide benefits. To achieve this, investments in post-harvest processing and storage are necessary, especially for crops important for food security. In 1977, the FAO established the Special Action Programme for the Prevention of Food Losses to address the problem of grain losses, which later expanded to include fresh fruits, vegetables, and roots and tubers. The approach was to create an agricultural sector focused on production, improved food self-sufficiency, and reduced post-harvest losses (Affognon *et al*., 2015). This was achieved by developing new models for handling and storage, such as improved drying facilities, larger-scale community storage, and a Warehouse Receipts System, which provided collateral for traders to access finance and improved the marketing system's performance. However, there is no evidence of progress toward the 1985 post-harvest loss reduction goal, and post-harvest losses remain a persistent problem that poses a significant challenge to food security, despite later actions and plans to address the issue (Affognon *et al*., 2015; Gorgatti-Netto, 1979; Bourne, 1977; Parpia, 1976).

2.6 Current state of post-harvest losses

Various strategies and technologies have been implemented since the 1974 World Food Conference to combat post-harvest losses (PHLs). However, more progress has yet to be made towards the 1985 goal for PHL reduction. However, the renewed focus on food security since the 2006 rise in food prices has led to several global food security initiatives and organizations addressing PHLs, including the United Nations' Comprehensive Framework for Action and the World Bank's Global Agriculture and Food Security Programme. Despite these efforts, PHLs continue to pose a significant threat to food security as the world's population grows. As the population is expected to reach 9.7 billion in 2050, there is a need to increase food production sustainably significantly. However, more than increasing production is required to meet the growing demand for food while maintaining environmental sustainability.

Sustainable Development Goal 12 focuses on ensuring sustainable consumption and production patterns and includes reducing food losses from production to consumption. Understanding the amount and pattern of waste or loss in food supply chains is crucial for

effective reduction. Achieving a sustainable global food system is a vital yet complex goal, and the current food supply's ability to feed the world from now to 2050 is still being determined. Therefore, minimizing post-harvest losses and reducing waste throughout the food supply chain is critical. Post-harvest and food loss are essential issues in agricultural policy globally. More specific information is available on the extent of such losses or their location along the value chain (Ambler *et al*., 2018; Sugri et al., 2021; World Bank, 2011). Food loss occurs throughout the value chain, resulting in higher food prices for consumers. Reducing post-harvest losses can also have macroeconomic benefits, such as decreasing the need for food imports and freeing up foreign cash. In the 1970s and 1980s, post-harvest storage systems were highly influential in Sub-Saharan Africa, especially when state-run grain marketing boards purchased food items. However, the opening of grain markets in the 1990s exposed farmers to price and quality risks, which may have reduced incentives to adopt post-harvest technology over time.

PHL may be measured by a decrease in the amount and quality of food. A post-production chain functions together logically, linking operations from "farm to fork." Quality losses can include a lower nutritional value, food-borne health risks, and economic losses when the product does not get a chance to sell. One major difficulty is that PHL might occur at any of several stages. As an example, some of these losses can happen at distribution, harvest, handling, preliminary processing, transportation, storage, spillage, pests, spoilage, contaminants and disease; and while processing due to inefficient technologies. These losses can also happen during commercialization (Kaminski and Luc 2014). A lack of reliable data and standard methods for estimating PHL are two things that make it hard to come up with long-term mitigation options and policies to cut down on PHL (Sugri *et al*., 2021; Ambler *et al*., 2018).

PHL are primarily determined by the technology available in a country and the level at which agricultural produce markets have become. Three interconnected global factors provide a framework that can be used to see the future reduction of PHL in developing countries (Parfitt *et al*., 2010)

1. Urbanisation and agriculture sector contraction. Agriculture's share of the world's population has dropped in recent decades, and 50% of the world's population currently are in urban areas, and by 2050, this number is predicted to reach 70% (Magdolen *et*

al., 2022). Rapid urbanisation has necessitated the expansion of FSCs to feed urban populations. Countries' road, transportation, and marketing infrastructures must be improved to allow affordable food to reach low-income groups. The evolution of these extended supply networks has global ramifications for food waste, both today and in the future (Parfitt *et al*., 2010).

2. Dietary change. Income growth, particularly in developed countries, is connected with decreased starchy food consumption and increased meat and fish consumption. The rate of eating starchy staples in the diet decreases as income grows. The trend toward more perishable, shorter-life items increase food waste and a greater demand for land and other resources. The transition differs by country and culture; for example, there is less pressure on resources in India than in China, where meat consumption is higher (Parfitt *et al*., 2010).
3. Trade has become increasingly globalised, and about ten per cent of the processed food sold worldwide is traded internationally. Agricultural exports may benefit from globalisation, but imports may threaten domestic markets with lower prices and high level of quality than what can be produced locally (Mbilima., 2021). As a result of trade liberalisation, multinational chains have been a significant force behind the rapid expansion of supermarkets in several transitional economies (Parfitt *et al*., 2010).

To achieve PHL reduction, all the stakeholders in and outside the farms must be equipped with the tools necessary to minimise post-harvest losses. However, to develop these tools effectively, more systematic evidence about where food is wasted and lost along supply chains and the magnitude of these losses is required, particularly in developing nations (Ambler *et al*., 2018). Various research may ask for further crop losses at the farm stage, which may misdirect efforts to reduce food loss. Given the high cost of prospective loss reduction techniques and reliable and consistent assessment, it is essential to ensure that the measurements of loss and waste within the supply chain are accurate and consistent (Sugri *et al*., 2021; Ambler *et al*., 2018). Food waste and loss estimates should be based on survey data rather than assumptions and national estimations to minimise future difficulties and misleading reports on PHL. For instance, the African Information System on Post-harvest Losses (APHLIS). This monitoring system is a multistakeholder system that was established in 2009 (Sugri *et al*., 2021; Ambler *et al*., 2018). It is also not apparent which procedures are used to calculate post-harvest losses when survey data is available, nor is it evident showing same methods are utilised across

multiple articles when survey data is available (Sugri *et al*., 2021; Ambler *et al*., 2018; Affognon *et al*., 2015).

2.7 Estimation and causes of post-harvest losses

Reducing post-harvest waste is crucial for ensuring the availability of food crops and increasing farmers' revenue, as Kuyu *et al*. (2019) highlighted. Starchy roots are particularly susceptible to spoilage during post-harvest processing, contributing to their ranking among the top ten globally lost foods. Parfitt *et al*. (2010) emphasize considering the perishable and non-perishable nature of foods and the suitability of the infrastructure supporting the food supply chain (FSC) to estimate food waste and losses. Physical loss or quality degradation can cause post-harvest food grain losses, with storage losses being the primary focus of many studies due to the complex nature of measuring grain quality degradation. This is particularly relevant for crops such as maize, wheat, rice, sorghum, and millet, which must be stored for extended periods (Parfitt *et al*., 2010).

Reducing post-harvest waste is crucial for ensuring food availability. The Sustainable Development Goals (SDGs) set a specific target for reducing post-harvest losses (PHL) to end hunger and promote sustainable consumption and production. This recognition of the importance of reducing PHL has been reinforced by recent research on the long-term sustainability of food systems, as stated by Cattaneo *et al* (2021). The outbreak of the COVID-19 pandemic in 2020 has further highlighted the risks of significant food loss, particularly for high-value and nutrient-dense foods like meats, dairy, vegetables, and fruits. The pandemic's social distancing measures disrupted food supply chains and reduced demand, potentially exacerbating food loss. The impacts of these disruptions on supply chains and consumer habits are still uncertain. However, they emphasize the need to address PHL as a critical food policy aspect, as Cattaneo *et al*. (2021) and FAO *et al*. (2020) highlight.

In the past decade, there has been a significant increase in empirical studies focused on Food Loss and Waste (FLW), with more than two-thirds of works on the subject being published after 2010, according to Xue *et al*. (2017). Before that time, literature on FLW was primarily technical and found in specialised periodicals, with limited contributions to economic literature. While there has been a recent surge in policy-oriented studies, there still needs to be more evidence to inform policymakers on the causes, magnitude, and remedies of FLW, which is highly diverse in terms of methods, value chain coverage, and definitions. However, recent

studies suggest that this trend is changing, and new literature is emerging, which could improve FLW measurement and provide insights into effective intervention strategies (Cattaneo *et al*., 2021).

While there has been an increase in empirical studies on Food Loss and Waste (FLW), most of these studies have been conceptual or based on meta-analyses and literature reviews. However, some recent studies have proposed and applied improved measurement methodologies for post-harvest losses (PHL). These studies have influenced the development of new protocols for accounting and reporting standards for PHL, which will be helpful for various stakeholders. In a Special Issue (SI) on PHL, the editors suggest that it is necessary to address the measurement of PHL, identify the causes of FLW, and formulate policies or actions that can reduce FLW. Effective policies and actions require adequate measurement of PHL and an understanding of their drivers (Cattaneo *et al*., 2021).

Over the past decade, there have been significant advancements in the conceptual and measuring frameworks for food loss and waste (FLW). These advancements have helped to clarify the boundaries of PHL, expand the evidence base, and refine global estimates of the magnitude of PHL. For example, Xue *et al*. (2017) provided quantitative estimates of PHL by global commodity groupings, while FAO (2019) estimated global food losses to be approximately 14% of food production, excluding waste generated in the retail and ultimate consumption stages. Cattaneo *et al*. (2021) conducted a meta-analysis of available quantitative evidence on food losses and how they vary by product and geography, finding that fruit and vegetable output loss are higher in Africa and Latin America than in Europe and North America, while cereal production losses are minor across all regions. The report also focuses on strategies to enhance the monitoring of progress toward SDG goal 12.3 and highlights the significant data problems that must be overcome.

2.8 Policymaking for food wates and loss reduction

This section explores different types of public interventions that can be employed to minimize food loss or waste and achieve wider social or environmental objectives. The previous research has identified the reasons why private actors invest in reducing food loss or waste (the business case) and why public intervention is necessary to achieve economy-wide efficiency gains from loss or waste reduction (the economic case), as well as to improve food security and nutrition or environmental sustainability (Marek-Andrzejewska and Wielicka-Regulska, 2021; Kosseva

and Webb, 2020). However, the need for more reliable data on the extent and locations of food loss or waste and the absence of knowledge on the costs of reduction measures are significant obstacles to developing effective strategies for loss or waste reduction. Therefore, this section provides a potential plan for gathering globally comparable and reliable data (Corrado *et al*., 2019).

The EU and its Member States are committed to achieving SDG 12.3, which aims to reduce food losses throughout the food production and supply chains by halving food waste per capita at retail and consumer levels by 2030. To achieve this goal, the EU Platform on Food Waste was established in 2016, bringing together EU institutions, experts from Member States, and key stakeholders to promote food waste prevention measures, share best practices, monitor progress over time, and support the European Commission in developing appropriate EU policies (EC, 2019a). The Waste Framework Directive (WFD) mandates that EU Member States monitor food waste generation and take steps to minimize it. A standard EU methodology for assessing food waste was introduced in late 2019 (EC, 2019b), designed to complement the approach used to measure progress toward SDG 12.3.

Denmark provides an example of how raising awareness can lead to a reduction in food loss or waste. Between 2010 and 2015, the country decreased food waste by 25% through several initiatives, including educating consumers and supermarkets offering discounts on food near expiration or with minor flaws (Halloran *et al*., 2014; Zamri *et al*., 2020). The Stop Wasting Food campaign, driven by individuals in both private and public sectors, was at the centre of this effort (Pearson and Perera, 2018). The campaign gave people suggestions for purchasing food and preparing more efficient meals. It also inspired food manufacturers and retailers to create new packaging and portion sizes. As a result, people saved money by not wasting food, and some cost-related measures resulted in lower food prices (Zamri *et al*., 2020; Halloran *et al*., 2014).

An NGO in China launched the Clean Your Plate campaign in 2013 to raise awareness about food waste, and over 750 restaurants in Beijing have participated in the campaign, with support from the public (Li *et al*., 2021; Piesse, 2017). Diners who do not leave any food on their plates can receive discounts or certificates. To reduce food waste, restaurants have begun serving smaller portions, encouraging the use of doggy bags, and urging customers to bring leftovers home. In 2014, the Chinese government introduced measures to reduce food loss or waste following the release of a circular titled "Practicing Strict Economy and Fighting Waste." The

effectiveness of these measures is still being determined, and there is no concrete evidence of their success (Li *et al*., 2021; Zamri *et al*., 2020).

In 2013, Turkey launched a campaign to reduce bread waste by raising awareness, cutting supply chain losses, and promoting whole wheat bread. The initiative was supported by various independent organizations and reduced wasted bread from 5.9 million loaves in 2012 to 4.9 million in 2013. Additionally, a campaign encouraging people to buy only the bread they could eat resulted in a 10% decrease in bread purchases and a total savings of USD 1.1 billion for consumers (Brusselaers and Van Der Linden., 2020). Since 2017, a North Macedonian civic-led group has focused on reducing organic and non-organic food waste by creating a platform for businesses to donate food to civil society groups, who can then distribute the food. The group also aims to change laws to make food donation easier and provide tax incentives for people who donate food. Another project is the Food Waste Experiential Programme, a pilot programme for high school students to learn about food waste (Brusselaers and Van Der Linden., 2020).

2.9 Recycling of food waste items

National studies have found that up to half of food loss and waste occurs at the consumer level in developed nations, with an economic cost of over 161 million USD annually in the United States (Mourad, 2016). In response, private businesses and community organisations have launched projects to tackle this issue by "recycling," "recovering," and "avoiding" what they refer to as "food waste." Different public and corporate entities have varying ideas about what constitutes surplus food and have established hierarchies for addressing the issue, with prevention, recovery, and recycling being the overarching priorities. These hierarchies score solutions based on their impact on the environment, the potential for generating profit, and their ability to provide food to people. Different categories of solutions are more likely to be implemented by different actors and organisations, depending on their priorities and objectives, such as environmental impact, economic benefits, or food recovery and redistribution. (Mourad, 2016; Refsgaard and Magnussen 2009).

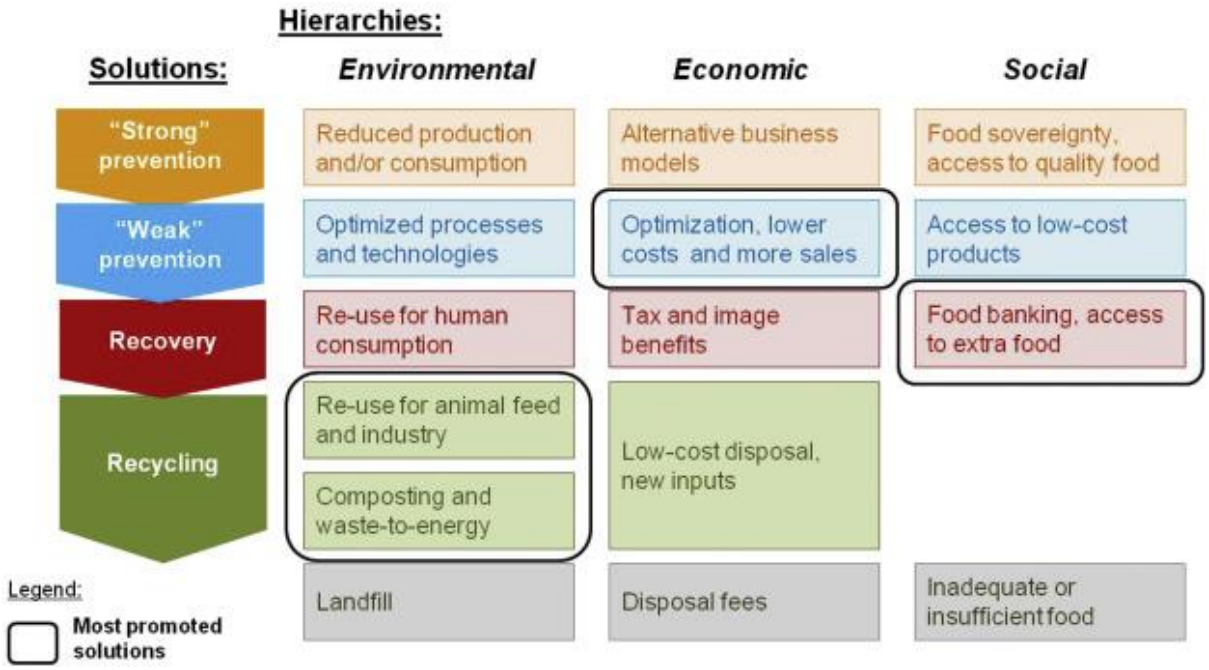

Figure 2.6: Competing hierarchies of solutions to surplus food

Source: Mourad., (2016)

2.10 Summary

Food loss and waste are significant problems in developed and developing nations, with estimates suggesting that up to half of all food waste occurs at the consumer level in developed nations alone. In addition, the economic cost of food waste in the United States is enormous, amounting to over 161 million USD per year. Given these challenges, many private businesses and community organisations have launched projects to address food waste, with an emphasis on "recycling," "recovering," and "avoiding" what they refer to as "food waste." However, there are divergent ideas about what constitutes "surplus" food, and as a result, there are different approaches to addressing the issue. Three distinct hierarchies of action have been established, prioritising prevention, recovery, and recycling. Within each hierarchy, specific categories of solutions are more likely to be implemented, with different actors and organisations taking different approaches depending on their priorities. For example, those concerned with pollution and environmental impacts are likelier to promote recycling, while businesses focused on economic benefits may prioritise process and sales optimisation. Non-profit organisations may be more committed to food recovery and redistribution.

In order to effectively tackle food waste, it is essential to understand the many causes of waste and the economic and environmental impacts it can have. This understanding can then inform the development of targeted solutions that consider the priorities of different actors and

organisations. By working together and implementing various strategies, it may be possible to reduce food waste and ensure that food is distributed more equitably to those in need.

CHAPTER 3: Theoretical framework

3.1 Introduction

The section seeks to be clear on the relevance of the research on post-harvest losses, emphasizing how geographers have used the commodity chain to highlight problems identified within the commodity supply chain of goods and services. (for example Cook 2006 and Harvey 1990). This section traces the knowledge gaps in commodity chains and attempts to fill these gaps. Focusing on the waste within the commodity chain is a relatively novel approach compared to traditional analyses of commodity chains that primarily focus on value creation and distribution. The traditional approach tends to focus on the economic aspects of the commodity chain, such as production, transportation, and marketing. However, by focusing on the waste within the commodity chain, we can better understand the entire chain's social, economic and environmental impacts. This approach helps us to identify areas where waste reduction efforts can be implemented to reduce the overall environmental impact of the chain, as well as identify opportunities for creating more sustainable and efficient production processes. It can also highlight the need for more responsible and equitable practices throughout the commodity chain, including fair labour practices and socially responsible sourcing. A focus on the waste within the commodity chain can provide valuable insights into the entire life cycle of a product to help us develop more sustainable and equitable production and consumption systems.

3.2 Conceptualising commodity chains

Hopkins and Wallerstein first used the term commodity chains in a 1977 paper outlining a research project to study how the modern world system grows and changes. To show how new areas were added to an emerging global division of labour during the long 16th century, they wanted to follow the production networks of certain goods. In this way, they and their colleagues looked at different commodity chains to find out where these activities took place and how the unequal returns made the world a more stratified place than it used to be (Bair 2014; Raikes *et al*., 2000). Hopkins and Wallerstein came up with the concept of the "commodity chain" to help them separate their understanding of capitalism's territorial scope from methods based on nationalist ideas about economic change. Instead of considering economic growth as a steady process, the authors propose that we should begin with a different assumption and focus on a final product that people eat or drink and the components that went into its manufacture, including raw materials, transportation, labour, and food.

This is what is referred to as a commodity chain (Bair 2014; Raikes *et al*., 2000)**.** Commodity chains originated in world-systems theory and were established during the globalisation era to connect the various activities and people involved in producing goods and services (Bair 2014; Raikes *et al*., 2000)**.** In the 1990s, there was much interest in a new intense phase of globalization (De Soysa and De Soysa, 2018; Dunning, 2014; Silver, 2003; Jakobsen, 2002). As a result, the commodity chain concept became more popular as one of the few analytical tools that could be used to look at the growing complexity of international production networks. The chain concept was used by a new group of scholars, many of whom were not familiar with the macro-historical tradition of commodity chain research (Bair, 2014). The complicated relationships between people, places, and commodities were causing increasing anxiety at the turn of the twenty-first century.

Individuals, consumer groups, country states, and supranational organisations increasingly questioned the ethics of specific production and consumption relationships. The growing interest in the mutual reliance on manufacturing, distribution, retailing, design, advertising, marketing, and final consumption stems from and is linked to these political concerns (Hughes and Reimer, 2004). Geographies of Commodity Chains brings together a diverse range of perspectives to critically investigate the areas that connect consumers to producers. Case studies cover a wide range of goods, such as clothing, fruit, furniture and geographical regions ranging from Africa to Europe and America. These examples not only aim to go beyond traditional conceptions of production and consumption, but they also directly engage with broader public debates about the meanings, origins, and histories of commodities (Hughes and Reimer, 2004).

Scholars used commodity chain to look at how industrial geography changed, the rise of organizational practices like outsourcing and offshoring, and the effects these changes had on both core economies and developing countries (Bair, 2014). This made the relationship between commodity chain analysis and world-systems analysis more complicated. The clearest sign of this growing separation was a major shift in how people thought about commodity chains as possible routes to development or upward mobility (Hartwick, 2015; Hartwick, 1998). Assuming that all commodity chains have a mix of "core" activities (those that make much money) and "peripheral" activities (those that make little money), commodity chain analysts saw that the mix of activities that happen inside a specific territory could change over

time (Bair 2014; Raikes *et al*., 2000). By the early 2000s, "commodity chain" was often used interchangeably with Global Production Networks (GPNs) and Global Value Chains (GVCs). The GVC is becoming the standard way to discuss global industries (Ponte and Sturgeon 2014; Ponte and Gibbon 2005).

This is especially true in studies that focus on policy or practice by international financial institutions. The World Trade Organization and the World Bank have also joined the global value chain analysis trend with the Department for International Development in the UK and the US Agency for International Development following suit (Bair 2017; Ponte and Sturgeon 2014; Bair 2014; Raikes *et al*., 2000).

3.2.1 The contribution of the value chain approach

Several methodologies have been developed to characterise and analyse the structure of production chains, allowing policymakers and other stakeholders to plan suitable actions to achieve economic and social benefits. The approach used and further developed by a group of researchers networked in the global value chain initiative focuses on analysing the impact of agribusiness export on development (Tamásy, 2012; Stringer and Heron., 2008). It goes beyond intra-firm supply chains and technical analysis of product flows (Surmacz and Wierzbiński., 2019) inviting an examination of a variety of chains and a technical examination of product flow. It promotes investigation of chain structure variation using conventional analytical techniques and concepts, focusing on power relations within chains and actors' opportunities to upgrade and so stabilise or improve their position (Surmacz and Wierzbiński., 2019; Tamásy, 2012; Stringer and Heron., 2008).

The question has arisen as to whether large companies govern value chains through their dominance of production technology (producer-driven chains, such as computers or automobiles) or their competencies in branding and market access (buyer-driven chains, such as clothes or fresh fruit). According to Trienekens (2011), establishing global commodity chains has created a divide between developed and underdeveloped countries, with the former being winners and the latter being losers. Regardless of the approach, the outcome is the same: both countries in the north (where lead firms are located) and the south (where suppliers and subcontractors are located) capture the same added value (Surmacz and Wierzbiński, 2019; Trienekens, 2011; Stringer and Heron, 2008).

3.2.2 Governance structure and their effects on weaker actors in the chain

Gereffi and Korzeniewicz (1994) initially proposed the distinction between producer-driven and buyer-driven value chains, producer-driven value chains are characterized by a strong lead firm that coordinates the activities of suppliers and subcontractors. In contrast, buyer-driven value chains are characterized by a fragmented network of small-scale suppliers that respond to the demands of influential retailers and marketers. However, as global economic dynamics have evolved, some scholars argue that more than this dichotomy is needed to capture the complexity of emerging forms of international divisions of labour. Gereffi, (2018) argue that the producer-driven and buyer-driven dichotomy is "too simplistic and misleading" because it does not account for the role of intermediate firms and the diversity of governance structures in global value chains. Global value chains (GVCs) are classified into two broad groups based on the actor with the most influence. This could be the buyer or the producer: Buyer-driven GVCs often have low entrance hurdles (Rodrik, 2018).

Producers are inextricably linked to customer decisions through design and marketing activities, particularly when it comes to retailing and brand names. Agriculture, textiles, footwear, and toys are the most critical sectors. Large dealers and wholesalers coordinate the orders of retailers and distributors. For example, the "quick fashion" sector is a consumer-driven paradigm that relies on supply networks that react to changing fashion trends and variable customer demand. A product can enter the market less than a month after being designed and ordered, but typical items can take more than six months (Trieneken, 2011; Kaplinsky and Morris, 2007; Gereffi, 2001).

The amount of money a producer can earn is determined by supply and demand relationships in different countries, which various institutional factors can influence. According to Kaplinsky and Morris (2007) and Gereffi (2001) specific industries, such as automobiles and aerospace, require significant capital and technology investments, making it challenging for new entrants to compete in the value chain. In these cases, producers mainly coordinate the value chain, while distributors focus on delivering subcontracted parts and finished products to the market. Researchers have identified five types of differently managed value chains to understand better the complexities of the new international division of labour. The first type is the market-based value chain.

Stringer and Heron (2008) and Raikes *et al*. (2000) define *relational chains* as those with a low power disparity and a high level of communication and information sharing among chain agents. This creates a favourable socioeconomic outcome where actors mutually depend on each other. In such chains, buyers may have easy "exit options," which can lead to profit squeezing at the top of the chain by threatening to switch providers. Relational chains, particularly in fair trade and organic markets, are often regulated by what conventional theory calls "civic coordination," where actors share common values, creating an internal desire to avoid conflict.

Stringer and Heron (2008) define *captive value chains* as a combination of buyer-driven and producer-driven value chains. In these chains, lead companies focus on functions that have high entry barriers and match their core strengths. However, agreeing on prices can be problematic, especially for actors at both ends of the chain and at the top. Consequently, income distribution along the chain tends to be uneven. According to Stringer and Heron (2008), *vertically integrated chains* are those where a single company carries out all the production steps. In such chains, the distribution of economic outcomes is similar to traditional capital-labour relationships, with the added dimension of globalization. In situations with a surplus of labour, the wages paid to unskilled workers are typically just enough to cover their basic needs, such as essential food crops. Only a few agribusinesses in developing countries have trade unions that can negotiate for higher wages. Even they may be limited by the threat of companies relocating to cheaper parts of the world.

3.2.3 The global commodity chain

The origins of Global Commodity Chain (GCC) analysis as a comprehensive paradigm can be traced back to a 1994 collection published by Gereffi, Korzeniewicz, and Korzeniewicz. While the book acknowledges Hopkins and Wallerstein's argument, the authors primarily focus on industrial commodity chains and the emergence of a new global manufacturing system. This system involves centrally coordinated but globally dispersed production of many activities along the supply chains of specific commodities or manufactured products. Since the 1990s, the GCC strategy has gained significant attention, leading to many case studies on producer-driven and buyer-driven GCCs (Bair, 2008). Although Gereffi has mostly used the GCC framework to examine clothing exports to the United States from East Asian countries, others have applied it to study the movement of other goods, such as tourism, fresh fruit and

vegetables, illegal goods, footwear, and electronics from the global south to the global north. (Bair, 2008; Raikes *et al*., 2000; Gereffi *et al*., 2005).

The GCC approach initially focused on industrial commodity chains that were globalized between 1960 and 1980, and it was developed to examine the organizational aspects of international trade. The approach includes four dimensions: inputs and outputs structure, a region covered, governing systems, and institutional framework (Raikes *et al*., 2000). Although GCC covers the same area as economic trade theory, it is distinguished by its focus on the complete range of activities from primary production to ultimate consumption and the linkages that connect them. GCC analysts study how to lead agents, establish, coordinate, and regulate the links and flow of output between raw material suppliers, processors, primary dealers, wholesalers, and retailers (Bair, 2014, 2008). They also examine the contractual forms, coordination of finance and business services, and the role of the broader regulatory framework in this process. While GCC has primarily been used to study industrial commodity chains, it has also been applied to other sectors such as tourism, fresh fruit and vegetables, illegal goods, footwear, electronics, and other goods from the global south to the global (Bair, 2014, 2008; Raikes *et al*., 200l north).

3.3 The follow the thing approach

According to Harvey (1990), radical geographers should go beyond the surface level of the market and expose the hidden connections between Western consumers and distant strangers responsible for producing the commodities they consume. He emphasized the need to reveal the true nature of commodities and to bridge the gap between producers and consumers by providing a more comprehensive account of the social reproduction process. Furthermore, he argued that radical geographers should raise moral and ethical concerns about exploiting workers who may not realize they are being mistreated. Harvey's call for de-fetishizing commodities and creating meaningful connections between consumers and producers highlights the importance of understanding the social and economic relations that underlie global capitalism (Harvey, 1990, p. 419).

Because of Harvey's (1990) encouragement to look behind the curtain and customers' increased interest in producing and distributing their items, commodity chain analysis has become widely used to connect individuals (producers and consumers) to commodities. The concept of following commodities, sometimes known as the 'follow the thing' strategy, combines

production and consumption locations. In the course of the investigation, actors, processes, locations, relationships, cultures, and communities are uncovered, allowing for the revealing of a complex reality that would have otherwise gone unnoticed (Burr, 2015; Brown *et al*., 2010; Cook *et al*., 2006; Harvey, 1990).

'Follow the thing' investigates the journeys of commodities from farm to plate and beyond, as well as "how, why, where, and between whom these values are unequally exchanged worldwide. The political economics of globalised agriculture" (Cook *et al*., 2006: p. 658). Food systems are touched by several government rules and programmes and are so politically charged. Food stories reintroduce the connection between food production and consumption and can expose hidden abuse across the supply chain. The interpretation of these hidden production features demonstrates the value of commodity chain analysis. Examples are when Barndt 'walked' the tomato chain from Mexico, where they are grown, to the United States where they are served. Ian Cook, likewise, tracked the papaya grown in Jamaica and consumed in the United Kingdom (Cook *et al*., 2004).

The approach of 'following commodities' or 'following the thing' combines production and consumption sites. Following reveals actors, processes, places, relationships, cultures, and communities, allowing for the disclosure of complex realities that would have been overlooked otherwise (Cook *et al*., 2004). Agriculture is the source of most food goods, including vegetables, meat, fruit and milk. They are either produced on farms or are based on agricultural products. Farmers cultivate food, harvest it, store it, and transport it to markets or processing companies for preservation and transformation into a range of food items (Rahiel *et al*., 2018). Geographers frequently refer to the study of food 'from source to the point of sale', 'from plough to plate', or 'from farm to fork', occasionally expanding the analysis to include food waste ('from farm to flush') (Jackson, 2014). Before it gets to the table, food goes through many steps, like farming or fishing and making or processing, transporting and selling. This supply chain is often complicated and lengthy, crossing international borders and involving many intermediaries (traders and sub-contractors). Some of them may not encounter the products they buy and sell (Jackson, 2014).

Arjun Appadurai came up with the phrase "Follow the Thing" (FTT) in 1986. Follow the Thing is a technique Appadurai (1986) used to reveal commodities' social lives and histories. Harvey (1990), who advocated for the necessity to look behind the curtain of commodities that customers buy, impacted this approach. FTT was inspired by discussions on commodity

fetishism, which refers to the neglect of social, environmental, and spatial relations in commodity production and people's proclivity to see the result of someone's labour in terms of links between objects (Ugoh, 2018; Cook 2006; Cook, 2004). Commodity fetishism is about exploiting people and the environment through market exchange and marketing. FTT is used to show the connections between consumption and production through actors, processes, places, relationships, cultures, and communities to better illustrate the complexity of reality previously overlooked (Wanasuk, 2019; Cook, 2006; Cook, 2004). This method can be used to show commodity biographies that illustrate cultural, economic, political, social, and environmental dimensions embedded in commodities and commodification.

As a result, hidden concerns of dominance, poverty, and exploitation at the personal level can be revealed. A Follow the Thing approach explains why and how chain actors (producers, consumers, traders, intermediaries, and suppliers) do things, what influences their activities, and how they react to challenges from internal and external pressures by presenting a wide range of perspectives and thoughts. Research has shown that all commodities have stories that encompass location and time, supply and demand, raw materials, and market forces (Cook and Harrison, 2007; Cook, 2006; Cook, 2004). Follow the Thing has been used to defetishise fruit and food products grown in the Global South and consumed in the Global North (Cook, 2006; Cook 2004). Like Cohen's work from (1997), Cook's ethnographic storytelling approach allows the reader to empathise with each chain actor's story. Cook's work has thus aided in expanding debates on social justice, the political economy of the supply chain, international commerce, the politics of ethical trade, critical citizenship, and stakeholder participatory democracy, particularly in the food business. As a result, researchers can use Follow the Thing to combine several theories in a study. Follow the Thing has also been used to track commodities such as caterpillar fungus in Tibet. This has allowed researchers to look at the geography of inequalities and the political and moral economies in the commodity chain. Even though ethical consumption is not discussed in most Follow the Thing studies, this does not mean it is not essential. Many of the studies still talk about ethical trade (Ugoh, 2018; Cook, 2006; Cook, 2004).

Like other commodity chain approaches, the Follow the Thing strategy is often used to track natural commodities like foods and clothing manufactured in the Global South and marketed in the Western consumer market. This indicates that western consumer and consumption behaviours become universal, ignoring consumers in the Global South, who have their own

consumer and market cultures (Ugoh, 2018; Gregson *et al.,* 2010). Most Follow the Thing studies focus on stabilised commodities rather than how they are created or generated from individual parts before exchanging them (Gregson *et al*., 2010). Gregson *et al.,* (2010) employ the Follow the Thing method to track the recycling of garbage ships from Asia into domestic furnishings marketed in Bangladesh. This contrasts with other Follow the Thing studies that follow a commodity from industrialised countries to developing countries while focusing on the rear end of the value chain. Another example of geographical work focusing on waste at different points along the value chain is Ugoh's (2018) study which traces citrus fruit waste from farm to markets and the final consumer in Benue state Nigeria.

Unusually for Follow the Thing approaches and commodity chain analysis more generally (Yeh and Lama, 2013; Cook and Harrison, 2007; Cook, 2004), this study explores the gendered nature of a commodity system's labour, livelihood and development; identifying key stakeholders (farmers, middlemen, traders and consumers) and their relationships to waste generated in the supply value chain. The research adopts a comprehensive approach by utilizing the "follow the thing" and commodity chain approach to understanding the nature of the tomato supply chain. The research seeks to understand the nature of the tomato supply chain as it explores the roles and responsibilities of each stakeholder in the supply chain. I am examining the intricate web of interactions, transactions, and dynamics between various stakeholders. It uncovered the underlying mechanisms that shape the exchange of tomatoes, including the influences of market forces, economic structures, and socio-cultural factors. Understanding the dynamics of the tomato supply chain within the broader context of global commodity chains was crucial for comprehending the complexities of trade, exchange, and value creation. This research contributes to a deeper understanding of how, why, where, and between whom values are exchanged within the tomato supply chain in Kaduna state, Nigeria. Shedding light provided valuable insights that can inform strategies and interventions to promote more equitable and sustainable practices within the tomato supply chain.

3.4 Commodity chain analysis and post-harvest losses

The analysis of GCCs normally begin with consumption and go backward to follow the movement of the commodity, with a particular emphasis on overall production and utilisation dynamics. This perspective depicts manufacturing by periphery countries to meet consumer demands and fuel the global economy's core. Because most products are manufactured in the

global south for customers in the north, GCCs are used with dependency theories to expose global inequity (Gereffi and Korzeniewicz 1994). This approach is criticised for its production bias because it ignores locales and people when studying the food system and instead focuses on globalisation and institutional relationships (Suwandi *et al*., 2019; Larsen *et al*., 2018).

The rising interest in commodity studies and commodity chain analysis is almost certainly due to two significant developments: agricultural industrialisation and globalisation. Although there has been growing literature on various elements of commodities over the last two decades, there has not been much focus on methodology (Suwandi *et al*., 2019; Larsen *et al*., 2018; Brown *et al*., 2010). An interesting group of studies is one that examines a specific problem using specific commodities and includes studies by Ugoh (2018) which explores the citrus chain in Nigeria with emphasis to post-harvest losses and Ian Cook's (2004) study of papaya from Jamaican farms to UK supermarkets. Globalisation has been a significant issue in research ranging from apples, sugar, and tomatoes. A number of studies have also employed commodity chain analysis to investigate commodities historically, either explicitly or indirectly. Mintz's (1985) study of sugar and Roche's (1999) analysis of the frozen meat sector are noteworthy in this regard (Suwandi *et al*., 2019; Larsen *et al*., 2018; Friedland., 2001).

A commodity chain encompasses a series of interconnected operations or transformations involving a diverse group of agents and is embedded within a market system. The behaviour of these agents is primarily motivated by their economic interests, which significantly influence their actions and decision-making processes (Hartwick, 2015; Hartwick, 1998). As a result, the chain outperforms processes that involve the physical movement of food from production to consumption. This vertical flow of commodities can investigate a single commodity system and society. As a result, commodity chains are spatial, formed "by space and location," and differ across national contexts (Hartwick, 2015; Hartwick, 1998). Production, consumption, distribution, and regulatory patterns influence the commodity system. As a result, the extent of commodity chain analysis is determined by the filière's activities (Burr., 2015; Brown *et al*., 2010). The term filière refers to a group of agents within an economic system linked structurally by the supply and demand of intermediate and final goods and who can influence and structure the economy in question.

Thus, the filière was described as a collection of players performing distinct technical and economic functions during the manufacturing and processing of a thing, from raw material to finished product. This idea can be used to examine the dynamics of agriculture's integration

into agri-food and agro-industrial systems, to quantify the generation and distribution of wealth within these systems, and to promote the development of technical and organisational innovations. (Lançon *et al.,* 2017). Anthropologists, social scientists, and economists will discover various things and meanings through the study of commodities. Commodity chains reflect deep and sophisticated social ties when the commodity is widely produced and consumed. Commodity studies provide insights into material culture, and because commodity transactions occur in a larger society rather than in a vacuum, they are not devoid of political and social significance (Smith, 2018).

Commodity chain research broadens the scope of development theories beyond production to include socioeconomic and political transformation (Bals and Tate, 2018; Jackson and Russell, 2006). Commodity chain analysis supports interdisciplinary research by combining multiple discourses. The commodities are examined outside the constraints limiting food production and consumption. As a result, food has the power to provide information about its molecular, physiological, social, economic, cultural, global, political, environmental, physical, and human geography (Roco and Bainbridge, 2003). The following questions are then addressed in response to the food stories: What is the origin of food? What is the relationship between food, politics and economics? What is the value chain's secret tale about our food? What would food have to say if it could talk about all the steps it took to get to our table (Bals and Tate, 2018; Jackson and Russell, 2006; Roco and Bainbridge, 2003).

Hartwick (2015) argues that commodity chain analysis ignores the natural environment during production in favour of revealing the chain's social reproduction and political economy via the relationships between chain members. Environmental factors have received scant attention in studies, despite their potential to influence chain actors' behaviours and attitudes, impact other people's well-being, and shape the chains' characteristics (Hughes and Reimer, 2004). As a result, the majority of commodity chain models have overlooked the relationship to political ecology, as the chain lacks a thorough integration of politics, consumerism, nature, labour and culture (Peet and Watts, 1996). This study addresses a gap in the literature by addressing environmental issues that are fundamental to the commodity chain and assessing the chain's impact on communities and the environment.

Shewfelt *et al*., (1985) recommended using a systems approach to examine PHL. Their study compares PHL and waste of food in developed countries (especially UK and USA) with those in developing countries. The post-harvest systems approach is defined as the transportation of

farm goods from the time and location of the harvest to the time and place of consumption with the least amount of loss, maximum efficiency, and maximum return to all stakeholders (Shewfelt *et al*., 1985). This method considers the socioeconomic dimensions of losses. He goes on to say that the products determine the system's complexity, which varies from country to country. The components of a system will vary, but significant parts will include packing, storage harvesting, communication, shipping, processing and marketing, across the chain, and overall system management (Shewfelt *et al*., 1985).

Osei-Kwarteng *et al*. (2017) developed the Commodity Systems Assessment Methodology (CSAM) to evaluate the post-harvest system of commodities systematically. This approach was developed in response to the need for a structured method to diagnose and resolve post-harvest challenges, considering all factors that affect the commodity system. The CSAM framework comprises 26 essential components (illustrated in figure 3.1) that help to identify and address post-harvest losses along the value chain, from planning through distribution to the end product. The CSAM methodology is divided into two critical value chain segments: preharvest and post-harvest, enabling an assessment of the entire commodity system and prioritising systemic issues. It is noteworthy that the CSAM's main objective is to evaluate and improve post-harvest losses in a commodity system (Osei-Kwarteng *et al*., 2017).

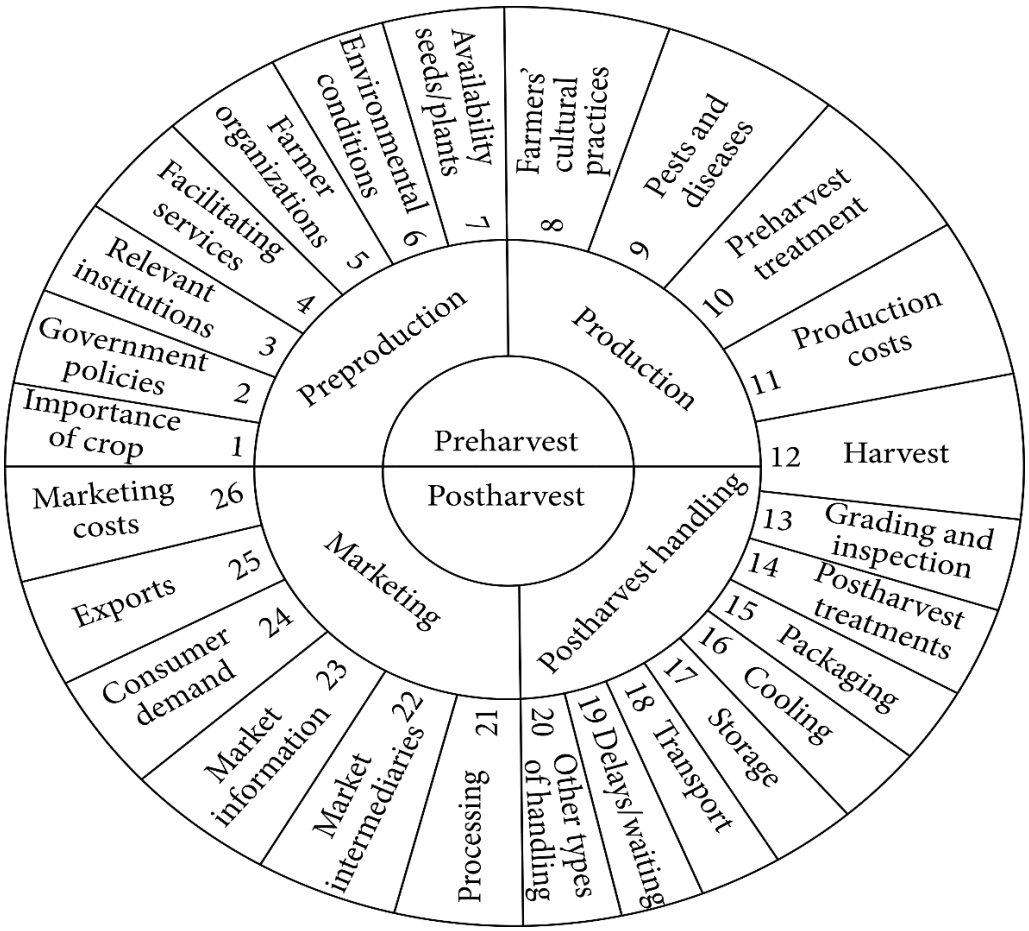

Figure 3.1: Components of a commodity system assessment

Source: Osei-Kwarteng *et al* (2017)

Drinkwater *et al*. (2016) and Osei-Kwarteng *et al*. (2017) employed the Commodity Systems Assessment Methodology (CSAM) to estimate post-harvest losses of various crops, including leafy vegetables, in South Asia and Sub-Saharan Africa, to improve the efficiency and productivity of these commodities' value chains. However, different authors and research aims may focus on specific aspects of post-harvest losses (Brouwer *et al*., 2020). Some food system frameworks used in policies prioritize research foresight but may overlook the socioeconomic factors that affect post-harvest losses (ibid.). The High-Level Panel of Experts (HLPE 2017) developed a framework highlighting the interconnections and feedback loops among three critical components of food systems, as depicted in Figure 3.2 (ibid.).

• food system drivers (external factors), such as climate change, economic growth, technological advancement, and urbanisation.

• food system components, such as food distribution, production (food value chains), and consumption, as well as the (public and private) food environments.

• food system outcomes, such as (healthy) sustainability, diets (resilience), and equity or inclusiveness (distribution) (Brouwer *et al*., 2020).

This has resulted in criticism of the term 'chain,' which divides the activities and phases of food movement into storage, planting, harvesting, retail, transit, processing, consumption and distribution, the chain's vertical connections (Brouwer *et al*., 2020).

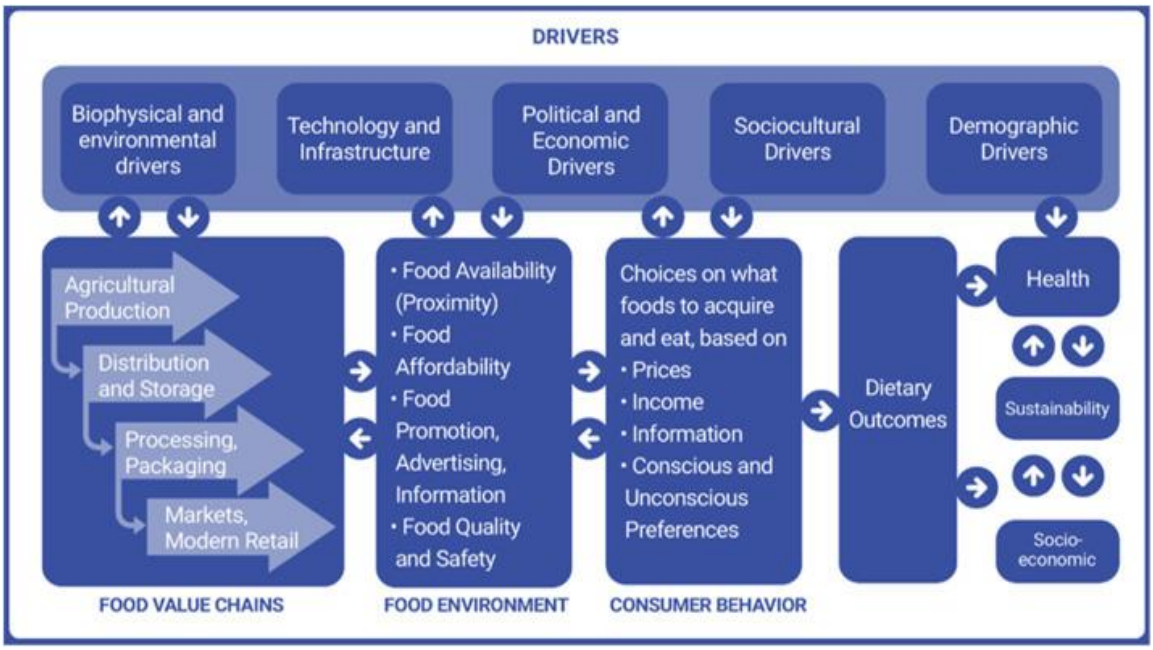

Figure 3.2: Food system framework

Source: (Brouwer *et al*., 2020).

The representation of the Food Supply Chain (FSC) implies that all causes of food loss fall into one of the chain's stages and portrays the FSC as being too rigid to account for the "dynamics of waste movement" along the chain (Read *et al*., 2020). Reducing food waste is essential to lower the impact of food systems on the environment. Additionally, Chauhan *et al*., (2021) argue that the system approach is more appropriate for studying post-harvest losses because it encompasses the dynamic, interconnected activities and operations occurring concurrently. In contrast, the term 'chain' ignores the system's dynamics and focuses exclusively on the physical operations occurring.

Recent advancements in research on the global supply chain and its efficiency have resulted in a paradigm shift in how the FSC is regarded, from a collection of distinct independent factors to a cohesive value chain connecting producers and consumers. This allows for more in-depth study to ascertain the primary players, the numerous disparities across countries, and to encourage increased system efficiency (Ishangulyyev *et al*., 2019). This technique may be

especially beneficial for policymakers, scientists, and governors seeking to understand global variance and its future implications. The primary objective is to determine the essential and beneficial technique for policymakers, scientists, and governors seeking to understand global variance and its future implications. Furthermore, to identify simple ways to determine the food waste and contamination source across the food supply chain (Ishangulyyev *et al*., 2019). Koester *et al*. (2020) suggest that the chain facilitates the study of food production and consumption's social, political, and environmental dynamics.

The chain is required to research losses that occur in "different national, institutional, and regulatory situations" (Bedoya-Perales and Dal'Magro., 2021). Nonetheless, research on food along the FSC is scarce, as most studies have concentrated on the chain's technical physical processes and attempted to examine the magnitude of the food waste within the supply chain (Bedoya-Perales and Dal'Magro., 2021). This is demonstrated by the initiatives and programmes provided to developing countries. Following the 1975 proclamation, the technical parts of the chain (limited to the farm) were investigated, and inadequate storage facilities, pests, and illnesses were identified as the primary causes of grain losses (Boxall *et al*., 1979; Adeyeye, 2017).

In 1977, the FAO Council Session recommended that PHL studies in various countries consider the "prevailing conditions" of the nations in question before reduction methods were implemented (FAO, 1980:2). In retrospect, the abovementioned prevailing conditions of countries were overlooked prior to providing solutions, as seen by the low adoption of technology by low-income countries. For example, in Malawi, an FAO-funded project distributed over 5000 metal silos to farmers for corn storage. Because Malawian farmers prefer to store their grains within their homes to avoid theft, the metal silos were designed to be placed outside their homes; however, this was not considered (Zorya *et al*., 2011; World Bank, 2011). Malawi's Ministry of Agriculture and Food Security (MAFS), director of crop development, has advised extension workers and agro-dealers to promote metal silos and super grain sacks to help farmers reduce post-harvest losses. Their objective is for at least half of Malawi's farmers to access metal silos or mega grain sacks.

3.5 Summary

This chapter studied commodity chains as a theoretical framework and their applications for assessing their influence on societies and the environment. As described in Chapter 1, this research examines the tomato supply chain in Nigeria using the Follow the Thing methodology.

Only a few studies have used commodity chain analysis in the natural tomato farm sector (Emana *et al*., 2017; Ugonna *et al*., 2015; Geoffrey *et al*., 2014). Follow the Thing integrates the salient characteristics of three commodity chain techniques (commodity networks, systems of provision and commodity circuits,) to trace both horizontal and vertical characteristics of commodity chains from production to consumption places. This study aims to track the waste in the tomato supply chain as it travels from farm gates to consumers along the value chain. Many studies concentrate on one of two topics: production or supply. After harvest, the plant receives less attention, and post-harvest waste and losses receive little attention or solutions for waste reduction. Despite this, this research builds on the usage of Follow the Thing by examining the four supply chain stakeholder holes (Framers, intermediary, traders and consumers). Drawing inspiration from this work, this study examines the quantity of tomato waste generated and the various causes of waste at different points along the value chain in Kaduna state Nigeria. A Follow the Thing approach is used to trace the tomato waste from point of harvest to point of consumption, highlighting power dynamics within the chain, and wider socioenvironmental effects on communities. Environmental protection, ethical trade issues, community development and ethical consumption in the chain are also explored.

Adopting Follow the Thing enables the disclosure of chain players' origins, identities, social status, and behaviours and their relationships, interdependence, activities, impediments, and challenges. As such, the entire commodity chain is examined to shed light on concerns of exploitation, dominance, and dependency throughout the chain (Dávila *et al*., 2021; Brooks, 2013). These are the fundamental principles that all commodity chain techniques seek to illuminate, regardless of how commodities are transported from the Global South to the Global North, vice versa, or even locally (Hanaček *et al*., 2022; Dávila *et al*., 2021; Brooks, 2013). The commodity chain's gendered character has received less attention. Thus, this research substantiates the literature by highlighting the significance of gender in labour, livelihoods, and development by identifying the amount of waste generated in the tomato supply chain, which is rarely understood (Hanaček *et al*., 2022; Dávila *et al*., 2021; Brooks, 2013).

The gaps in the literature indicate that a thorough examination of how the commodity chain interacts with nature and affects the environment is still lacking. This research addresses this information gap by utilising the Follow the Thing approach to elucidate socioenvironmental linkages along the tomato supply chain. This research examines Kaduna's entire tomato supply chain to quantify waste generated and identify potential mitigation measures. Thus, this

research contributes to the larger body of knowledge by demonstrating that the Follow the Thing technique may be employed in various geographical locations. Similarly, its application can be used to benefit the value chain's openness and fairness and local communities and the environment.

Chapter 4: Methodology

4.1 Introduction

The methodology is the systematic and structured approach employed in this research to investigate and gather facts, analyse information, and draw reliable and valid conclusions. It encompasses a set of principles, techniques, and procedures that guide the research process, ensuring the integrity and robustness of the findings. The methodology plays a crucial role in conducting a comprehensive study focused on understanding and addressing the waste issue throughout the tomato supply chain. The tomato supply chain typically utilizes quantitative and qualitative research methods to gather and analyse data on the various factors affecting tomato production, distribution, and consumption. Surveys are commonly used to collect information from different actors involved in the tomato supply chain, including farmers, processors, distributors, and retailers, regarding their production practices, pricing strategies, and supply and demand patterns.

In addition, interviews with key stakeholders can provide more nuanced insights into the challenges and opportunities within the tomato supply chain and illuminate the decision-making processes employed by different actors. Case studies and data analysis are also commonly employed in tomato supply chain studies to identify trends and patterns in the data gathered through surveys and interviews. These methods can help researchers to develop predictive models for future trends and outcomes within the tomato supply chain. Ultimately, the choice of specific research methods will depend on the research objectives and the quality and availability of the data.

4.2 The study area

Nigeria is positioned on the coast of the Gulf of Guinea between 4° and 14° North and 3° and 15° East. Its total land area is 923,768 km2, making up nearly 14% of West Africa (Balarabe *et al.,* 2016). Water covers about 13,000 km2 (1.4%) of the country. In contrast, the remaining 98.6% consists of diverse ecosystems ranging from extensive mangrove forests and rainforests in the south to a nearly arid region in the northeast (Bashir and Kyung-Sook., 2018). Moreover, the Niger Delta accounts for around 80% of the country's total shoreline distance. Nigeria is bordered west by the Benin Republic, the east by Cameroon, the north by Chad, the north-west by the Niger Republic, and the south by the Atlantic Ocean (Tabi and Ndum, 2020; FAO-Aquastat, 2016; Ezealor, 2001). Agriculture is the primary source of income for local farmers

even though Nigeria and Cameroon have found other ways to make money, like petroleum, gold, bauxite, and other mineral products. Nigeria is still, to a large extent, the most industrialised country. Besides Cameroon, Nigeria's neighbours are part of the Economic Community of West African States (ECOWAS) (Tabi and Ndum, 2020). Nigeria is still growing faster than many other countries of its population size, but the rate has slowed down a little in the coming years.

The current rate of 2.62% is expected to drop to 2.04% by 2050. Nigeria presently has two hundred and six million people in Nigeria as of 2020 and is estimated to have 264 million by 2030 and 300 million by 2036. The country has 36 states, a Federal Capital Territory, and 774 Local Government Areas (World population review, 2022). The country has the Guinea savannah, the Northern Sudan savannah, and the Southern rainforest as ecological zones (Bashir and Kyung-Sook., 2018). Rainfall, soil, humidity, and temperature determine which agroecological zone a given location lies in; however, these zones are further subdivided into eight distinct regions for irrigation purposes. The main rivers in the country are the river Niger, which flows south-east, and the river Benue, which flows west from Cameroon and joins the Niger as it turns south to form the lower Niger. Before it goes into the Atlantic Ocean, the lower Niger splits into many different channels. These channels form the Niger Delta, Africa's most extensive coastal wetland. The Sokoto-Rima and Hadejia-Jama'are river and the Nigerian part of Lake Chad have important wetlands.

Nigeria has a tropical climate with distinct wet and dry seasons, and its climate varies across the country. The length of the wet season and the amount of rainfall decrease as one moves north from the coast, with some coastal areas receiving up to 4,000 mm of rain annually, while the far north receives only about 600 mm (Reports, 2022; Tabi and Ndum, 2020; Akpu *et al*., 2017). The coastal region, including Lagos, experiences temperatures ranging from the mid-70s to the low 90s Fahrenheit and receives the highest rainfall, averaging 70 inches annually. The rainy season occurs between May and October, with the most significant rains falling along the coast. The humidity level remains high throughout the year but decreases during winter. On the central plateau of Abuja, temperatures can reach over 100 degrees Fahrenheit between March and June. Abuja experiences a hot and humid rainy season from June to September, with an average rainfall of 50 inches annually. During the colder months of December and January, humidity levels decrease significantly, and nighttime temperatures can drop to the 60s (Tabi and Ndum, 2020; Reports, 2022).

Northern Nigeria has a dry climate, with annual rainfall averaging as little as 20 inches in the extreme north (Tabi and Ndum, 2020; Reports, 2022). The harmattan, a dry north-easterly wind that transports sand from the Sahara to Nigeria's coast from December to February, is characteristic of Nigerian weather. The harmattan's effects are highest in the north and gradually diminish as one travels south. Visually, the harmattan creates a haze that, on certain days, can completely obscure views of the Abuja region's neighbouring hills. This time of year, many people encounter eye, nose, and throat difficulties (Tabi and Ndum, 2020; Reports, 2022). Kaduna State was chosen as a case study due to its high tomato production, familiarity with the area, region's climatic conditions, culture, population, and soil type permit planting various kinds or varieties of tomato seeds each season (cold, dry, or rainy season) and understanding of the language. The major ethnic groups in Kaduna State include the Hausa, Fulani, Gbagyi, Adara, Jaba, and Kagoma (Yaya *et al*., 2018).

They are predominantly Muslim and have a rich culture reflected in their language, clothing, food, and music. The largest ethnic group is Hausa, and the language is widely spread across Northern Nigeria. The Hausa language is the most widely spoken in Kaduna State and is recognized as one of the official languages of Nigeria. The meaning of words changes depending on the tone in which they are spoken (Yaya *et al*., 2018). Understanding the language can help communicate with the people. Hausa people are known for their colourful traditional attire, which includes the babanriga for men and the hijab and bubu for women. Hausa cuisine includes popular dishes like tuwo shinkafa (rice meal), miyan kuka (Baobab soup), and miyan taushe (pumpkin soup) (Yaya *et al*., 2018).

Kaduna state, located in northern Nigeria, experiences a tropical continental climate with a seasonal alternation of dry and moist air masses. The dry season occurs from November to March, while the rainy season begins in April and ends in October. The temperature peaks in March and April, reaching as high as 37°C. Humidity is high during the day and low at night. Kaduna state is named after the Kaduna River, which divides the city into two parts, and its main tributaries are Rivers Rigasa and Romi. Tomatoes are a daily staple in the local diet, and the state is divided into Kaduna Central, North, and South (Akpu *et al*., 2017). The State lies under the guinea savannah vegetation belt with scattered trees and woody shrubs and extensive grass cover. The land is suitable for agricultural and aquaculture production, providing a suitable climate for most of the crops produced in the country. The predominant occupation of

the ordinary Kaduna resident is farming. They produce crops like rice, mango, yam, potato, tomato, and soya bean, to mention a few.

Kaduna state is one of the largest horticulture producers in Nigeria. The population of Kaduna was about 1,582,102 consisting of 455,697 females and 515,373 males, according to the 1991 census (Akpu *et al*., 2017; Akpu *et al*., 2017). The population reached 1,729,142 with 811,440 females and 917,702 males in 2012. As a result, much pressure has been put on social amenities and land agriculture. The city is multiplying (Akpu *et al*., 2017; Akpu *et al*., 2017). As of the year 2021, it was estimated that the population in Kaduna was approximately 8.9 million (Alabi and Anekwe, 2023). This number represents the people of Kaduna State. The magnitude of the population includes both males and females of varying ages, ethnicities, and socioeconomic backgrounds. As a significant urban centre and one of the most populous states in Nigeria, Kaduna has a culturally, economically, and socially dynamic population in various ways. Kaduna's population significantly impacts the state's socioeconomic landscape, influencing infrastructure development, healthcare services, education, employment opportunities, and overall societal welfare.

Figure 4.1: The study area

Source: Authors

4.3 Ontological and epistemological underpinning the study

Research serves as the bedrock of knowledge, and it generates evidence and informs measures that can benefit society more broadly. The knowledge that researchers develop because of their research can improve the well-being of individuals, their societies, and the communities in which they live (Liamputtong, 2019; Vogl *et al*., 2019). In social science, the methods used are linked to the social world and how it should be studied (Liamputtong, 2019; Vogl *et al.,* 2019; Guyon *et al*., 2018). Human geography research has progressed throughout time. Since the 1960s, philosophical discussions have created diverse approaches to studying human geography. Social scientists embraced fundamental philosophical viewpoints to explain human behaviour, ontological and epistemological paradigms (Strauss, 2020; Plesa, 2019).

Alharahsheh and Pius (2020) assert that ontology is a fundamental concept concerned with the nature of reality, precisely the existence of phenomena. This implies that ontology aims to determine the truth or solution to a research problem by identifying and categorizing different types of knowledge related to the phenomenon under investigation. The authors' definition underscores the significance of ontology in research, as it provides a framework for understanding the nature of reality and the various ways knowledge can be obtained. The analysis of this definition highlights the importance of ontology as a foundational aspect of research that influences how researchers approach their investigations and how they make sense of the phenomena they study. Ontology is a discussion between two viewpoints on the nature of reality: realism and idealism. The critical question is whether there is an actual universe outside human perception. Realists hold this viewpoint, whereas idealists disagree, believing there is no actual universe beyond what the human mind can create.

Numerous questions arise from this viewpoint regarding what humans may learn and whether there is a deeper universe beyond the human mind's realisations (Escobar, 2019; Grossmann, 2019). As a philosophical perspective on knowledge theory, epistemology focuses on how we acquire knowledge. According to Alharahsheh and Pius (2020), epistemology concerns a researcher's understanding of reality and how they seek knowledge to arrive at it. It involves discriminating between right and wrong and viewing the world around them. Different paradigms may have varying beliefs about reality and knowledge, resulting in different study strategies and methodologies. Hothersall (2019) also suggests that epistemology deals with how we know what we know. The paraphrased passage maintains the text's original meaning while using different words and sentence structures. The authors' ideas about epistemology are

conveyed, and the reference is correctly cited. Additionally, the paraphrased passage provides more context by discussing the role of paradigms in shaping researchers' beliefs about reality and knowledge.

According to Alharahsheh and Pius (2020), positivism has multiple meanings. In natural science, positivism refers to a philosophical approach that utilizes empirical evidence to generate generalizations about the world. The focus is on producing objective and unbiased data and facts, devoid of any human interpretation or bias, and emphasizing their relevance in a general sense. Hothersall, (2019) holds that positivist perspectives hold that the social world may be examined using the same methods as the natural sciences, depending on justifying principles in opposition to empirical evidence. Cunningham, (2019) states that positivism rejects metaphysical questions as unmeasurable, and they believe that the only path to knowledge is through evaluating various laws and ideas against scientific facts. Interpretivism opposes positivism as a model for social science and attempts to analyse and comprehend human behaviour (Mazurkiewicz, 2019). It adopts an idealist ontological perspective, viewing social order as a continuous comprehension and interpretation of the social environment (Lee, 2020). According to idealists, knowledge and reality are subjective, and understanding the meaning and interpretations of external structures helps define what is real and what constitutes human action. To idealists, existence is determined by an individual's assessment of their social surroundings. As a result, behaviour patterns can only be described if the underlying beliefs are comprehended (Lee, 2020; Cunningham, 2019; Mazurkiewicz, 2019).

According to Alharahsheh and Pius (2020), interpretivism emerged as an alternative to the subjective approach of positivism. Interpretivism focuses on the specific variables and elements of a context, recognizing the uniqueness of humans compared to physical phenomena. This perspective emphasizes the importance of adding depth to understanding the meaning behind human actions, which cannot be studied in the same way as physical phenomena. In contrast to natural science research, social science research requires differentiation between cultures, situations, and historical periods that contribute to distinct social realities. Interpretivism is concerned with the causes of human activity — the human goals and ideas. Three fundamental characteristics define human activity: reflexivity, intentionality and reason. It is necessary to comprehend and interpret individual behaviours and traits essential to the source of action; thus, interpretivism is subjective (Pulla, and Carter, 2018).

The essence of idealism is a knowledge of how individuals interpret, whereas realism describes the impact of extrinsic systems on human conduct. Ryan (2018) asserts that studying external structures comes before studying human behaviour, as these structures are responsible for human action (Pham, 2018; Pulla, and Carter, 2018). To idealists, knowledge comes from how people think about how they come to know the world, so there are multiple realities. Each person has a different view of rules, culture, norms and other outside structures. This constant understanding and interpretation allow for a better understanding of the individual's environment, affecting how the person acts (Liamputtong, 2019; Pham, 2018; Pulla, and Carter, 2018; Guyon *et al*., 2018)

According to Alharahsheh and Pius (2020), interpretivism and positivism have different goals. While positivism aims to establish universal laws that can be applied to everyone, regardless of their specific circumstances and factors, interpretivism focuses on gathering insights that capture the richness and complexity of a particular situation. In other words, interpretivism seeks to understand the nuances and intricacies of a situation rather than aiming for universal generalizations. It is essential to know the difference between positivism and interpretivism. Positivism tries to explain, while interpretivism tries to understand how people act. Positivism is criticised for being exclusive; positivists believe that the same approaches can explain physical and social phenomena. On the other hand, interpretivism maintains that humans are separate beings and that natural science methods overlook human qualities and the spatial patterns in social, economic, and political institutions that influence human behaviour (Giraldo, 2020; Ryan, 2018).

The methods used to describe human behaviour (human action) differ from natural scientists' methods of evaluating hypotheses (Alharahsheh, and Pius, 2020). Alharahsheh, and Pius, (2020) observe that ontological perspectives on what exists do not always correspond to naturalism and anti-naturalism. A positivist or interpretivist perspective, on the other hand, can represent a realist or idealist ontology (Ryan, 2018). While positivist research uses numbers, statistics, and quantifiable empirical evidence to verify theory (Alharahsheh, and Pius, 2020), interpretivism research draws on the actual human experience. It collects 'words' about how individuals make sense of and interpret the social world (Ryan, 2018).

4.3.1 Qualitative and quantitative methodological approach

The argument over the relative merits of quantitative and qualitative methods has gained substantial momentum over the years (Amaratunga, and Baldry, 2001; Bryman, 1984). While the precise composition of the two approaches varies slightly between authors or is characterised by varying degrees of clarity, there is widespread agreement regarding the underlying antinomies and their practical implications for research conduct. However, one of the difficulties in portraying the divergences between the two techniques is the tendency for philosophical and technical issues to be tackled concurrently and occasionally confounded (Amaratunga, and Baldry, 2001). In recent years, the nature of the debate has changed a little bit. Now, the focus is on comparing quantitative and qualitative methods. A significant change has been the rise of textbooks and journals that only deal with qualitative methods and special issues of more general journals that deal with qualitative methods. These include Qualitative Sociology, Urban Life and Anthropology, and Education Quarterly (Bryman, 1984).

Conventionally, there were two main types of research which are qualitative and quantitative ways to do things. Quantitative and qualitative approaches are often considered separate things at opposite ends of a continuum. There is a big difference between them because of how they think about knowledge and how they think about things. Quantitative research focuses on how to measure things when collecting and analysing data (Alharahsheh, and Pius, 2020). It strongly prefers positivism and post-positivism regarding how we know things in the world of thought. Another one of its central beliefs is that social reality is genuine and not made up. Subscribers to this method believe in testing theories inductively, preventing bias, and being able to generalise and repeat findings (Alharahsheh, and Pius, 2020). Variables are measured to generate and analyse numeric data using statistical procedures (Alharahsheh, and Pius, 2020).

On the other hand, qualitative research is thought of as research that puts more emphasis on words than numbers when collecting and analysing data from a social constructivism perspective and its scientific method of inquiry (Darlington and Scott, 2020; Tracy, 2019). Many scholars think qualitative research is easier to do than quantitative research because it emphasises finding new or unanticipated findings and the ability to change research plans when these things happen (Darlington and Scott, 2020). This starkly contrasts the quantitative methodologist's research design, which emphasises fixed measurements, hypothesis testing, and a much shorter amount of time in the field (Kalman, 2019; Amaratunga, and Baldry, 2001).

One essential thing about qualitative research is that it is always exploratory because it needs to be structured and there are no set hypotheses. Consequently, the qualitative researcher takes a journey of discovery, not verification (Kalman, 2019; Tracy, 2019; Amaratunga, and Baldry, 2001). This means that the research is likely to lead to new leads and avenues of research that the quantitative researcher will not come across but can be used as a starting point for more research, which is what qualitative research is all about (Kalman, 2019; Tracy, 2019). So, this kind of research will follow up on the leads suggested by qualitative research and try to confirm or deny them using a natural science approach and a quantitative methodology. (Darlington and Scott, 2020; Kalman, 2019; Tracy, 2019; Amaratunga, and Baldry, 2001).

Most data collection techniques apply to both quantitative and qualitative research. The distinction is primarily due to the constraints placed on the degree of structure, flexibility, depth, sequential order, and freedom during the research process. Quantitative approaches advocate for these constraints, whereas qualitative methods oppose them (Darlington and Scott, 2020; Rinjit, 2020). Both quantitative and qualitative approaches have limitations, and as a result, they frequently cannot establish sufficient evidence to make new conclusions. To address the constraints approach, using both methods in a single study has emerged and is gaining acceptance in social research (Rinjit, 2020; Kalman, 2019; Tracy, 2019). Mixed methods research uses quantitative and qualitative methods in the same study. A mixed-methods study incorporates quantitative and qualitative methodologies into one investigation. Rutberg and Bouikidis (2018) define mixed methods research as research. The researcher collects and analyses data, integrates findings, and develops conclusions utilising qualitative and quantitative approaches or methodologies in a single study or programme of inquiry. This strategy may enable the researcher to acquire two sets of data (Rutberg and Bouikidis 2018).

The mixed method uses qualitative and quantitative research, giving a more in-depth understanding of the research problem (Strijker *et al*., 2020; Greene *et al*., 2005). It is best for studies where the researcher wants to generalise the findings to a group of people and give detailed explanations of the studied issue (Strijker *et al*., 2020). Many journals encourage mixed methods research in the modern world, but the journal of mixed methods research requires quality and quantity (Rutberg and Bouikidis 2018). Even though this is a new method, it has been used in the social and human sciences (Rutberg and Bouikidis 2018). Rutberg and Bouikidis (2018) define mixed methods research as research that opposes a solely quantitative or qualitative approach. In other words, it represents an integration or combination of

quantitative and qualitative research methods within a single study. Furthermore, there are some things that could be improved with this method. (Greene *et al*., 2005). The researcher must also be experienced in qualitative and quantitative methods (Strijker *et al*., 2020; Rutberg and Bouikidis 2018; Greene *et al*., 2005). This study adopted a mixed-methods approach based on a collective (or many) case study methodology. The researcher chose the methodologies to utilise after considering the nature of the research difficulties, the study's aims, the availability of existing data, and the practical constraints associated with fieldwork.

4.3.2 Mixed methods

According to Taguchi (2018) and Creswell and Plano (2017), mixed methods research is when both quantitative and qualitative data are collected or analysed in the same study. The data are collected simultaneously or sequentially, given more attention and combined. This definition shows how mixed methods research design and data collection differ from other research types. First, quantitative, and qualitative data are collected simultaneously or at different times. Second, quantitative, and qualitative data can be given the same amount of attention, or one type of data can take precedence over the other. The decision about which data should be more critical takes work. Creswell and Plano's (2017) definition reveals an important point which is 'data integration.' The authors underline that a mixed-methods approach does not imply the inclusion of disparate types of data and data analysis methods in a single study. To adequately address the study issues, several data sources must be firmly integrated (Creswell and Plano 2017).

When discussing mixed methods, Hendren *et al*., (2018) indicate that mixed methods research must systematically use quantitative and qualitative methods to help each other out. In addition, they argue that mixed methods must be used for a specific reason. So, just collecting and analysing quantitative and qualitative data does not make a study a mixed methods study just because it does that. Instead, mixed methods research is about systematically using both quantitative and qualitative methods to obtain strengths from each. If quantitative and qualitative data do not interact, it is not a mixed method. If a study is called mixed methods, it must be done with the help of two different methods. Mixed methods can answer research questions more meaningfully than quantitative or qualitative methods alone, and this is because mixed methods combine data from both quantitative and qualitative sources (Hendren *et al*. 2018).

Mixed methods research has a variety of advantages. According to Hendren *et al*., (2018) and Taguchi, (2018), mixed techniques can answer research problems that other methodologies cannot, generating better and stronger inferences from the data. This strength is reasonable because mixed methods synthesise two distinct philosophical and methodological perspectives. Quantitative approaches are confirmatory and are used to confirm (or disprove) theories, whereas qualitative approaches are exploratory. By combining the two, researchers can test hypotheses while delving into the significance of (dis) confirmed theories. Another advantage of mixed methods research is that it can reveal a broader range of diverse perspectives than quantitative or qualitative methods alone (Hendren *et al*., 2018). Historically, researchers employed mixed methods primarily for cross-validation, meaning that inferences generated from quantitative and qualitative data converge. However, scholars now recognise that convergence only sometimes occurs. We may discover something in quantitative data but not in qualitative analysis. Hendren *et al*., (2018), suggest that such varied findings are significant because they provide new insight into the issue.

The study adopted mixed methods approach, which came with various benefits. Firstly, it allows the researcher to gather quantitative and qualitative data, providing a more comprehensive understanding of the topic under investigation. Concerning tomato waste in the supply chain, surveys can provide quantitative data on factors such as production levels, pricing, and demand. On the other hand, interviews with stakeholders can provide qualitative data on challenges faced by different actors, their decision-making processes, and their perceptions of the tomato supply chain. Using mixed methods can enhance the credibility and validity of the study. Triangulation, which involves using multiple methods to study the same phenomenon, can help to cross-validate the findings and increase confidence in the results. For example, if surveys and interviews yield similar findings on the challenges faced by tomato farmers, this can provide more robust evidence to support the conclusions drawn from the data.

Moreover, using mixed methods help address the limitations of particular research methods. For instance, surveys may suffer from response bias or lack of depth, while interviews may suffer from small sample sizes or lack of representativeness. By combining these methods, the researcher could mitigate each approach's weaknesses and obtain a more accurate and nuanced understanding of the topic under investigation. Finally, mixed methods provided more flexibility in the research design and allowed the researcher to adapt to unexpected findings or

changes in the research context. Using quantitative and qualitative methods, researchers can shift their focus from one approach to the other depending on the emerging research questions and insights. Using mixed methods can bring about several benefits in research, including a more comprehensive understanding of the topic, increased credibility and validity, addressing the limitations of individual methods, and flexibility in research design.

4.3.3 Sampling strategy

A research sample can be defined as a subset of the population, according to Acharya *et al*., (2013) while Riley *et al*., (2019) define a research sample as a collection of materials drawn from a population in some way. Furthermore, Hayes (2020) defines it as a subgroup of the population that is selected for the study. Multi-stage sampling (also called multi-stage cluster sampling) is a more involved cluster sampling method involving two or more stages of sample selection. Multi-stage sampling divides significant population clusters or areas into smaller clusters or phases to facilitate the collecting of primary data (Yarahmadi, 2020; Chun tie *et al*., 2019). This research adopted multi-stage sampling to divide the state into three geopolitical zones and cluster tomato farms and markets identified to increase efficiency, enhance representativeness, and improve practicality and feasibility. By dividing the population into smaller clusters or stages, multistage sampling allows for a more manageable and cost-effective data collection process. Furthermore, it enables the selection of a representative sample, ensuring that subgroups within the population are appropriately represented and increasing the generalizability of the findings.

4.3.4 Data collection

My research began by contacting the Kaduna State Ministry of Agriculture in search of information to guide my data collection. When I met the Head of Horticulture in the Ministry, he highlighted a significant research gap in post-harvest activities and crop losses in the state, as already mentioned in Chapter one. He indicated that the Kaduna State Ministry of Agriculture held no records or data on post-harvest losses for any crop as their focus is on improving farm produce's supply and yields for the coming planting season. This conversation confirmed that my focus on post-harvest losses in tomatoes was a valid and essential research goal that would provide helpful information to the Ministry that could shape future agricultural strategy in the State. I then proceeded to Kaduna State University's Department of Geography and Department of Agriculture and Food Policy, looking for reports, information and student

dissertations on post-harvest losses or food waste. This search also confirmed a lack of information on post-harvest losses. Generally, most of the dissertations were on food production guidelines and policies, waste generation and management in general because there is no waste segregation in Nigeria. I was advised to go to the Federal Ministry of Agriculture in Abuja to get more information on post-harvest losses and wastes.

It took much work to gain access to the Ministry, even after presenting the letter from the University of Nottingham, showing my ID card as a student, and stating that my visit was only for research purposes. After I presented my Army ID card, showing that I was a military man, I was allowed to enter the ministry. In the absence of the Federal Minister for agriculture and rural development, I was introduced to the head of Horticulture of Nigeria. We spoke for about 30-45 minutes, and I told him about my research and asked permission to record our conversation, but he declined. I was hoping to get records or some data on post-harvest losses, but I was told that the Ministry concentrates on producing and supplying fertilizer and loans to low-income farmers in areas where they have a shortfall of products they import. The Head of Horticulture confirmed that the Ministry needed records of post-harvest losses for any fruit. This further confirmed a clear research and information gap in Nigeria. He provided me with photos of how the government has supported some local farmers in building tomato indoor farms and invited me to contact him if I needed further information for my research. There was abundant information on grains, cereals, legumes, tubers, and tomatoes, but something other than post-harvest losses.

4.4 Questionnaire administration with all stakeholders

The questionnaire was a critical component in conducting any research. To develop an effective questionnaire, it is necessary first to outline research aims and objectives, as a successful questionnaire accomplishes the researcher's objectives. As such, the primary purpose of the research questionnaire is to collect data that will aid in answering the study's research questions. I then visited the Kaduna State Ministry of Agriculture and the Kaduna State Horticultural Development Authority to find information on agricultural policies and strategies for coping with post-harvest losses. They stated that their job description should have included losses. They did not have any agriculture policies on paper, unfortunately. However, I spoke with some attendees, who supplied me with helpful information on tomato production in Kaduna. Although tomato waste was a recognised issue, doing such a survey was expensive. Others did not consider it a problem because they believed that post-harvest losses in tomatoes were a

regular occurrence. After all, reducing waste may cost more than what is used to produce it (looking at the cost and benefits).

With guidance from the Kaduna state Ministry of Agriculture, we identified tomato collation markets in 15 Local Government Areas in Kaduna State. We spoke with the leaders of these markets on issues related to data and records of tomato post-harvest activities that take place daily in these markets. With some of this information, we selected three major tomato collation markets in each of the three geopolitical zones in the state to provide a geographical spread for the data collection. These markets were selected based on having a high amount of tomatoes and the number of farmers and intermediaries that flood the markets daily. Table 4.1 and figure 4.2: below show the areas where data collection occurred.

4.5 Materials and methods

This study utilised multi-stage sampling as explained in 4.3.3 to partition the state into three geopolitical zones and identify tomato growers and market clusters. We identified tomato collection markets in 15 Local Government Areas of Kaduna State with the assistance of the state's Ministry of Agriculture. We spoke with the heads of these markets about difficulties linked to the data and documentation of daily tomato post-harvest activities. There was no documentation or records accessible, only knowledge based on experience. Using some of this information, we chose three leading tomato gathering market places in each of the state's three geopolitical zones to ensure geographical diversity in the data collection. These markets were chosen based on their abundance of tomatoes and the number of farmers who throng them daily.

Table 4.1: Tomato markets in Kaduna

Kaduna State	Zaria (District A)	Kubau tomato market
		Zaria city tomato market
		Sabon-gari tomato market
	Igabi (District B)	Kaduna central tomato market
		Igabi tomato market
		Giwa tomato market
	Kaura (District C)	Kaura tomato market
		Kajuru tomato market
		Kachia tomato market

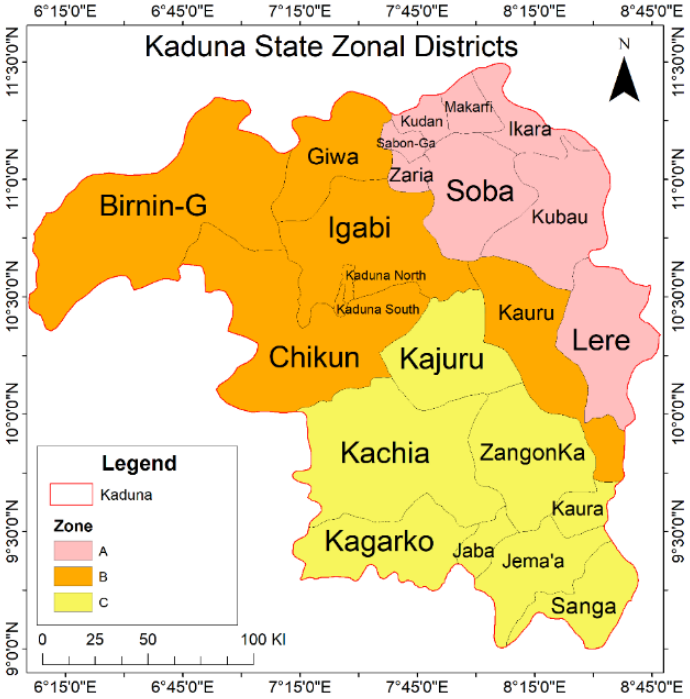

Figure 4.2: Map of Kaduna showing Zones A, B and C

From June to September 2019 and January to February 2020, surveys were conducted to ascertain the dynamics, issues, and obstacles that farmers, intermediaries, traders, and consumers confront inside and outside the farm gates. Following a pilot survey with 15 farmers to determine the questionnaire's readability and order corrections and modifications were made before the questionnaire was finalized for data collection. Questionnaires acquire primary quantitative data from individuals on their "behaviour, attitudes, opinions, and awareness of specific issues" (Anokye, 2018). The questionnaire was chosen as the data collection tool in this study due to its cost-effectiveness, ease of delivery, and ease of quantitative analysis. I chose questionnaires due to the nature of the information I required from farmers, intermediaries, traders and consumers. (Appendix 1).

The questionnaire was designed with great care to ensure that the questions were concise, straightforward, clear, and comfortable to discuss to obtain the correct data without causing harm to the participants. Also, questions with dual meanings that could lead to individual responses were avoided. It was constructed using a variety of questions developed by the researcher and contained open-ended, yes/no, category, rating, scale, and quantity questions. Different questions were utilised to cover each issue, and participants were provided explicit instructions to avoid confusion. The questionnaires asked about the actors' socioeconomic demographics, farming, purchasing, and sales habits, attitudes, beliefs, and perceptions about

the magnitude of their losses and the causes of these. This survey section was the most challenging, as I needed to avoid leading questions; nonetheless, after carefully editing and testing the questionnaires, I could ask objective questions that offered solutions to my research topic.

The first set of questions was about the farmers' demographic information, which included age group, marital status, gender, and level of education. The second part tried to get information about farm produce, such as the type of crops they grow, the yield per year, the size of the farmland and how they acquired their farmland. The third part asked questions on post-harvest losses and waste, where farmers have experienced high losses and the reasons for the losses. To complement the data obtained from the questionnaire, field observations, focus group discussions, photographs, and interviews were used to improve the quality and validity of the data collection. Interviews and information were also gathered from Federal and State ministries of Agriculture and Horticulture, farmers' association leaders, intermediaries, association leaders, retailers and other important stakeholders involved in the tomato market industry, including individual car drivers, sorters and workers in the tomato markets. This allowed vital information to be put together from several value chain actors.

4.5.1 Key informants

I met farmers who wanted to teach me about their agricultural procedures and show me the differences between tomato types, the differences between the types they plant in a particular season and ones that will only grow if planted in a particularly dry season. One farmer was so happy with our conversation that he offered a basket of tomatoes for free. However, things got even better when the research team came across Mallam (Chairman of the tomato middlemen association). He is a farmer who has been growing tomatoes for 25 years before becoming an intermediary who buys tomatoes to sell in markets within and outside Kaduna State. He introduced me to other middlemen who have also been in the business for some time. So, data collection for farmers and intermediaries continued simultaneously. At first, he was not interested in what we were doing because of his previous negative experience of assisting with some other research done by the government.

The Kaduna state government had invited him to give information on tomato farming and what government intervention was needed to help the industry. After helping to identify the fundamental problems, he was disappointed to find that more needed to be done to address them. He further lamented being invited to a radio station for a programme on farmer problems.

He identified specific problems but again found that nothing arose from this. After I approached him and introduced myself as a student researching tomato post-harvest losses, he decided to help. With his guidance, we were able to gain more understanding and information about tomato farms and tomato collation markets in the 15 Local Government Areas in Kaduna State, where we spoke with the leaders of the markets on issues related to data and records of tomato sales that take place daily in these markets. No documents or records were available, but we got information from interviews and direct observation. I selected farmers from different parts of the 15 LGAs visited to avoid collecting the same information from neighbouring farmers with similar farm environmental conditions. I got responses that reflected the farmers' perspectives and captured their attitudes, perceptions, and feelings, which helped me to interpret the data.

4.5.2 The survey and farmers

The data collection process started with a questionnaire survey of farmers, followed by intermediaries, traders and consumers. A total of 80 surveys were conducted for farmers using 64 responses. Data collection via surveys is prone to answer errors (Brace, 2018). I found some unsatisfactory responses to the questions and rejected 16 responses from the farmers' data. Phone numbers of respective farmers were collected for clarity of responses when needed. All interviews and data gathering were done in person for quality and data validity. Table 4.2: below shows the distribution of data collected along the value chain. A total of 174 responses were collected for this research.

Table 4.2: Distribution of value chain actors

Kaduna Zones	Farmers	Intermediary (Middlemen)	Traders	Consumers	Total
Zone A (Kaduna North)	22	7	3	7	39
Zone B (Kaduna Central)	22	12	32	23	89
Zone C (Kaduna South)	20	8	10	8	46
Total	64	27	45	38	**174**

Personal field observation and travel experience have shown a need for more care given to food items and livestock such as goats, cows, and camels in transit from one point to another. Doing this research on tomatoes made me have a closer look at what is happening in the tomato markets and how minor or no attention has been given to the farm produce after harvest, from improper handling technics to a lack of storage facility on-farm to poor storage containers and from poor transport systems to poor distribution patterns (Adepoju 2014; Gani and Adeoti 2011). A high amount of what is produced would have gone to waste before getting to the consumer's table. The LGAs visited include Kubau LGA, Zaria LGA and Sabon-gari LGAs (Zone A), Kaduna central LGA, Igabi LGA and Giwa LGA (Zone B), and Kaura LGA, Kajuru LGA and Kachia LGA (Zone C) to interview farmers, intermediaries, and traders. This was done to gain a sense of the whole process and know what information the questionnaires would provide so that analyzing the data obtained in questionnaires could quickly be done.

A personal car was used during my travels and data collection. Using a personal automobile was the safest and most reliable means to get to the LGAs where I needed to be, as the local transportation system needed to be more trustworthy and convenient for reaching the locations where fieldwork was conducted. I was accompanied by a male and female researcher assistant. My research assistant accompanied me to every meeting venue (farmers' homes) to secure my safety and to aid with the Hausa-English translation and easy access to female farmers middlemen and traders. I travelled along the highways that connected LGAs and spoke with identified farmers. I had two female farmers who were initially hesitant about speaking with me but eventually opened up when they saw a female among us. I explained to them that, I was a student and that my questions were strictly for research purposes. I saw that the farmers, traders, and intermediaries were enthusiastic about what they did and eager to share their knowledge of tomato production, trading, and post-harvest losses. Most of the data collection was centred on farms along the main road and farmers that bring their products to these markets because the security situation at the farm in isolated locations outside Kaduna state capital was not guaranteed. There have been several reports of banditry, kidnapping and insurgency in recent times both within and outside the Kaduna state capital (Gadzama, 2018). These markets have the most significant tomato inflow daily, so the number of farmers and intermediaries is high.

4.5.3 Intermediaries survey

The term "intermediaries" refers to people or businesses who purchase goods or services from producers and resell them to consumers (Bhatt, *et al*., 2022; Issa, and Munishi, 2020). The term "middlemen" is used in this research compared to market intermediaries that purchase farmers' produce in large quantities and then resell it to either vendors, hawkers, or the final consumers. Since they are the main facilitators of this process, the currently available literature demonstrates that intermediaries play a crucial role in the supply chain for urban fresh fruits and vegetables (Aworh, 2021; Issa, and Munishi, 2020; Trienekens, 2011). The roles played by intermediates in the supply chain for fruits and vegetables include, but are not limited to, aiding transportation, value addition and quality improvement, storage services, as well as providing marketing information for fruits and vegetables grown in metropolitan areas (Bhatt, *et al*., 2022; Aworh, 2021; Ugoh, 2018). The middlemen in Nigeria's tomato marketing chain are essential to bringing farm products to the consumer. As a result, they must pay more and take on more risks. The main cost issues include buying, transportation, loading and unloading, sorting, storing, waste, and price risk.

According to Adeoye *et al*. (2009), the total cost of marketing includes the price of shipping the product from its place of origin to its point of sale. Therefore, the product must reach the consumers between two and fourteen days after the farmers have harvested it for the distribution system to work correctly (Adeoye *et al.,* 2009). Intermediaries must transport the product to the market where it will be sold to end users, while wholesalers frequently go to the market where retailers are waiting for the merchandise. Due to storage concerns, intermediaries have found it challenging to keep ideal daily or weekly stock levels (Obetta *et al*., 2020; Ocholi, *et al*., 2020; Adeoye *et al*., 2009). Because there is not enough room for storage and there isn't a standard way to weigh produce, the intermediaries only buy from the farmers what they can sell right away. Considering this, the purpose of the study is to ascertain whether the actions of middlemen have any effect on the PHL of tomatoes that are quickly perishable. Post-harvest handling of fresh fruit is critical for establishing its shelf life and its level of microbial activity (Issa, and Munishi, 2020). Transporting and storing fruits from the farm to the market is an essential value chain component (Issa, and Munishi, 2020). Most farmers sell to intermediaries, who then sell to dealers and consumers. They purchase red and green tomatoes from farmers and pay a flat rate (Boonanant, 2020).

The questionnaire for intermediaries was modified after a pilot survey with 10 participants each (Appendix 2). The questionnaire focused on the intermediaries' demographic information, such as age, marital status, gender, and educational level. The second section attempted to obtain information regarding farm purchases, such as where they buy their tomatoes, the annual purchase, the distance between the place of purchase and selling point, and the maturity of the tomatoes they buy. The final section focused on post-harvest losses and waste, specifically where intermediaries have suffered significant losses and the reasons for such losses. The research team travelled along main roadways to surveys farmers, traders, and intermediaries.

Unlike the farmers, the intermediaries' data was collected in a mixture of single or group surveys. Some intermediaries came around when they saw us talking with one or two of their colleagues. Sometimes they stood and listened with a single spokesperson, while other groups had everyone discussing and contributing answers to various questions. All surveys took place after a formal introduction of myself as a student conducting research seeking their consent to carry on with my inquiry. They were also notified that they were free to leave if they felt uncomfortable about any aspect of the research. The discussions were casual and recorded, and the interview questions were a guide to ensure all points were covered. The intermediaries were found and approached in the marketplaces where they do their business. The time to talk to them was limited as they were sometimes approached by clients or attended to other responsibilities. During conversations with some of them, customers occasionally diverted their attention before they returned and continued, while others lost interest after being interrupted.

In some cases, intermediaries were relieved that someone was finally looking into their concerns. However, they were also disappointed because they had complained about the problems for years, but the government had turned a blind eye. It should be noted that although responses from the intermediaries comprises of both single and group surveys, no variation in the data was identified.

Figure 4.3: Intermediaries segregating tomatoes

Author's photography. July 2019

Figure 4.4: Waste tomatoes after segregation

Author's photography. July 2019

Figure 4.5: Author weighting tomato baskets

4.5.4 Trader's survey

With the already established contacts and experience in the field, the traders' surveys were mainly conducted simultaneously with the intermediary surveys. However, most traders' data were collected during January and February 2020. This is when the amount of tomatoes harvested is high compared to the June to September 2019 survey. This was done before the covid 19 pandemic. The questionnaire for traders was also amended after a pilot survey with 8 participants outside the primary survey (Appendix 3). The demographic information of the traders, such as their age, marital status, gender, and educational level, was the first focus of the questionnaire. The second component sought information on farm purchases, such as where they acquire their tomatoes and how often they buy them. The distance between where they buy tomatoes and where they sell them and how mature they are when they purchase them are factors that significantly impact the quality and price of the tomatoes and the profitability of the sellers. The distance between the purchase and sale locations can affect the freshness and shelf-life of the tomatoes, while the maturity of the tomatoes when purchased can affect their taste and texture. Additionally, the amount of loss or waste generated can impact the overall business and its profitability and environmental impact. Therefore, it is essential for tomato sellers to carefully consider these factors and develop strategies to optimize their supply chain and minimize waste.

Three categories of traders were observed during the fieldwork in Kaduna state: those that sell by the roadside under a shade, the mobile traders using wheelbarrows, and those found in the marketplaces. All these traders appeared to be much more aware of their operation (they knew the quantity of tomatoes they could sell on a typical day). They knew the number of baskets to buy in a day or a week and they only bought after selling off what they had in stock. All three types of traders have their pros and cons. During interviews with mobile tomato sellers, they appeared to be busier as they moved from one point place to another, either in the marketplace or within the streets. Interviews were undertaken as they moved around and as a result, gaining information from them took more extended periods than for the other two trader groups. Collecting data from market traders was also tricky, as they needed to serve customers and do their business. Their first impression was always how much tomato was needed (referring to us buying tomatoes).

4.5.5 Field observation

Field research is a qualitative form of data collecting that aims to comprehend, observe, and interact with individuals in their natural environments (Harvey, 2021). Therefore, when social scientists refer to being "in the field," they refer to being immersed in the everyday lives of the individuals they are studying. Sometimes, researchers refer to this data collection as ethnography or participant observation. Observations are constructive for gaining insight into a particular situation and actual behaviour instead of reported behaviour or opinions (Busetto, 2020). Qualitative observations might be participant-based or non-participant-based. In participation observations, the observer is a part of the observed environment. Both sides of the participant observer's position have advantages and disadvantages. Complete observers may overlook essential parts of group interaction and need help comprehending the lives of the people they witness (Ciesielska. *et al*., 2018).

Conversely, sitting back and observing may allow individuals to see conversations they would miss if they were engaged. Complete engagement gives researchers a true feeling of what it is like to be a member of the group they are studying. Some contend that participation is the only way to comprehend what we investigate. On the other hand, total participants may find themselves in the circumstances they would prefer to avoid but cannot avoid since they have assumed the role of complete participant. As a participant in all data collection efforts, the researcher made observations during the data collection period. During the distribution of questionnaires, observations were made, questions were posed, and responses were recorded

in a field journal. Noting observations is an essential component of participant observation. Typically, these are "detailed accounts of events" that contain the researcher's reflections (Phillippi and Lauderdale, 2018). Farmers were more concerned with how they sell their tomatoes than with cleaning or separating the red and green varieties. In contrast, the intermediaries were primarily concerned with the quality of their products to traders and customers. The producers fill the basket with red and green tomatoes that have reached maturity, and the intermediaries sort the tomatoes and sustain losses in the process. As a result, the price of tomatoes sold directly by a farmer is lower than that of intermediaries. To attract both traders and consumers, intermediaries must pay for cleaning and sorting the product before shipping it to market.

4.5.6 Interviews

Matyas (2020) explains that study employed qualitative research methods such as in-depth interviews, Focus Group Discussions (FGDs), observation, and field visits to gather data. The author highlights that in-depth interviews and FGDs are interactive techniques that involve the interviewer and the participants and that written and spoken discussions are essential for comprehending the social world. Similarly, Darlington and Scott (2020) suggest that these methods help investigate participants' experiences and interpret their responses' significance. The study used flexible semi-structured interviews, which allow for two-way conversation, as described in Appendix 4. The advantages of using this approach, according to FAO (2008), are that researchers can ask additional questions during the interview to explore specific issues, and they can control the interview process.

Probing is done to gain extra information or double-check information obtained from interviews. The researcher also utilised 'interpreting questions,' which are questions that are designed as interpretations of the responses. These interpretive questions were used to ensure that the researcher's interpretation of an interviewee's information corresponded to what the subject intended to say. For example, one participant stated, "In addition to tomato cost of production, we also suffer from lack of storage". "Do you mean you do not have a cool storage point after harvesting? Preliminary interviews were conducted to understand the nature of the stakeholder directly involved in the tomato industry in Kaduna State, as recommended by Campbell and Munden-Dixon (2018), before performing a real case study. The director of the Kaduna State Ministry of Agriculture and the Federal Ministry of Horticulture were both interviewed on issues and problems of post-harvest losses of fruits and vegetables. They were

interviewed on the present status of the intervention of the government to reduce the problems and how they intend to establish and implement majors that will further improve the tomato market sector. The questions also addressed what were thought to be the most pressing issues with post-harvest losses in the tomato sector experienced by farmers.

The discoveries from these studies gave field-experience understandings and familiarisation with the subject. They were used to arrange more in-depth interviews and focus group discussions with other participants. In-depth interviews were conducted based on value chain actors, including direct and indirect ones. (Appendix 5). Several in-depth interviews were conducted with farmers, intermediaries, tomato truck drivers, and farm labourers. Light chat outside of the topics was conducted during the interviews as an icebreaker to make the interview procedure fun and stress-free for the respondents. The benefit of this strategy was that interviewees felt more at ease and were more willing to express what they wanted to say. However, in this case, the researcher ensured that control was in place to guarantee that the interviewing process did not stray too far from the research topic, which was a benefit of using the semi-structured interview technique.

4.5.7 Research diary

The theoretical framework and methodological approach play a crucial role in defining the nature of research, guiding the route of investigation, and determining the weight given to various information sources. As a researcher, I have learned that creating a plan for collecting field notes is essential before starting any study. Therefore, I have developed a plan consistent with my theoretical framework and methodological strategy. In my plan, I have included details on how I will collect, use, distribute, and preserve field notes. I have also considered the importance of obtaining participant consent and institutional review board permission to collect field notes. This ensures that I adhere to ethical guidelines and maintain the privacy and confidentiality of participants. Field notes contain contextual information that situates the research within a particular period, place, or population. This information is valuable and can contribute to the understanding of the research findings. However, I also recognize the need for additional security measures to protect the confidentiality of participants and any sensitive information that may be disclosed in the field notes.

My plan for collecting field notes is comprehensive and considers the various ethical, theoretical, and methodological considerations. By following this plan, I collected valuable

data that will contribute to advancing knowledge in my field of study. During my fieldwork, brief notes were gathered during interviews and observations, as Phillippi and Lauderdale (2018) suggested. Further notes were added to the information collected at the end of each day. The day's events were recalled, and the field diary documented these. An observation made during the surveys revealed that intermediaries tended to be drawn towards the survey being conducted, thereby impacting the participation rate of intermediaries who should have ideally taken part. Observations made during fieldwork were utilised to analyse and interpret the results.

The theoretical framework provided a foundation for identifying hidden challenges within the tomato supply chain, including waste generation by various stakeholders. By applying this framework, the researcher could pinpoint specific instances, such as farmers not typically sorting matured green tomatoes from matured red ones. Additionally, the framework revealed that intermediaries exploit farmers during tomato purchases due to the increased cost of sorting the tomatoes.

4.6 Data analysis

Qualitative data analysis is a well-established method in various fields such as sociology, anthropology, psychology, and education. Mohajan and Mohajan (2022) describe the process of qualitative data analysis as a systematic interpretation of non-numerical data to identify patterns, themes, and insights that can inform decision-making. The process involves several steps, including data organization, coding, theme development, triangulation, and interpretation. Triangulation involves comparing and contrasting data from multiple sources to increase the reliability and validity of the analysis. The final step in qualitative data analysis is to interpret the findings and draw conclusions grounded in the data. (Gaete, 2019; Lindsey and Rathbone, 2022; Mohajan and Mohajan, 2022) Miles et al., 2014; Guest *et al*., 2012; Creswell & Poth, 2017). There are numerous ways of analysing and interpreting the data collected, depending on the parameters of the data gathering (Crang, 2013; Silverman 2015). Data analysis is a term that refers to categorising, tabulating, testing, or recombining evidence to reach conclusions based on empirical data (Crang, 2013; Silverman 2015).

Data for this research were collected through in-person interviews, questionnaires, an online survey, direct observation and photographs. All interview and questionnaire data were transcribed during and after data collection. As a researcher, I understand the importance of having an interpreter present when collecting research data from people of different languages.

Communication barriers can significantly impact the quality and validity of data collected from research participants. Therefore, the presence of an interpreter is critical to ensure accurate and reliable data collection. I understand the importance of having a qualified research assistant who can act as an interpreter. It is crucial to have someone who can effectively communicate between the researcher and the participants. Having a research assistant who can interpret was essential for several reasons. Firstly, accurate and reliable data collection is critical for any research study. The research assistant help ensures that the questions are understood, and responses are accurately translated, leading to more reliable data. Secondly, cultural sensitivity is crucial when conducting research, especially when working with participants from different cultures.

We built trust and rapport with participants, creating a comfortable environment for participants to share their experiences and perspectives. My research assistant speaks the same language as the participants, and this help creates a culturally sensitive environment and ensures that the participants understand the research process. it saved us time and money. Ethical considerations are vital in any research study. The research assistant helped ensure that informed consent is obtained from participants and informed them that their confidentiality is protected throughout the research process. The researcher and research assistant translated the Hausa-language interview into English. The data from the questionnaires were initially exported to Excel sheets. The transcript was then cleaned, gaps were filled in, and grammatical problems from the data-collecting process were fixed. Mixed methods permitted the collection of a quantifiable set of data, which were then analysed using Microsoft Excel to identify response patterns, commonalities, and correlations, simplifying the data aggregation and comparison (Harb *et al*., 2017). The aggregated results became accessible, and respondents' responses were filtered out in addition to those from incomplete questionnaires. The backdrop for the analysis was provided by material from the research diary and discussions with academics and stakeholders.

4.7 Reliability and validity of the study

Reliability and validity are essential aspects of a study that determine the degree to which the research is devoid of bias (error-free) (Hayashi *et al.*, 2019; Nardi, 2018). As a result, the researcher's measurements are consistent throughout time and the numerous instruments used (Hayashi *et al*., 2019). Researchers should ensure those study findings are transparent, credible, and thoroughly achieved. Reliability and validity are often employed for testing or analysing

quantitative and quantitative research (Hayashi *et al*., 2019; Nardi, 2018). The consistency of the methodologies and procedures used in evaluating the relative appropriateness of the tools used for accomplishing specified research aims and objectives is referred to as reliability in research (Sileyew, 2019). Reliability and validity necessitate competent, accurate, and systematic research and complete transparency in the data gathering, analysis, and presentation of study findings.

This study used various data sources and data-gathering procedures, including observation, questionnaires, interviews, and photographs. According to Shenton (Turner *et al.*, 2017), using many approaches simultaneously provides the advantage of accounting for the specific limits of each method while maximising their respective benefits (Turner *et al*., 2017). Furthermore, engaging with other supply chain workers (e.g., truck drivers, tomato sorters, labourers, and market officials) allowed for comparing individual perspectives and experiences, resulting in a rich and holistic picture of the attitudes, needs, and behaviours of those under investigation. The interviewer could interact and connect with the respondent during the research to guide and change the interview based on the conversation flow. The interviewer was knowledgeable about the subject and evaluated the data collected so that the data quality was not affected negatively.

Lectures, literature, and internet searches were used to gain knowledge on post-harvest losses, supply chain participants, and tomato production and post-harvest management. Bias can arise when conducting human research; the researcher should be aware of the problem and avoid it (Sileyew, 2019). As a result, a research diary was used to document everything that happened. These research approaches were chosen because they were the most effective in obtaining the information needed. To ensure that the interview questions and questionnaires were within the scope of the study, they were regularly compared to the study's aims and objectives. Triangulation provided a variety of perspectives on the advantages of research and assisted in identifying the effect and local elements that were unique to the study. Opportunities for scrutiny of the work by supervisors and other university colleagues and peers and criticism from other academics during conference presentations and research seminars were appreciated. These many viewpoints challenged one's beliefs, allowing fine-tuning and improvements to enhance the interpretations of findings considering the feedback received. This necessitated a comprehensive and extensive account of individual experiences to explain the actual occurrences under investigation and the contexts in which they occurred (Sileyew, 2019).

4.8 Challenges and limitations

The process of collecting data using the questionnaire surveys was associated with many challenges. The weather was not friendly because it was the rainy season, and rain fell almost every day we went out for data collection making it difficult to reach places where roads were not concrete. Many times, we had to go off the road into the farms. The roads were so slippery and the fear of the car getting stuck made the driver more careful and a bit slower than normal. Moving slowly got us to the areas safely but we took more time on the road than we anticipated. On getting to the farm areas, it was difficult to get farmers' attention as they were busy working and going about their businesses. However, a few farmers saw this as an avenue to make some money, so they asked the researcher to pay for information, even after being introduced as a student doing research. Some perceived the government's promises to bring about improvements as deceitful and not being kept. Sometimes after following roads that were not easily accessible by car to get to farmers in interior villages, nobody was there, so we came back empty-handed.

Most of these LGAs visited are places I had not been to, so we had to be extra careful. The security situation in Kaduna was not good as kidnapping and banditry were at a high level. The Kaduna State Government decided to switch off internet connections and phone networks in some parts of the state to tackle the insecurity issue. This lasted for about two months. At this time, I had to leave my comfort zone to go to the state capital to be able to communicate. Interviews with traders saw some challenges as some of the traders were afraid to answer questions. This was noted when a few of the traders declined to continue with the questionnaire when they were asked about the challenges they faced in the marketplaces. At that period, the Kaduna state government started its urban renewal programme. This was a programme to rehabilitate the road, markets, hospitals and other public structures in the state. The traders feared that we were a government agency, and if they told us their challenges, their market might be demolished like the others. Since they were small traders with little income, they feared that they may not be able to afford a shop in the market if a new structure was built.

Other challenges reflect difficulties associated with the covid 19 pandemic. The survey was intended to cover a broader range of respondents, but data collection had to stop as the world went into lockdown. My supervisors advised that given the difficulties associated with further data collection, we needed to make the best use of the data collected before the pandemic.

4.9 Positionality and ethical issues

According to Manti and Licari (2018), research ethics concerns how researchers create and explain study topics, design research, gather data, process and store data, analyse data, and write up findings ethically and responsibly. Ethical difficulties arise throughout the entire study process, and the study's principal ethical concerns are around the data-gathering stage. In terms of ethics, participants' informed consent must be obtained before the study begins. According to Barrow (2021), a researcher informs participants about the study's objective, how data will be utilised, what kind of participation is necessary, how much time will be required, and that participation in the study is voluntary. Ethical guidelines were diligently followed in conducting this research to ensure the study's integrity and adherence to ethical standards. Several measures were implemented to protect the rights and well-being of the participants, maintaining the highest level of research ethics. Firstly, ethical approval was obtained from the University's ethics committee before initiating the research. This involved submitting a detailed research proposal outlining the study's objectives, methods, and ethical considerations. This step demonstrated a commitment to conducting the research following established ethical standards.

Informed consent was a vital aspect of the research process. Participants were fully informed about the study's purpose, procedures, potential risks, and benefits before voluntarily participating. Clear and comprehensible consent forms allowed participants to ask questions and make informed decisions. Participants' autonomy was respected throughout the research, and written consent was obtained, ensuring privacy and confidentiality. Appropriate measures were taken to anonymize participants' data to ensure privacy and confidentiality. Identifying information was carefully removed or replaced, and strict control over data storage and access was maintained to prevent unauthorized disclosure. Efforts were made to minimize potential harm or discomfort to participants. Research procedures were designed to be non-invasive and avoid unnecessary risks. Furthermore, the highest academic integrity was maintained by accurately reporting and analyzing the collected data. Findings were presented unbias and transparently, acknowledging any limitations or potential biases that may have influenced the study.

Although some participants anticipated compensation for their participation, no compensation was provided. The reason for this was that rewards may have created an incentive to participate when the respondent would have declined otherwise. Before we began, some participants

inquired about the questions and were told about the broad subject areas and reassured that the questions were easy and straightforward to answer. The researcher, being affiliated with the prestigious University of Nottingham (UON) and Nigerian Army (NA) was able to gain easier access to appropriate organisations upon presentation of NA Identity Card (ID) and University letters. As a result, I was treated with respect and was considered knowledgeable and competent. Nigerians attach a great deal of importance to the NA. The NA is a well-known and respected organisation. As such, one has a higher chance of receiving favours. I realised that I obtained better access to officials when I introduced myself with my Nigerian Army ID card and University of Nottingham student credentials. For instance, when I went to the Federal Ministry of Agriculture Abuja, the gate denied access even after showing evidence of being a PhD student conducting research, but I accessed the premises when I used my Army ID card. Our interactions were focused, and they wanted to provide all the help and assistance needed.

The interviews were extensive to understand better the implications of tomato losses from the viewpoints of farmers and other stakeholders. This allowed me to have a comprehensive comprehension of my research problem. Rodríguez *et al*., (2021) say that an insider's interpretation of data is more accurate than an outsider's because an insider is more likely to comprehend and resonate with what the respondents are saying due to a shared worldview. Data gathering began with a worldview and preconceptions about how the research would emerge. However, this altered dramatically over the process. That is one of the most exciting aspects of qualitative research. The research took shape within the parameters of the main goal, resulting in a wealth of precise information. I had to carefully guarantee that my basic knowledge and insight did not influence how the data was interpreted (Barrow *et al.*, 2021; Boldosova and Luoto 2019).

4.10 Summary

This chapter has examined the approaches utilised to address the aims and objectives of this research. In addition to discussing the study's theoretical viewpoints, the author addresses ethics, positionality, and reliability concerns. In addition, the chapter included detailed descriptions of the strategies utilised to elicit the required information. Chapter 5 examines the reasons for tomato post-harvest losses, nutritional advantages, and industry constraints. Chapter 6 focuses on farm and post-harvest losses in Kaduna. The intermediaries and the tomato losses they cause along the trading routes are examined in Chapter 7. The focus of

chapter 8 is on traders and consumers in the tomato supply chain. Chapter 9 investigates tomato waste and presents results and discussion for all supply chain stakeholders.

Chapter 5: Tomato production and consumption

5.1 Introduction

Tomatoes are an essential and widely cultivated horticultural product around the globe. Tomatoes rank third by weight in the large-scale production of all horticulture crops, behind only sweet potatoes and potatoes (Arah *et al*., 2015). They can be grown in a wide range of climates, in heated glasshouses, or under protection in plastic greenhouses (Innes 2014). In 2012, Africa produced about 17,938 million tonnes of tomatoes, with Egypt producing the most at 8,625,000 tonnes. Table 1 displays the leading 15 producing nations in Africa.

Table 5.1: The ten highest tomato producing countries in Africa

Rank	Country	Production (tonnes)
1	Egypt	8,625,219
2	Nigeria	1,560,000
3	Morocco	1,219,071
4	Tunisia	1,100,000
5	Cameroon	880,000
6	Algeria	796,963
7	South Africa	564,740
8	Sudan (former)	529,200
9	Kenya	397,000
10	Ghana	321,000
11	Tanzania	255,000
12	Mozambique	250,000
13	Benin	244,742
14	Libya	225,000
15	Niger	188,766

Source: (FAOSTAT 2014); Arah, *et al*., (2015)

Nigeria is the leading producer of crude oil in Africa, a country with abundant land, and the sixth highest producer of crude oil in the world (Eregha, and Mesagan, 2020; Omolade *et al*., 2018). Given this resource endowment, Nigeria is seen as a country that should meet its essential needs, especially in food security. It is ironic that relatively recently, Nigeria spent 1 billion Naira daily and 1.3 trillion Naira annually on importing rice and other food items (Tiri *et al*., 2014). Nigeria is the second-largest producer of tomatoes in Africa and plants around 65

percent of all tomatoes grown in West Africa (Amurtiya and Adewuyi, 2020; Babarinsa, *et al*., 2018). Despite Nigeria's position in the world and regional rankings for tomato production, the nation imports tomatoes to meet the demand. Contrary to popular belief, Nigeria is west Africa's top importer of tomato paste, purchasing around 150,000 metric tons of concentrate year at a value of $170 million. Tomatoes are heavily consumed in all parts of the country, accounting for approximately 18% of household daily vegetable consumption (Amurtiya and Adewuyi, 2020).

The tomato plant's lifespan is between four and three months, and varies with the cropping scheme (Bakshi, *et al*., 2019; Nassarawa and Sulaiman, 2019). Due to the influence of seasonality, tomatoes are cultivated extensively in Nigeria's northern regions (Nassarawa and Sulaiman, 2019). Over the last 20 years, the cultivation of tomatoes has been widely encouraged all over Nigeria. The government has made fertilizers, insecticides, farming tools and bank loans available to attract farmers (Adenuga *et al*., 2013). According to Ganiyu *et al*., (2018) between 0.5 and 4 hectares of land is typically used to plant tomatoes in the northern part of the country. Small-scale farmers cultivate less than 4 hectares of land, accounting for 90 per cent of all producers (Faostat, 2014). Large-scale tomato cultivation in Nigeria is mainly irrigated during the dry season when moderate temperatures and relative humidity are low.

The production of tomatoes during the rainy season is typically hindered by pests and diseases that thrive in humid and warm weather conditions. According to Ajibade *et al*. (2021), Bashir *et al*. (2018) tomato farmers are limited by low soil fertility, sudden loss of improved seeds, lack of technological improvements, dearth of pest and weed regulation, high post-harvest losses, and poor infrastructure for managing and marketing. (Ajibade, *et al*., 2021; Bashir, *et al*., 2018). Presently, tomato yield per hectare in Nigeria is projected to be between 20 and 40 tonnes per hectare per year, and 40 to 50% of the crop is wasted owing to poor handling, managing, and safeguarding procedures (Faostat, 2014). Likewise, the prevalence of debilitating illnesses exacerbates the farmers' difficulties, especially in 2016 when the Tuta Absolute decimated the farmers' yearly produce.

The Tuta absoluta is a small moth native to South America that has become a notorious pest of tomato crops worldwide. When the Tuta absoluta infests a tomato plant, it lays its eggs on the leaves, and the larvae that hatch from those eggs feed on the plant's leaves, stems, and fruit. As the larvae feed, they create tunnels in the plant tissue, causing significant damage to the crop. When the Tuta absoluta infests a tomato crop, it can quickly cause significant damage, leading

to a decimation of the farmers' yearly produce. This is because the pest can rapidly reproduce and spread and can be challenging to control with conventional insecticides. The damage caused by the Tuta absoluta can significantly reduce the yield of tomatoes, which can have a devastating impact on farmers who rely on tomato crops for their livelihood. Furthermore, because the Tuta absoluta is such a destructive pest, it can have a broader impact on the local economy. If tomato crops are decimated, it can lead to a shortage of tomatoes, which can drive up consumer prices. Additionally, suppose farmers need more tomatoes to meet demand. In that case, they may be forced to import tomatoes from other regions or countries, negatively impacting local trade and commerce.

5.1.1 Tomato consumption

Customarily, fruits and vegetables constitute an essential part of African cuisines (Kok, *et al*., 2019; Nassarawa, and Sulaiman, 2019). However, fruit and vegetable intake varies by country and location (Florkowski and Takács, 2022; Harris, 2021; Scheelbeek *et al*., 2020). This difference in consumption is attributable to ancient and agroecological variables (Harris, 2021; Mensah et al.,2021; Scheelbeek *et al*., 2020). According to Boateng, (2021), tomatoes, onions, and spicy peppers are Africa's most important vegetables owing to their regular consumption. Also essential are okra, African eggplant, pumpkins, cabbage and carrots. Nigeria is a populous African nation, with a 30% population increase between 2007 and 2017 (Taiwo *et al*., 2022; World Bank, 2017). Population expansion increased affluence, and urbanization contributed to increased total vegetable intake.

As indicated previously, many vegetables are eaten in Africa, but the tomato is a staple in every household (Aina *et al*., 2021; Kok, *et al*., 2019; Nassarawa, and Sulaiman, 2019). It represents around 18% of the average daily vegetable consumption in Nigeria. Additionally, tomato is part of the national food security programme (Obisesan, 2021; Kok, *et al*., 2019; Nassarawa, and Sulaiman, 2019). This combination of features makes it an essential crop for food production. The survey conducted as part of this research revealed that consumers buy tomatoes in the city market and favour the fresh tomato types of Roma and UC82B tomatoes in larger and moderate sizes. Tomatoes are purchased yearly, with higher prices being paid during the off-season (Nassarawa, and Sulaiman, 2019).

5.2 Nutritional benefits of tomato

Tomato is classified as a fruit and grouped with vegetables (Sharma, 2019; De Luna, 2019). Tomatoes are an essential component of cuisines worldwide, particularly in the Mediterranean. Moreover, by enhancing the flavour of food, consuming tomatoes can significantly improve health (Offringa, 2019). They can be found in pasta, pizza, tomato ketchup, and numerous beverages. They are simple to maintain and multiply, making them an excellent food supply, which explains why tomatoes are a staple diet in many countries (Hyman, 2019; Kirpichenkova, 2019). Tomatoes may benefit eye health, gut health, and lower blood pressure (Collins, *et al.*, 2022; Ramya and Patel, 2019). They can assist in managing diabetes, skin conditions, and urinary tract infections. In addition, they may promote digestion, boost blood flow, lower cholesterol levels, enhance fluid balance, safeguard the kidneys, detoxify the body, prevent premature ageing, and reduce redness. In addition to being a valuable source of vitamins and minerals, they can protect against cardiovascular illnesses (Collins, *et al.*, 2022; Ramya and Patel, 2019).

Tomatoes' health benefits are due to their abundance of minerals and vitamins. The U.S. Department of Agriculture (USDA) reports that tomatoes are abundant in vitamin A, vitamin C, vitamin K, and B vitamins, folate, and thiamine (Collins, *et al.*, 2022; Ramya and Patel, 2019). In addition, they are an excellent source of magnesium, potassium, manganese, copper and phosphorus (Ahmad, 2021; Anjum, *et al*., 2020). They may include a high concentration of water, dietary fibre, protein, and a variety of chemical substances, such as lycopene, that contribute to their health advantages (Ahmad, 2021; Anjum, *et al*., 2020). Tomato varieties differ in terms of their caloric content. One hundred grammes of raw green tomato contains around 23 calories, while 100 grammes of raw orange tomato comprises 16 calories (Ahmad, 2021; Anjum, *et al*., 2020). Due to preservatives in canned tomato juice and puree, the calorie content in these variations may be slightly higher (Rodríguez-Ortega, *et al*., 2019).

A single tomato offers approximately 40% of the daily need for vitamin C (Athinodorou *et al*., 2021). Vitamin C is a natural antioxidant that protects the body's systems from damage caused by free radicals. Additionally, it may contain vitamin A, potassium, and iron. Potassium can be crucial in sustaining neuronal health, and iron is essential for regular blood circulation (Ahmad, 2021; Anjum, *et al*., 2020). Vitamin K, crucial for blood clotting and regulating blood flow, may also be rich in tomatoes (Ahmad, 2021; Athinodorou *et al*., 2021; Anjum, *et al*., 2020).

Tomatoes are an excellent source of iron, vitamins, carbohydrates, fibres, vital amino acids, phosphorus and dietary minerals (Arah *et al*., 2015). Therefore, when consumed, they function as a source of essential nutrients. The table below provides 15 essential nutrients and their volumes achieved by consuming 123 grammes of ripe tomatoes.

Table 5.2: The 15 Major nutrients derived from tomatoes

Nutrient	Amount
Calcium	1.2mg
Carbohydrate	4.7g
Copper	0.073mg
Dietary	1.5g
Fat	0.2g
Iron	0.33mg
Magnesium	1.4mg
Niacin	0.731mg
Pantothenic acid	0.109mg
Phosphorus	3mg
Potassium	292mg
Protein	1.0g
Thiamin	0.046g
Total sugar	3.23g
Vitamin C	16.9mg

Source: Arah et al., 2015

5.3 Review of tomato post-harvest handling in Nigeria

Poor packaging and rough handling during truck loading and unloading are most likely to blame for the high rate of mechanical damage to tomatoes being supplied to markets within Nigeria (Yusuf, 2020; Pretorius, 2016). Since bamboo and cane baskets are cumbersome and need to work better with modern transportation systems, tomatoes should not be packaged in these materials (Yusuf, 2020; Arah, *et al.,* 2016). A truck's baskets can be damaged if overloaded due to their rough sides and sharp edges. Inner linings made of dried leaves are not usually effective in protecting against damage when used (Arah, *et al.,* 2016; Arah *et al*., 2015). High tropical temperatures in non-refrigerated open trucks may hasten the rapid oxidation of reduced ascorbic acid in tainted tomatoes. Tomatoes at various stages of ripeness, including green ones, are commonly packed together in Nigeria (Arah, *et al.,* 2016; Arah *et al*., 2015). Tomatoes with damage may have prematurely matured due to damage during transport, as evidenced by their lower titratable acidity, total solids, and solubility. Table-ripe tomatoes are said to have higher soluble solids levels than their green counterparts (Arah, *et al.,* 2016; Arah *et al*., 2015). Other researchers have discovered that the acidity of Florida MH-1 tomatoes decreases as they mature, contrary to the findings of Collins, *et al.*, (2022) and Yusuf (2020).

Tomatoes lose a significant amount of vitamin C due to poor post-harvest handling in Nigeria's marketing system (Collins, *et al.*, 2022; Ramya and Patel, 2019). This is in addition to the substantial losses already reported (Arah, *et al.,* 2016; Arah *et al*., 2015). It is possible to reduce these losses by improving packaging and shipping methods and arranging marketing and distribution channels more efficiently (Arah, *et al.,* 2016; Arah *et al*., 2015).

5.4 Challenges of tomato processing and post-harvest handling in Nigeria

After harvest, most cultivated fruits and vegetables lose quality and shelf life due to improper tomato care and handling. When harvesting tomatoes, for example, complicated handling can result in mechanical damages that affect the quality and life of the tomatoes after harvesting (Li and Thomas, 2014; Arah, *et al*., 2015; Spricigo, *et al*., 2021). Producers must be aware of the correct post-harvest handling procedures to ensure the strength and shelf life of cultivated tomatoes in underdeveloped countries (Arah, *et al*., 2016). Cleaning, Precooling and disinfection, sorting and classification, packaging, shipping and storage are just a few techniques covered in material handling.

5.4.1 Harvesting and containers

The physical maturity of any tomato fruit during harvest significantly impacts the post-harvest quality (Yao, *et al*., 2020; Arah *et al*., 2015). Care must be given when harvesting the fruit to achieve the most outstanding quality. Post-harvest physiologists divide fruit and vegetable shelf life into stages: senescence, ripening and maturation. The maturity stage indicates when the fruit is set for harvest (Arah, *et al*., 2016; Arah *et al*., 2015). Tomatoes can be collected while grown green, somewhat ripened, or mature. Tomatoes, being climacteric fruits, can be collected at the developed green stage, enabling maturing and readiness to proceed throughout the fruit's post-harvest time (Li *et al*., 2020; Wang *et al*., 2019). Producers aiming for distant markets should pick their tomatoes in a developed green form (Wang, *et al.*, 2019). Gathering tomatoes in a ripened green stage gives producers time to prepare the product for selling and prevents mechanical damage while harvesting. Sadly, most growers in Third world countries, particularly in third-world countries, harvest tomatoes when they are almost or fully matured (Rajkumar, *et al.*, 2021). Ripe tomatoes are more exposed to mechanical damage for the period of harvesting, causing in a reduced shelf life (Rajkumar, *et al.*, 2021; Arah, *et al*., 2016).

To avoid tomato injuries, which may expedite deterioration, care must be exercised when picking ripe tomatoes. To avoid bruising and cutting of the fruits, packing and harvesting

containers with sharp edges should not be used (Spricigo, *et al.,* 2021; Arah, *et al*., 2015; Li and Thomas, 2014). Fruit harvesting ought to be done early morning or late evening of the day to prevent unnecessary field high temperatures. The failure of producers to follow these critical harvesting procedures, combined with some inefficiencies (such as the absence of market and treating facilities) in the whole value chain, may clarify some losses in tomatoes harvested at full ripeness in developing countries (Spricigo, *et al.,* 2021; Arah, *et al*., 2015; Li and Thomas, 2014). In most underdeveloped nations, access to a quick market is very important when trading with highly delicate crops such as tomatoes (Izah and Aigberua 2020; Tura and Hamo 2018). This difficulty can be due to various variables, the most significant of which is the production pattern that results in large gluts. The difficulty is intensified by a need for more processing facilities or equipment to convert the crop into more resilient products for late use (Amurtiya, and Adewuyi, 2020).

Changing tomatoes to a form that enables it to last longer will allow it add value, which will ultimately increase the crop's market (Abdul, *et al*., 2020; Agri, *et al*., 2018). To supply tomatoes, producers from wealthy nations always have supply contracts with global grocery chains. For example, Australian tomato producer Blush Tomatoes serves Coles and Woolworth stores with tomatoes, making market access predetermined (Arah, *et al*., 2016; Arah *et al*., 2015) This may be the primary cause of the disparity between output and available markets. Therefore, producers must trade off their produce at low prices to avoid a total loss.

In a developing country like Nigeria, farmers need more appropriate implements for harvesting their products. They use manual picking in harvesting tomatoes, and many farmers use wooden baskets or rough crates to store or carry vegetables (Arah *et al*., 2015). This cutting surface usually causes mechanical injuries to the harvested fruits. There is a need to be more careful to avoid mechanical damage that can cause pathogens to the fruits harvested (Arah *et al*., 2015). The farmers know the damages caused to the tomato by the inappropriate containers they use. They carry the tomato in rough-surfaced containers and load one on top of the other, which usually crushes the ones at the base of the basket (Hurst 2010). The basket is typically big and can contain 65-70 kg in one basket with a resulting crushing force upon the fruits at the base of the basket (Hurst 2010). Recently, researchers (Babarinsa *et al*., 2018) advised the use of plastic crates to minimise the waste caused by the traditional baskets. However, farmers, intermediaries, and traders in the tomato market in Nigeria often resist the adoption of plastic crates for storing and transporting tomatoes. This resistance stems from cost implications and

logistical challenges. Plastic crates tend to be more expensive than traditional baskets, making them less appealing to stakeholders in the supply chain. Additionally, the transportation of empty plastic crates back to the farms is more costly than traditional baskets. This is because plastic crates cannot be nested or stacked efficiently like baskets, resulting in higher transportation costs.

Furthermore, the use of plastic crates poses a challenge for consumers. The crates have a larger volume but contain fewer tomatoes, leading to consumer dissatisfaction as they perceive a higher cost when purchasing tomatoes with the crate included. This consumer perception is often a barrier to the widespread adoption of plastic crates in the tomato market. It is important to note that using plastic crates is a relatively new innovation in the Nigerian tomato market. As a result, the availability of plastic crates within the system is limited, further complicating their adoption. The insufficient supply of plastic crates makes it difficult for stakeholders to fully transition from traditional baskets to plastic crates.

Figure 1 below illustrates the type of container farmers use to carry tomatoes in Kaduna.

Figure 5.1: Baskets used to carry tomatoes

Source: Authors photographs July 2019

5.4.2 Precooling after the harvest

Ground heat is typically excessive and unwanted during the harvesting phase of a lot of fruits and vegetables but ought to be eliminated as soon as possible prior to post-harvest treatment

(Arah, *et al*., 2016; Arah *et al*., 2015). Disproportionate field heat causes an unfavourable rise in metabolic activity; hence, quick chilling after harvest is crucial (Raseetha, *et al*., 2022; Akbudak, *et al*., 2012). Precooling reduces the impact of metabolic activity, microbiological activity, ethylene production and respiration rates (Shahi, *et al*., 2012) while reducing ripening pace, water loss, and degradation, thereby conserving quality and longer shelf life (Arah, *et al*., 2016; Arah *et al*., 2015). The optimal heat range of approximately 13–20 C for processing tomatoes can be reached in the early morning or evening (Kabir, *et al.*, 2020; Hatami, *et al*., 2019). If the fruit is collected outside the advised harvesting periods, it must be precooled to eliminate undue field heat. If clean water is not an issue, immersing harvested tomatoes in hydro cooling with purifiers such as sodium hypochlorite and thiabendazole is a cost-effective method for precooling tomatoes in impoverished nations. This technique efficiently eliminates field heat and lowers microbial burdens on harvested fruits (Kabir, *et al.*, 2020; Hatami, *et al*., 2019).

To lessen field heat, tomato growers in developing nations, particularly those from Africa, assemble their harvest under the shade of trees (Kabir, *et al.*, 2020; Hatami, *et al*., 2019). However, tree shade is not a dependable and practical method for decreasing the field temperature of harvested crops. Therefore, Arah *et al*., (2016) recommended that implementing a basic on-farm structure, such as a tiny thatch hut, may be advantageous for precooling harvested tomatoes.

5.4.3 Cleaning or disinfecting

Cleaning and disinfecting of tomatoes at post-harvest can prevent the prevalence of food-borne diseases that can be communicated to people and proper hygiene is paramount for all produce handlers (Shittu, and Barau, 2020; Arah, *et al*., 2016; Arah *et al*., 2015). As shown in a report by the Indian government, pathogenic microorganisms such as Cyclospora, Salmonella, hepatitis A virus and the Cryptosporidium have been transmitted to consumers through natural vegetables. (Arah, *et al*., 2016; Arah, *et al*., 2015). Unfortunately, most tomato handlers in developing nations, particularly in Africa, only sometimes clean or disinfect tomatoes after harvest. This behaviour may result from a lack of potable water in the production locations or simple ignorance. Disinfectants used in washing or cooling water, however, can prevent post-harvest and food-sustained illnesses in fruits and vegetables in areas where water is not scarce. (Arah, *et al*., 2016; Arah, *et al*., 2015).

The use of several disinfectants in tomato post-harvest processing is extensively documented (Mishra, *et al*., 2018; Arah, *et al*., 2016). For example, sodium hypochlorite solution purifies tomato fruits to lower the occurrence of fungal contamination before post-harvest treatment (Arah, *et al*., 2016). Applying a thiabendazole solution to tomato fruits reduced their microbial load (Workneh, *et al.*, 2012). After cleaning, fruits and vegetables are commonly cured with chlorinated water to lessen microbial burden before packaging. Workneh, *et al*., (2012) propose that anolyte water increases the disinfection of tomatoes, decreases the microbial burdens on the fruits and preserves their exceptional quality during storage. In conjunction with hydro cooling, disinfection can simultaneously reduce excessive field temperature and microbial contamination (Mishra, *et al*., 2018; Arah, *et al*., 2016).

5.4.4 Sorting and grading

Sorting and grading are crucial steps in the packing and marketing of fruits and vegetables (Kok, *et al*., 2019; Arah, *et al.,* 2016). Sorting entails separating rotting, broken, or bad fruits from healthy and spotless ones. Scratched or bad fruits can emit multiple levels of ethylene, negatively affecting neighbouring fruits (Kok, *et al*., 2019; Arah, *et al.,* 2016). Grading also categorises fruits and vegetables according to their colour, size, maturity level, or degree of ripeness. The two steps, sorting and grading are crucial for preserving the post-harvest condition of harvested tomatoes. Sorting prevents the transfer of infectious bacteria from rotten tomatoes to healthy tomatoes while post-harvest handling (Odeyemi, *et al.*, 2021). Grading also allows workers to classify fruits and vegetables according to a similar criterion, facilitating handling. For example, grading based on colour or stage of maturity would assist avoid overripe fruits, which quickly create ethylene to accelerate the maturation of the entire batch (Odeyemi, *et al.*, 2021).

Typically, commercial tomato growers employ sophisticated systems requiring accurate grading and sorting criteria for their yield fruit. In contrast, small-scale farmers and dealers in developing nations may not employ formal sorting and grading and criteria, yet the product must still be arranged and proportioned before being sold or processed (Odeyemi, *et al.*, 2021).

5.4.5 Packaging

Packaging is also an essential factor to consider when attempting to reduce post-harvest losses in fruits and vegetables (Dandago, *et al*., 2017; Arah, *et al*., 2015 Olayemi *et al*., 2010). It encloses food products to protect them from mechanical damage, tampering, and physical,

chemical, and biological contamination (Prasad and Kochhar 2014). As a post-harvest handling procedure in tomato cultivation, packaging is necessary for dividing the crop into manageable sections. However, improper packaging might result in fruit breakage and subsequent losses (Arah, *et al.,* 2016; Idah, *et al*., 2007). In some developing countries, woven palm baskets, wooden crates, plastic crates, cardboard boxes, nylon sacks, polythene bags and jute sacks are utilised as packaging materials (Arah, *et al.,* 2016). Most of the previously listed packing tools do not provide the necessary protection for the product. While the bulk of these packing materials, such as nylon sacks, do not permit adequate aeration within the packaged product, leading to an increase in temperature due to respiration, some, such as the woven basket, have rough surfaces and edges that cause mechanical damage to the produce.

The primary deficiency of the wooden container is its height, which causes much compressive stress on the fruits positioned at the base (Onu, *et al*., 2021; Aghadi, 2019). These unfavourable compressive stresses result in interior damage that ultimately impairs the post-harvest quality of tomatoes (Aghadi, 2019). According to Samwel (2019), tomatoes should be packaged in a modified wooden crate. The depth of the crate should be significantly reduced to avoid the accumulation of compressive pressures that can cause physical harm to fruits at the bottom of the crate after packaging. A study by Idah *et al*., (2007) have also suggested that woven palm baskets should be woven with the smooth side of the cloth facing inward.

5.4.6 Storage facilities

Tomatoes have a relatively high moisture content, making long-term storage at room temperature extremely challenging (Ochida, *et al*., 2019; Arah, *et al.,* 2016; Jayathunge, *et al*., 2015). In the meantime, storage is typically required in the value chain to ensure the ongoing flow of raw materials to processors. Storage extends the processing season and aids in maintaining product availability throughout the seasons (Ochida, *et al*., 2019; Arah, *et al* 2016). Tomato fruits can be stored in ambient situations for a short period (up to one week) if sufficient air circulation prevents heat build-up from respiration. For longer-term storage, ripe tomatoes can be kept between 10 and 15 degrees Celsius and 85 to 95% relative humidity (Affandi, *et al*., 2021; Kabir, *et al*., 2020). Both ripening and chilling damage are minimised at these temperatures (Affandi, *et al*., 2021; Kabir, *et al*., 2020).

These conditions are challenging to achieve in most tropical nations, resulting in significant losses of harvested tomatoes (Ochida, *et al*., 2019; Arah, *et al* 2016). This supports the claim

that tomato quality is diminished when exposed to heat and relative humidity (Ochida, *et al*., 2019; Arah, *et al* 2016). Storage at low temperatures is also hazardous to numerous tropical fruits' shelf life and quality, such as tomatoes. For example, chilling a tomato would diminish its flavour, a characteristic of tomatoes regulated mainly by the fruit's whole soluble solids (TSS) and pH (Affandi, *et al*., 2021; Kabir, *et al*., 2020). Learning the proper temperature control methods while storing tomatoes is crucial for increasing the fruit's shelf life while preserving its quality. Using woven jute bags for an evaporative cooling method, tomato handlers in tropical nations can keep tomatoes for short to medium periods (Affandi, *et al*., 2021; Kabir, *et al*., 2020).

In the meantime, any setback concerning tomato harvest and eating can cause losses (Verma, 2019; Arah, *et al* 2016). Producers incur approximately 20 per cent losses owing to shipping delays (Verma, 2019; Arah, *et al.,* 2016). To prevent delays, producers will employ any available mode of transportation, regardless of its suitability, to convey their goods. Human labour, donkeys, public transit, rental trucks, buses, lorries, gasoline tankers, articulator trucks, and pick-up trucks are examples of transportation (Arah, *et al.,* 2016). However, suitable transportation for tomatoes is crucial for post-harvest care for the fruit. Proper packing and stacking should be used to immobilise produce during shipment to prevent excessive movement or vibration (Arah, *et al.,* 2016). Vibration and impact during transportation due to road undulations cause post-harvest losses of vegetables and fruits, particularly tomatoes (Yusuf, 2020). Due to the poor condition of motorway networks in most developing countries, these disadvantageous transportation variables result in substantial losses.

The hazardous nature of most trucks, combined with the poor road conditions, results in massive mechanical damage to the goods before they reach their destination (Yusuf, 2020). In contrast, handlers from affluent nations use cold containers and trailers that travel on decent highways (Berners-Lee, 2020; Metcalfe, 2019). Transporting tomatoes in cooling vans is practical and effective for protecting tomatoes' quality (Yusuf, 2020; Arah, *et al.,* 2016). Therefore, handlers in underdeveloped nations move their products utilising the most cost-effective mode of transit without considering the impact on post-harvest quality (Yusuf, 2020; Arah, *et al.,* 2016).

5.4.7 Accessible road and transportation

Transportation is the subject of the second section. In most developing countries, the production sites of many tomato farmers are not located close to the market centres and are

unreachable by road (Villareal, 2019; Barwell, *et al.,* 2019). Transporting produced fruits to market on poor motorway networks and in the absence of suitable transportation such as refrigerated vans is a significant difficulty for farmers and wholesalers (Verma, 2019). Tomatoes are one of the most widely consumed vegetable crops worldwide (Pretorius & Steyn, 2019). Tomatoes are sensitive to mechanical damage during transit; as a result, a significant portion of freshly harvested tomatoes never reach the consumer due to bruising sustained during transportation and handling. As a result, the profit margins of the grower and the retailer are reduced (Pretorius, 2016).

The state of the roads has a direct bearing on the amount of damage caused. As road conditions deteriorate, vibrations increase, and so does the damage to tomatoes. Moreover, one of the primary objectives of most commercial enterprises is to maximise profits (Pretorius, 2017). Agricultural enterprises are not unique in this way. Because tomatoes have a short shelf life, it is essential to regulate the variables that accelerate the deterioration of their quality. Shipping, handling, and distribution can result in different cuts and bruises that diminish the flavour and appearance of fresh tomatoes (Pretorius, 2017). Transportation is an essential aspect of any nation's economy, and Nigeria is a rapidly rising economy with one of Africa's most significant road networks. After the breakdown of the rail transport infrastructure in the early 1980s, road travel is Nigeria's most resilient means of transport. The significance of the inland road network as a vital contributor to the country's social and economic growth is underscored by the fact that road transportation accounts for more than 90 per cent of freight and passenger services for inland transportation (Jacob, *et al*., 2020).

The worsening condition of Nigerian roads and the lack of suitable road infrastructure have been a concern for road users and farmers over the past decade (Nwafor and Onya, 2019; Arah, *et al*., 2015). The more the accessibility of the roads, the lower the cost of transportation, and the greater the quality of the roads, the fresher the fruit arrives at its destination. The condition of the roads in Nigeria is one of the many factors that discourage persons from investing in the tomato processing industry. On the other hand, local farmers cannot afford to construct industries near their farms to preserve their product's freshness. Most farmland is in rural, unimproved areas, making access to competitive markets difficult and expensive (Nwafor and Onya, 2019; Arah, *et al*., 2015). According to Arah *et al*. (2015), twenty per cent of the tomatoes may be lost due to the delay in shipment. However, the number may have been

understated due to the unpredictability of the food supply system. If the van breaks down en route, sixty to eighty per cent of the tomato crop may be destroyed (Arah, *et al*., 2015).

Figure 5.2: J5 Peugeot carrying tomatoes after an accident

Source: Authors photographs Jan 2020

Figure 5.3: 911 Lorry carrying tomatoes after an accident

Source: Authors photographs Jan 2020

5.4.8 Mode of transportation

Medium heavy-duty vehicles are used for local tomato transport and heavy-duty vehicles are used for long-distance transport, creating separate processes for local and non-local transport in the United Kingdom (Striebig, *et al*., 2019), whereas in Bangladesh, trucks and heavy vehicles are used for long-distance transport of fresh tomatoes (Uddin, 2010). Idah *et al*. (2007) found that most Nigerian farmers need a vehicle to carry their produce from farmers' markets to supermarkets and processing plants. In the Nigerian city of Kano, farmers frequently pool their resources and hire a van to deliver their fresh harvest from Kano to Ibadan. They typically utilise the 911 truck, which is somewhat slow but less expensive than many other vehicles. It is favoured because it can transport between 250 and 300 baskets of fresh tomatoes. (7500kg to 9000kg). The need for more vehicles to transport their commodities from one location to another is a significant obstacle for farmers (Idah *et al*., 2007). Therefore, they must utilise whatever resources are available to them. There is no efficient way to prevent excessive motion or vibration during travel, which exacerbates waste.

Nigerian roads are often poor, resulting in vibrations, the movement of products, and delays, so a one-day journey may take three or four days. Consequently, farmers typically experience a substantial amount of post-harvest loss owing to transportation (Idah *et al*., 2007). These transportation issues are rare in industrialised nations. In affluent nations, tomatoes are transported in refrigerated trucks that are both handy and retain the freshness and quality of the crop (Arah *et al*., 2015). Most farmers in Nigeria need more cars with air conditioning or refrigerated trucks for transporting their fruits and vegetables (Idah *et al*., 2007). The farmers convey their products using the most accessible and cost-effective way of transit without much regard for food waste in the process.

Figure 5.4: Tomatoes compressed in transit

Source: Authors photographs Jan 2020

Figure 5.5: Inappropriate means of transportation

Source: Authors photographs Jan 2020

Figure 5.6: Inappropriate means of transporting tomatoes

Source: Authors photographs Jan 2020

5.4.9 Tomato processing factories

Numerous businesses, enterprises, and factories in Nigeria are closed due to a lack of electricity. The Federal Government's insufficient provision of electricity has resulted in a need for Nigeria's infrastructure development to be enhanced. (Ikpe *et al*., 2018). Insufficient provision of electricity by the Federal Government of Nigeria has negatively impacted the country's infrastructure development, as electricity is crucial for powering industries, businesses, and households. The lack of adequate electricity has hindered economic growth and development by preventing businesses from operating at full capacity. Additionally, essential services like healthcare and education have been affected by the shortage of electricity, which further impedes the country's progress. Addressing the issue of insufficient electricity provision is necessary for enhancing Nigeria's infrastructure development.

Some factories, enterprises, and industries in the country can no longer afford to use other power sources, such as power generators because using alternative power sources will impact the market's average product price. In addition, factories that are still operational are obsolete and disregard the health and quality of the goods they produce (Arah *et al*., 2015).

5.5 Summary

Vegetable consumption in Nigeria has attracted attention due to its contribution to food and nutrition security and smallholder incomes. In Nigeria, tomatoes, chilli peppers and onions are the most popular daily market vegetables. In 2013, Nigeria produced 58% of West Africa's tomatoes and 9% of Africa's total (Li and Thomas, 2014; Arah, *et al*., 2015). Farmers in Nigeria lack vital inputs such as modern technology, leading to decreased yield and productivity. Significant Post-harvest losses (PHLs) caused by long transportation distances and a dearth of processing and marketing facilities limit the efficiency of the tomato value chain and endanger the health of tomatoes. According to the available research, tomato farmers in Nigeria encounter numerous obstacles. Estimates and reasons for post-harvest tomato losses in Nigeria have been documented in the available literature. Farmers in Nigeria have been hampered by a shortage of tomato processing factories, inadequate transportation, and inadequate storage, packaging, and harvesting techniques. Most research was conducted from the farmer's perspective, revealing an existing gap that this research seeks to address because most harvested fruits and vegetables lose quality and shelf life due to improper care and handling. Complicated handling can harm tomatoes during harvest, reducing their quality and shelf life (Li and Thomas, 2014; Arah, *et al*., 2015; Spricigo, *et al*., 2021). Producers must know basic

post-harvest practices to preserve tomato quality and shelf life in impoverished regions (Arah, *et al*., 2016). Material handling consists of cleaning, precooling, disinfecting, sorting, packaging, shipping, and storing.

Chapter 6: Farmers tomato post-harvest losses: A case study of Kaduna state, Nigeria

6.1 Introduction

Tomatoes are an essential ingredient in many Nigerian dishes, as authors like Oso (2020), Oktay and Sadiloglu (2018) and Ochid *et al*. (2019) have identified. Tomato farming is becoming a critical aspect of agriculture in the country. One of the states that excel in tomato farming is Kaduna, located in the northern part of Nigeria. The tomato farmers in Kaduna have earned a reputation for producing high-quality tomatoes, contributing significantly to the country's food supply chain. Tomato farming in Kaduna has been a source of livelihood for many families in the region. The farmers use various farming techniques to grow the crop, including irrigation systems. These techniques ensure the tomatoes are grown optimally, resulting in high yields and good quality. The farmers in Kaduna have also embraced modern farming practices, including using hybrid tomato seeds and applying fertilizers and pesticides, as seen in this research. These practices have helped to increase productivity and minimize losses due to pest attacks and diseases. One of the notable achievements of the tomato farmers in Kaduna is their ability to supply tomatoes throughout the year. The farmers grow tomatoes in different seasons, ensuring a constant supply to consumers.

Additionally, the farmers work closely with intermediaries to transport the tomatoes to various markets in the country. This collaboration ensures that consumers can access fresh tomatoes at affordable prices. Despite the success of the tomato farmers in Kaduna, they face some challenges such as access to credit facilities, which limits their ability to invest in modern farming practices, lack of storage, and lack of adequate and reliable supply chains. The tomato farmers in Kaduna are essential to Nigeria's food supply chain. They have embraced modern farming practices, ensuring high yields and good quality. However, stakeholders need to support the farmers with access to credit facilities and better transportation systems to help overcome the challenges faced by farmers. Additionally, the farmers need help transporting their produce to distant markets to mitigate the losses and waste generated on the farm at storage and in transit to increase their profitability.

6.2 Results and discussion

Table 6.1: Socioeconomic characteristics of tomato farmers surveyed in Kaduna state

Variable	Categories	Number of participants	%
Zonal area	North	20	31
	Central	20	31
	South	24	38
Gender	Female	6	10
	Male	58	90
Age group	18-29	4	6
	30-39	21	33
	40-49	21	33
	50-59	13	21
	60 and above	4	6
Marital status	Married	43	67
	Single	13	20
	Widow/Widower	8	13
Level of education	Arabic education	2	3
	Nonformal education	28	44
	Primary	9	14
	Secondary	17	27
	Tertiary	8	13

The results in Table 6.1 show that some socio-cultural factors in the area may have influenced the farming habits of respondents. There are few female farmers in the area, as 90% of the respondents are male. Young and middle-aged people dominate agricultural production in the study area, with their ages ranging from 30-49 and 50-59. Age is crucial in agricultural production since it impacts a farmer's physical strength (May *et al*., 2019). Young individuals devote more time to diverse agricultural tasks: This claim is more straightforward and can be evident because young people generally have more physical stamina and are often willing to take in a broader range of tasks. However, it is essential to note that this may only sometimes

be the case, as some older individuals may have more experience and skills in specific agricultural tasks, which can offset any physical limitations.

Echoing studies by Issa *et al*. (2014), Adekunle *et al*. (2009) and Milone and Ventura, (2019), inadequate capital can limit agricultural production, limits the tendency of younger farmers to engage in additional activities such as livestock management, marketing and planting additional crops (e.g. rice, soybeans, maize and pepper) can boost productivity, reduce their households' dependency, and improve the standard of living and income. Only 6% of the respondents were above 60 years and above, showing less engagement of the older generation in farming activities in the study area. Sixty-seven percent of respondents are married, 13 percent are widows/widowers, and 20 percent are single.

Fifty-six percent of respondents have attained some education: This indicates that over half of the tomato farmers in Kaduna have some formal education. This could have positive implications for adopting new farming techniques and the potential for increased access to information and resources. The demographic information provided about the tomato farmers in Kaduna suggests that some generational and family dynamics may be at play in the area. The relatively low percentage of older farmers may be a concern for the sustainability of tomato farming in the long term. In contrast, the high percentage of married farmers and those with some level of education may be positive factors for the success of tomato farming in the area.

Table 6.2: Tomato farm characteristics surveyed in Kaduna State

Variable	Categories	Number of participants	%
Hired labour	No	4	6.3
	Yes	60	93.8
Use of Fertilizer	No	6	9.4
	Yes	58	90.6
Fertilizer purchased from	Government	14	21.9
	Market	42	65.6
	Market and Government	3	4.7
	Non	5	7.8
Fertilizer improve productivity	No	4	6.3
	Yes	60	93.8
Irrigation	No	1	1.6
	Yes	63	98.4
Farmland Acquisition	Inherited	39	60.9
	Purchased	14	21.9
	Rent	11	17.2
Farm size	Less than one hectare	13	20.3
	1-4 hectares	30	46.9
	5-9 Hectares	17	26.6
	10 hectares and above	4	6.3
Use of mechanized equipment	No	14	21.9
	Yes	50	78.1

Based on the data presented in Table 6.2, tomato farming is a significant agricultural activity in the region. However, the reliance on unskilled and untrained hired labour is a significant concern as it leads to a decrease in product quality during harvesting. Farmers use these labourers because of their low wages, indicating that labour cost is essential for farmers. It is also noteworthy that most of the farmers inherited their farmland, indicating that they have experience in farming. This experience could benefit the production process, as they may know traditional farming practices. Additionally, using irrigation systems to provide water with all year round is a positive indication of modern farming practices, ensuring that the crops receive

the required water supply. Most farmers engage in medium-scale agriculture, with 46% of respondents using 1-4 hectares of land to cultivate. The use of mechanized equipment for land preparation is prevalent among farmers, with 78% using tractors for cultivation. This indicates that modern farming practices are gaining popularity among tomato farmers in the region. The data presented in Table 6.2 provides valuable insights into tomato farming practices in the region. The findings suggest that there is room for improvement in terms of labour practices and the use of modern farming technologies.

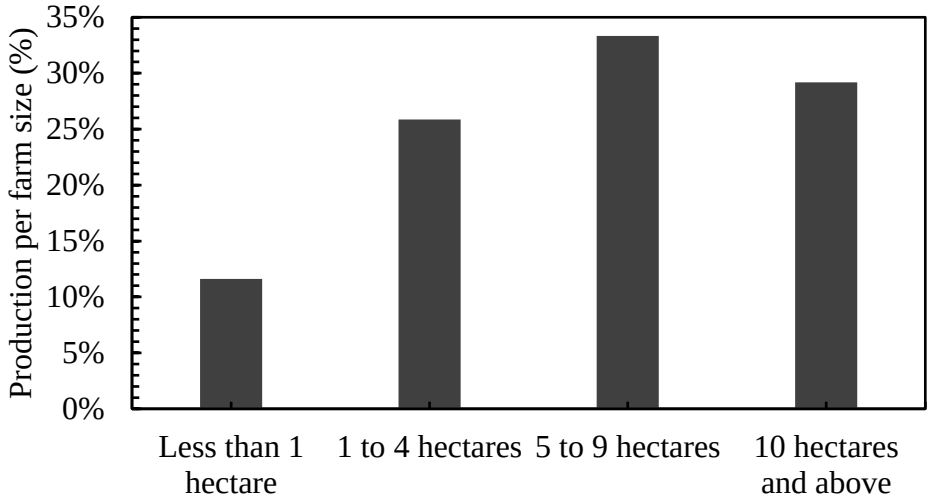

Figure 6.1: Percentage of tomato production per farm size (n= 64)

According to Figure 6.1, the percentage of tomato production varies across different farm sizes. The findings indicate that farmers with a farm size ranging from 5 to 9 hectares contribute the highest proportion of tomato production, accounting for 33% of the total. This is closely followed by farmers with a farm size of ten hectares and above, representing 29% of the total production. Conversely, farmers with less than 1 hectare of land yield the lowest amount of tomatoes, constituting a mere 12% of the overall production.

6.2.1 Bad fertilizer usage

Farmers use fertiliser to grow tomatoes. Since irrigation and fertilisation go hand in hand, tomatoes need to be watered correctly to keep nutrients from leaching into the groundwater and polluting it as described by famers in this research. This is especially important for growing tomatoes, which need a lot of nitrogen fertiliser (Mehdizadeh *et al*., 2013). Also, García-Raya, *et al*. (2019) found that the yields of tomato fruits went up when N and K were added through a drip system instead of before planting. Like applying water often, applying fertiliser in two parts at different times through fertigation improves the quality and quantity of tomatoes.

Caradonia *et al*. (2019) found that water-soluble NPK fertilisers applied through fertigation increased tomato yield by 33% compared to banded and furrow irrigation or banded and drip irrigation.

The use of manure from animal farms is a cost-effective and eco-friendly alternative to chemical fertilizers. The survey findings suggest that manure as a substitute for chemical fertilizers in tomato farming is gaining popularity, with 9% of respondents using manure instead of fertilizers. Additionally, using different types of manure, such as chicken, horse, cow, rabbit, and sheep manure, indicates that farmers have a diverse range of options for their fertilization needs. The finding that farmers till the soil before planting tomatoes to allow the manure to decompose is a good farming practice that maximizes yield and reduces the risk of adverse effects on the plants. This shows that farmers are knowledgeable about the importance of soil preparation for optimal crop growth.

The fact that 91% of respondents use chemical fertilisers in their tomato farming indicates that they are still widely used in the region. However, the survey also reveals that the incorrect use of fertilisers can lead to tomato losses. This indicates a need for farmers to understand the appropriate usage of fertilisers to maximise their crop yield. The survey raises another concern about using inexperienced labourers to apply fertilisers. The lack of training and experience among labourers can result in incorrect usage of fertilisers, leading to harvest losses. It is recommended that farmers provide proper training to their labourers to ensure that they apply fertilisers correctly. Farmers can improve their farming practices and achieve optimal crop growth by doing so. The survey highlights the need for farmers to be knowledgeable about the appropriate usage of chemical fertilisers to minimise crop losses.

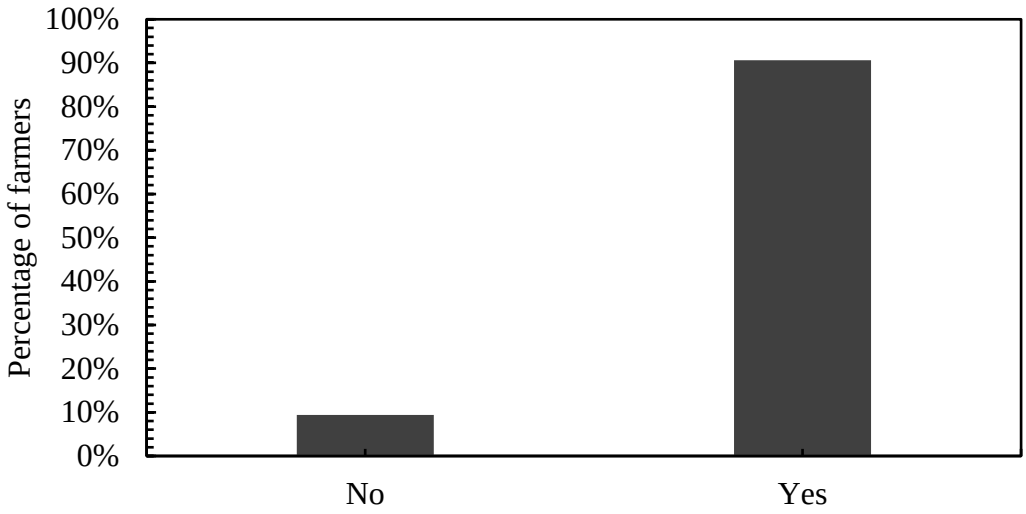

Figure 6.2: Fertilizer use by farmers (n= 64)

6.3 Farming seasons and tomato production

Today with modern agricultural practices such as greenhouse farming and irrigation systems, tomatoes can be grown throughout the year in Kaduna and other parts of Nigeria. These practices help to create a controlled environment that provides the necessary conditions for tomato growth and development, regardless of the season.

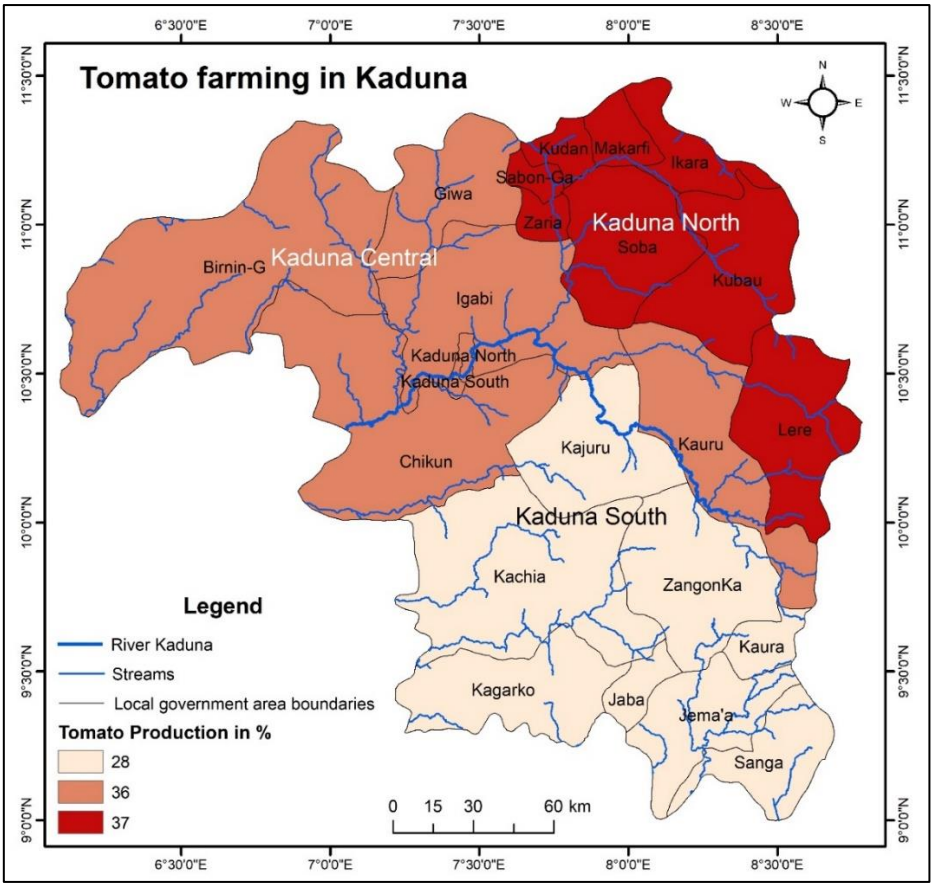

Figure 6.3: Showing the annual tomato production in the study area indicating Kaduna north with 37 percent of overall production and Kaduna south with 28 percent of annual production

Source: Author

Figure 6.2 above shows some seasonal streams and the river Kaduna, running through Kaduna South and Kaduna North local government areas in the central region, down to Kauru ocal government area. This research shows that Kaduna north area produces the highest amount of tomatoes across all seasons annually with 37% of annual production, followed by Kaduna central with 36% of annual production and Kaduna south, with 28% of annual production. Farmers within the river area take advantage of the rivers during the dry season. The presence of the river sometimes comes with devastation during the rainy season because the rain causes riverbank erosion, which is a significant problem for small-scale farmers. Riverbank erosion can cause farmers to lose 50% or more of their farm produce (Pima 2021). However, findings shows that, the northern region which includes Zaria, Soba, Sabon gari and Ikara Local Government areas produced the highest amount of tomatoes in the study area. There are several reasons these places are favourable locations for tomato production. The area has a favourable climate with relatively high temperatures and low humidity, ideal for tomato cultivation. The availability of irrigation water from the Kaduna River and other water sources enables farmers to grow tomatoes year-round. The availability of fertile soil, combined with modern farming

techniques and technologies, allows farmers to achieve high yields and produce high-quality tomatoes.

Table 6.3: Estimate of the amount of tomato produced by farmers surveyed in Kaduna state

Variable	Mean	Std. deviation
Dry season	169.86	96.54
Rainy season	124.72	76.75
Cold season	224.15	145.63
Annual	169.34	91.19

Drawing from the survey carried out in this research, estimates of tomato yields were collected from the sampled farmers in Kaduna state on a seasonal basis and descriptive statistics such as mean and standard deviation were used to explore production and waste in the study area. Most of the respondents had not received formal education but relied on experience and local knowledge of how weather and climatic conditions affect tomato production. They have a general agreement on how temperature influences the yield of tomatoes either positively or negatively. Results show that many of the respondents experienced greater yield reductions during the dry and rainy seasons compared to the cold season. The temperature during the cold season appeared friendlier to tomatoes even after harvest. Farmers lack the capacity to grow their tomato plants in a greenhouse, which would allow them to have a good harvest all year round.

Based on observations made in the field, the packaging materials used in the study area significantly impact the weight loss, decay rate, colour score, overall acceptability, and marketability of tomato fruits. Common packing materials in Kaduna include woven palm baskets, nylon bags, and jute sacks for fresh and dried tomatoes (Figures 4 and 5). As mentioned earlier, the packing needs to provide the necessary level of protection for tomato fruits. Tomatoes wrapped in nylon sacks are not adequately aerated, resulting in a build-up of heat due to respiration. Rough surfaces and edges of woven palm baskets cause mechanical damage to the tomato (Onu *et al*., 2021). Tomatoes at the base of the crates suffer internal damage due to the compressive force caused by the baskets' height (Arah *et al*., 2015).

Figure 6.4: Baskets of tomatoes (Rainy season)

Source: Author

Figure 6.5: Tomatoes in Baskets (Cold season)

Source: Author

6.4 Growing tomato in Kaduna

Farmers use various seeds, including Roman VF, UC 82-B, and Divar. Roman VF is a determinate variety of tomato plants, which means it grows to a certain height and then stops growing, making it easier to manage and harvest. It produces large, bright red fruits that are meaty and has a good balance of sweetness and acidity. The "VF" in the name stands for *Verticillium* wilt and *Fusarium* wilt, which are diseases to which this variety is resistant. UC 82-B is an indeterminate variety of tomato plants, which means it continues to grow and

produce fruit until the frost kills it or it is otherwise removed. It produces firm, small, deep red fruits with a good flavour. The "UC" in the name stands for the University of California, where this variety was developed, and the "82-B" indicates the breeding line. Divar is a hybrid variety of tomato plants with high disease resistance and yield. It produces elongated, dark red fruits that are meaty and have a rich flavour. This variety is also suitable for storage qualities, making it a popular choice for commercial growers.

Nevertheless, only some of the seed types can be planted every season in Kaduna. Farmers' testimonies suggest that the Roman seed, a commonly used tomato variety, is best planted during the cold season. This implies that temperature variations associated with climate change can influence the growth and performance of specific tomato plant varieties in Nigeria. Additionally, Maritz and Peters (2022) conducted a study indicating a strong correlation between weather conditions and tomato plant varieties in the country, further emphasizing the influence of climate on the selection and cultivation of tomato varieties. Furthermore, the soil and environment significantly limit tomato yield and production, with rainfall, temperature, and humidity being critical factors. The findings, consistent with those of Maritz and Peters (2022), reveal that the high rainfall intensity between March and June hinders the cultivation of healthy tomatoes. This period coincides with the onset of the rainy season in Nigeria, which may lead to excessive moisture and potential disease issues. Moreover, the unreliable precipitation experienced from May to August yearly adversely affects tomato output, as highlighted by Maritz and Peters (2022).

The rain causes product scarcity and raises post-harvest losses along the supply chain. Specifically, the study found that when there is inconsistent or insufficient rainfall during the dry season, it negatively impacts the growth and yield of tomato plants, ultimately leading to a reduction in tomato output. This suggests that precipitation during this critical period is crucial for the successful cultivation of tomatoes.

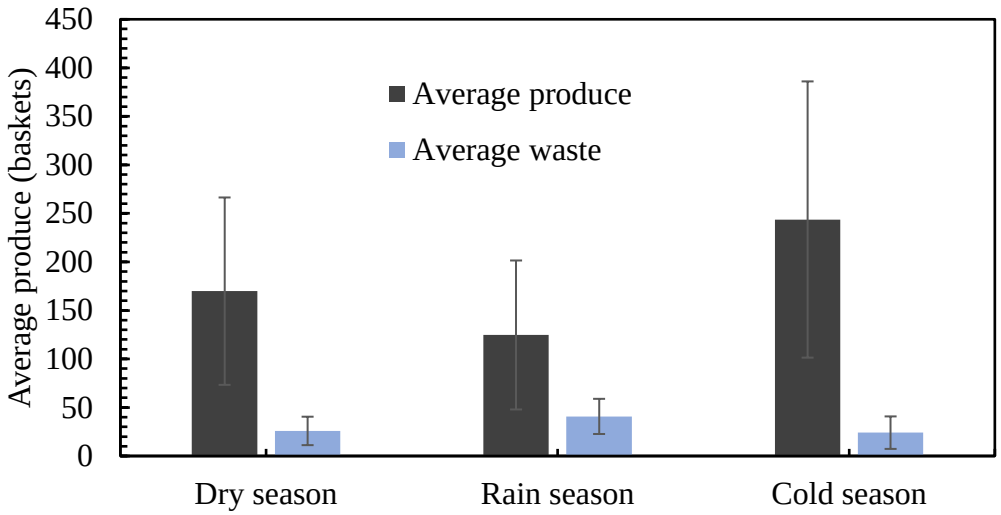

Figure 6.6: Annual average tomato production per season per farmer (n=64)

6.4.1 Variations between seasons and farm size

Figure 6.5: shows the average number of tomato baskets and waste farmers make in a season. Excel software was used to add the number of farmers' baskets in all three seasons. These results of post-harvest losses are those recorded on the farms by farmers. This result does not cover the losses that may occur in transit as the product travels from one point to another (e.g. from intermediary, trader or consumer).

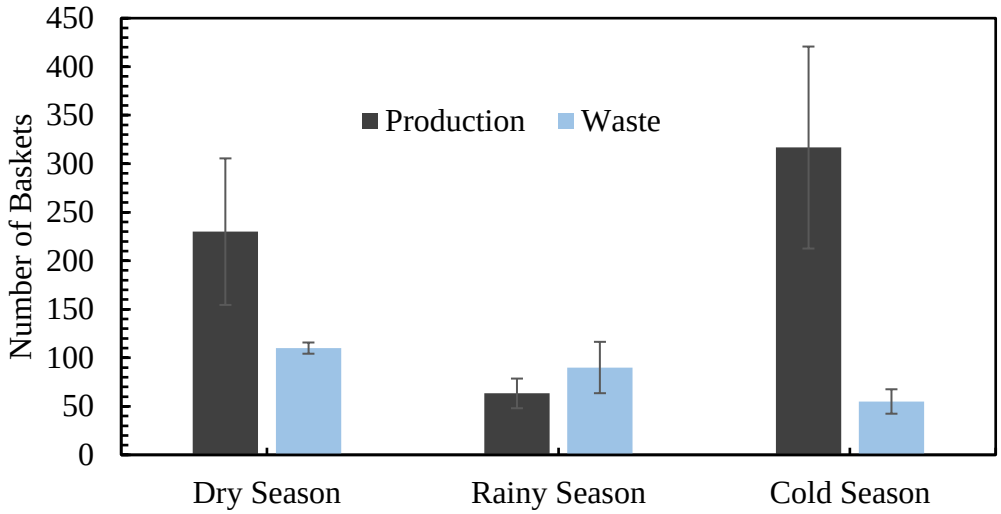

Figure 6.7: Tomato production and loss per season and per farmer for 10 hectares and above (n=64)

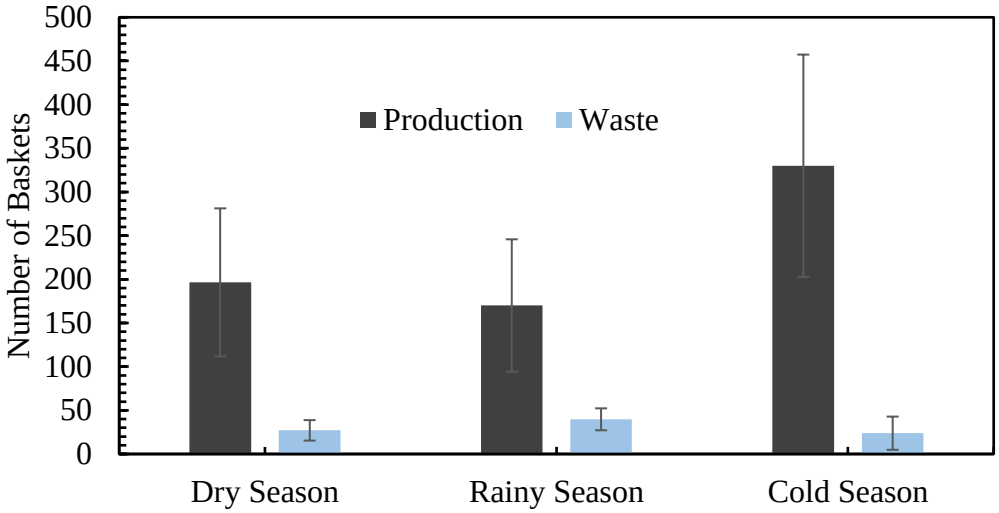

Figure 6.8: Tomato production and loss per season and per farmer for 5 to 9 hectares (n=64).

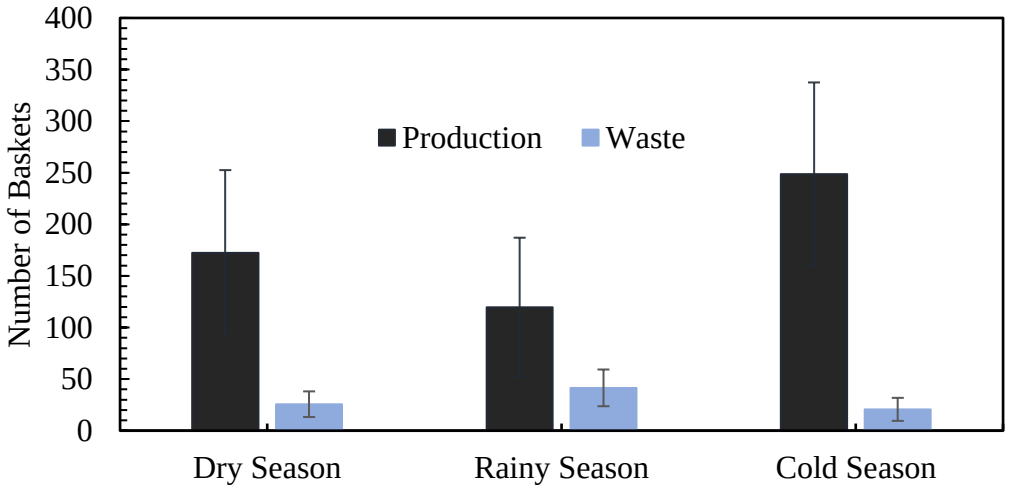

Figure 6.9: Tomato production and loss per season and per farmer for 1 to 4 hectares (n=64)

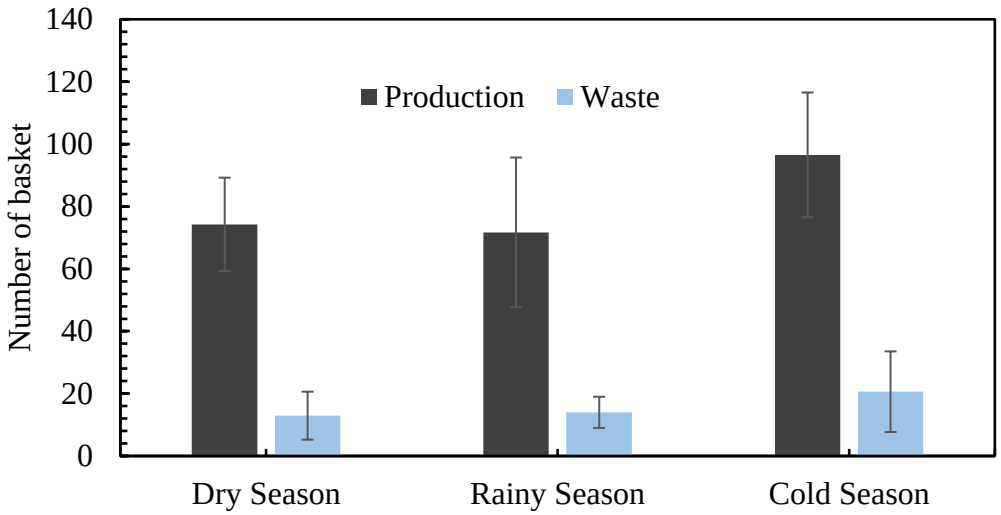

Figure 6.10: Tomato production and loss per season and per farmer for less than a hectare (n=64)

Figures 7-10 show the differences in farmers' farmland in the study area alongside the production and waste generated by each farmer. The survey results, as shown in Figures 6.6 – 6.9, demonstrate a significant variation in the tomato produce and waste generated across different farm sizes and seasons. Specifically, tomato production generally increases with farm size, the waste generated also tends to vary with farm size and seasons. Figure 6.9 indicates that the smallest farm size category has the highest efficiency, as measured by the ratio of produce to waste. In contrast, the largest farm size category has the lowest efficiency. The results suggest that farm size is a critical determinant of tomato yield and efficiency in Kaduna, with larger farms generally producing more tomatoes and generating more waste. Additionally, the data highlights the potential trade-off between maximizing yield and minimizing waste, with smaller farms potentially being more effective at achieving this balance. However, the survey did not capture data on the seed type used, which may also significantly affect tomato yield and efficiency.

Results observed that farmers have the lowest tomato output during the rainy season, and variation in yield levels among seasons indicates that rainfall influences tomato yield. Most farmers use baskets to measure the tomatoes harvested in a season. The farmers care little about the ripeness of the tomato, according to research conducted in the field. This was observed in the field during the survey. It was further discussed with two chairpersons in the intermediary markets who buy tomatoes directly from the farmers. However, we do not have any quotes for

this. A basket of tomatoes can contain mature green and red tomatoes, with the red much more than the green ones. The tomatoes were assessed in baskets utilizing a weight scale, as depicted in Figures 6.10 and 6.11. The maximum recorded weight was 70kg, while the minimum weight observed was 60kg. Consequently, the researcher resorted to employing the mean value to ascertain the quantity per basket. The average basket weighs 64 kg - 0.064 metric tonnes of tomato (Figures 6.10 and 6.11).

Figure 6.11: Basket of tomato (70kg)

Source: Author

Figure 6.12: Basket of tomato (60kg)

Source: Author

6.4.2 Dry season tomato farming

Tomatoes are grown three times a year. During the dry season, the farmers depend directly or indirectly on tomato production and sales for their livelihood. However, due to unstable weather conditions, Kaduna dry season agriculture has become increasingly difficult. The underground recharge makes it difficult for farmers to plan their irrigation schedules according to Ahmed *et al*. (2020) and it has become necessary for the farmers in Kaduna to find methods of conserving scarce natural resources to benefit from the efficient and effective use of the available resources. Tomato dry-season farming is mainly done on a small scale by many farmers although farmers also grow tomatoes during the wet season to ensure that tomatoes are available all year and also to provide a source of year-round income to farmers (Adenuga, *et al*., 2013). Farmers in Kaduna work hard all year long to grow tomatoes. They use baskets to measure their harvest each season (Figures: 6.3 and 6.4).

Findings have shown that farmers have a limited water supply for irrigation during the dry season, and as such, farmers have to rely on available sources such as boreholes, streams, or dams. Small-scale farmers find it easier to access and manage these sources than large-scale farmers. Many small-scale farmers in Kaduna have limited land access, making it difficult for them to engage in large-scale farming activities. Findings shown that 20% of respondents use

less than one hectare of land and 46% of respondents use 1-4 hectares of land. As a result, they opt for dry-season tomato farming, which requires less land than other crops. Dry-season farming requires less capital investment, making it more accessible to small-scale farmers. There is a high demand for tomatoes during the dry season when the supply is limited. Small-scale farmers in Kaduna use this demand to sell their produce at a higher price, thus earning more income.

6.4.3 Rainy season farming

Most of the tomato production in underdeveloped countries is rainfed (Arah, *et al*., 2016; Arah *et al*., 2015). This results in vital peaks in output during rainy periods, which are always more significant than the crop's local consumption. Some farmers can only produce during the wet season because they lack an effective irrigation system that would allow them to cultivate throughout the year (Fajinmi *et al*., 2010). It is not necessarily true that tomato farmers switch to planting other crops when it begins to rain. Tomatoes are generally grown in various climates, and many farmers have developed strategies to grow them in wet conditions. However, heavy rain can harm tomato plants. Excessive moisture can lead to fungal diseases and cause the fruit to split, resulting in a reduced yield and lower-quality tomatoes. In some cases, farmers may shift their focus to other crops that are less vulnerable to these problems. The availability and price of tomatoes can also be influenced by various other factors, including demand, transportation costs, and general trade patterns. Therefore, while rain can impact tomato production, it is not the only factor determining its availability and price. Adigun *et al*., (2018) in his research also identified tomato farmers switching to planting other crops during the rainy season.

Consequently, there is a tomato shortage during the rainy season, as illustrated in Figures 6.5 to 6.9 above Nevertheless, some farmers continue growing tomatoes during the rainy season using rain-fed varieties and local types that thrive in the rainy season although losses tend to be quite high during this time. The specific impact on tomato yields in Kaduna would depend on various local factors and farming practices. It is important to note that farmers may also take steps to mitigate the impact of weather patterns on their crops, such as choosing tomato varieties that are more resistant to disease or adjusting their planting and harvesting schedules.

6.4.4 Cold season farming (Harmattan)

Many northern Nigerian states cultivate tomatoes with irrigation as it has been identified by Abraham *et al*., (2021). According to the survey results, a farmer in this region can harvest an

annual average of 240 baskets of tomatoes. Depending on parameters like farm size, season, appropriate framing type, and the planted species. In the cold season a typical famer can harvest ten baskets in the first week of harvesting the matured tomato. They will harvest twenty to twenty-five baskets during the next week and forty to forty-five baskets during the third week of harvest. This pattern continues until six weeks of harvest, sometimes five weeks, before the quantity of tomatoes harvested starts to decrease in a similar pattern for the next five to six weeks. As they testified during the survey, planting tomatoes during the cold season in Kaduna state can offer several advantages for farmers. Cooler temperatures are not conducive to breeding and reproducing pests and diseases that typically affect tomatoes. The cooler temperatures during the cold season can help to reduce pest and disease pressure, resulting in higher yields and better-quality tomatoes. Additionally, the cooler temperatures can help to slow down the ripening process, which can result in better quality and longer shelf life for the harvested tomatoes.

Another advantage of planting tomatoes during the cold season in Kaduna state is the lower water requirements. During the cold season, there is typically less evaporation and transpiration, which means that less water is required to grow the tomatoes. This can be particularly beneficial in areas where water is scarce or expensive. Farmers can reduce their water usage and save costs by requiring less water. Planting tomatoes during the cold season in Kaduna state can provide farmers with several advantages, including reduced pest and disease pressure, better quality and longer shelf life, lower water requirements, higher prices, and diversification of income. These benefits can help farmers to achieve higher yields, reduce production costs, and increase profits, contributing to the overall development and sustainability of the agricultural sector in Kaduna state.

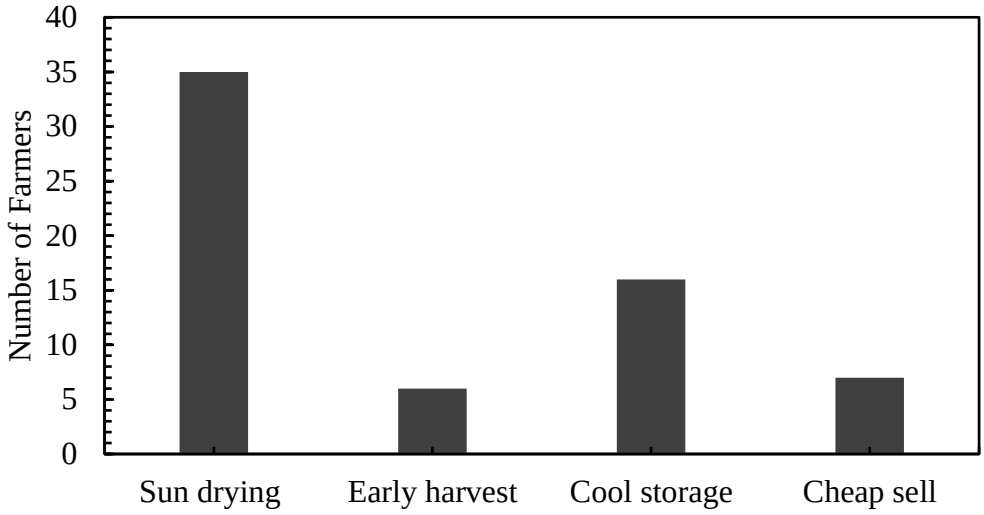

Figure 6.13: Strategies for waste prevention- sun dry, early harvest, cool storage and cheap sell (n=64)

6.5 Strategies of waste prevention

Tomato farmers in Kaduna have identified several measures to prevent and minimize tomato waste. These measures include sun drying, early harvest, cool storage, and cheap sales. To prevent and minimize tomato waste, farmers in Kaduna have identified sun drying, early harvest, cool storage, and cheap sales as practical measures. By implementing these measures, farmers can reduce waste, increase their profits, and contribute to food security in Nigeria. However, it is crucial to note that these measures require investment in infrastructure and training, and the government should support farmers to ensure their success.

6.5.1 Sun-drying

The survey findings showed that 35 of the 64 surveyed farmers in the study area are using sun-drying to prevent total loss or waste of their produce. Sun-drying is a traditional method of preserving tomatoes, where the fruits are sliced into thin pieces and left in the sun to dry out. While this method can effectively preserve the tomatoes for a more extended period, it also has several implications that should be considered (Figures 6.13, 6.15 and 6.16). One of the main implications of sun-drying tomatoes as a method of storage or preservation is the potential for contamination. During the drying process, the tomatoes are exposed to the environment, which can lead to contamination by dirt, dust, and other pollutants. This can compromise the safety and quality of the dried tomatoes, mainly if they are not appropriately stored after drying. Another implication of sun-drying tomatoes is the loss of nutrients. Sun-drying can cause

tomatoes to lose some of their nutritional value, particularly vitamin C and other water-soluble vitamins. This can have implications for the nutritional content of dried tomatoes, particularly if they are a significant source of these nutrients in the diet.

Additionally, sun-drying tomatoes can be time-consuming in areas with high humidity or frequent rainfall. The drying process can take several days or even weeks, during which the tomatoes need to be monitored and protected from pests and other environmental factors. The farmers lack better preservation methods, and the factories built to save the wastage in the tomato value chain have been locked down for one reason or the other. According to Ochonma and Okojie (2016), the Ikara LGA tomato processing plant that has been built for over two decades only operated for two years. It was hoped that the factory reopening in 2016 in the partnership between Kaduna state government and Springfield agro limited would bring a lasting solution to storage problems in tomato farming. The factory is situated in a tomato belt area for easy access and reduced wastage in the tomato value chain. I visited in January 2019 to ascertain the reality on the ground but saw no indication of ongoing work on the tomato factory site.

Figure 6.14: Tomato drying area at Zaria LGA Kaduna state

Author's photography. Jan 2020

Figure 6.15: Data collection in Zaria LGA Kaduna state

Author's photography. Sep 2019

Figure 6.16: Tomato drying area at Ikara LGA Kaduna state

Author's photography. Jan 2020

Figure 6.17: Tomato drying area in Igabi LGA Kaduna state

Author's photography. Feb 2020

Due to a lack of processing facilities, farmers are compelled to rely on direct local consumption by the populace. A farmer stated, "The absence of a market has forced us to dry the tomatoes to prevent a total loss" (Figures 6.13; 6.15 and 6.16).

6.5.2 Early harvest

Harvesting tomatoes early means picking the fruits before they are fully ripe. This was practised by 6 of the farmers who participated in this survey (Figure 6.12). Early harvest of tomatoes can significantly reduce the loss and waste of tomatoes, which is an essential concern for farmers. Early harvesting reduces the risk of damage to the fruits from pests and diseases. Tomatoes left to ripen on the vine for too long are more susceptible to insect infestations, fungal diseases, and other forms of damage. By picking the fruits early, farmers can reduce the amount of damage that occurs, which can help to ensure that more of the crop is usable. Early harvesting allows for better quality control. When tomatoes are harvested early, farmers can inspect each fruit more carefully to ensure it meets the required size, shape, and colour standards. This can help reduce the amount discarded or sold at a lower price due to quality issues. Early harvesting extends the shelf life of tomatoes. When tomatoes are picked before they are fully ripe, they are less likely to spoil quickly. This means that farmers can store the fruits for longer periods, giving them more time to sell or process the produce.

6.5.3 Cool storage

Cool storage of tomatoes can be an effective way to prevent the loss and waste of this perishable crop. For the survey, 17 respondents store their tomatoes in cool places to prevent loss and waste. By controlling the temperature and humidity of the storage environment, farmers and distributors can extend the shelf life of tomatoes, reduce spoilage, and minimize the amount of produce that goes to waste. There are several ways in which cool storage can help prevent the loss and waste of tomatoes:

Firstly, cool storage slows down the ripening process of tomatoes. Tomatoes continue to ripen after they are picked, and the rate of ripening is influenced by temperature and humidity. By storing tomatoes in a cool environment, farmers can slow down the ripening process, extending the product's shelf life. This means more of the crop can be sold and consumed before spoilage occurs. Cool storage can help prevent mould and bacteria growth on tomatoes. Mould and bacteria thrive in warm and humid environments and can quickly spoil tomatoes if left unchecked. By storing tomatoes in a cool and dry environment, farmers can create less hospitable conditions to mould and bacteria, reducing the risk of spoilage and waste. Cool storage can help maintain the quality of tomatoes. Tomatoes are sensitive to changes in temperature and humidity, and exposure to heat and moisture can cause them to lose flavor, texture, and color. By storing tomatoes in a cool and consistent environment, farmers can help maintain the quality of the produce, which can make it more attractive to consumers and less likely to be discarded.

6.5.4 Cheap sell

The high price of tomatoes can deter consumers from buying them, leading to an oversupply of unsold tomatoes that eventually go to waste. Conversely, lowering the price of tomatoes can stimulate demand and reduce oversupply, reducing waste. Selling tomatoes at a lower price can effectively prevent tomato loss and waste, as identified by seven farmers in a survey. Lowering the price of tomatoes can encourage more consumers to buy them, including those who would have avoided them due to high prices. This increased demand can help prevent an oversupply of tomatoes that would otherwise go unsold, reducing the likelihood of waste. Additionally, selling imperfect or damaged tomatoes at a lower price can prevent waste by utilizing products that would have otherwise been unsold due to consumer preferences for aesthetically pleasing tomatoes. Lowering the price of tomatoes can also stabilize prices and reduce fluctuations. High tomato prices can cause consumers to delay purchases, which reduces demand and causes

prices to drop rapidly, resulting in a cycle of oversupply and waste. Farmers can maintain steady demand by lowering the price, reducing the risk of oversupply and waste.

6.6 Pre-harvest causes of losses

Pre-harvest losses of tomatoes have been a significant concern for farmers and policymakers. Pre-harvest losses can be attributed to various factors such as pests and diseases, inadequate irrigation, poor soil fertility, and unfavourable weather conditions (Endalew *et al*., 2020). For instance, tomato diseases such as bacterial wilt, powdery mildew, and *Fusarium* wilt have been known to cause significant losses in tomato yield (Abdul *et al.,* 2020). Similarly, inadequate irrigation and poor soil fertility are significant factors contributing to Kaduna state's low tomato yield (Ilesanmi *et al*., 2018). The effects of pre-harvest losses of tomatoes in Kaduna state are multifaceted and can be seen at different levels. At the farm level, pre-harvest losses can lead to reduced farmer income and increased poverty, food insecurity and reduced economic growth.

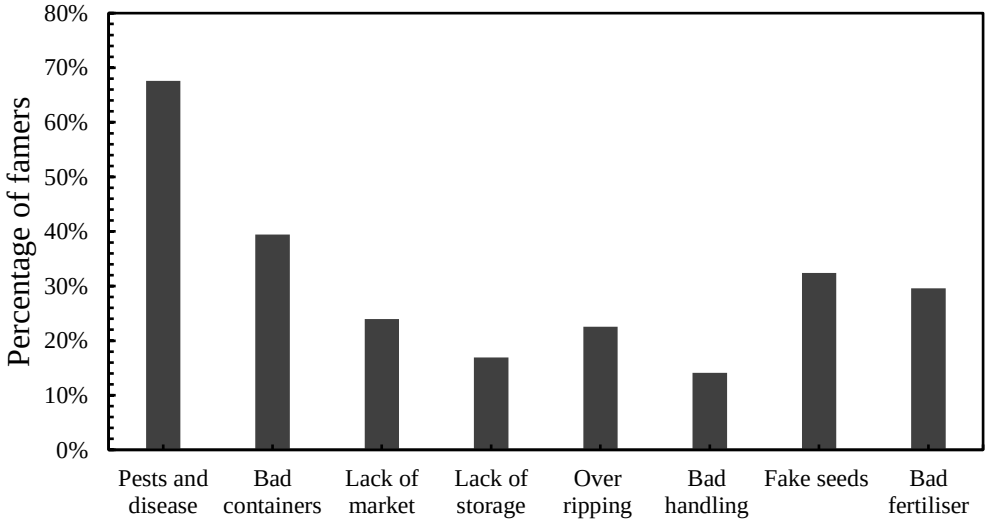

Figure 6.18: Percentages of leading causes of tomato post-harvest losses identified by farmers (n=64)

6.6.1 Pest and diseases

Pest and diseases are significant factors impeding the tomato output in Nigeria, and numerous hectares of tomato-planted land may be lost due to pests and weather as many farmers lack the necessary tools and financial capacity to combat pests and diseases (Fajinmi et al., 2010). As seen in the figure below, the research findings did not suggest otherwise. Sixty-eight percent of farmers concur that pests and diseases are a significant problem on their farms. Twelve

percent of farmers cited inadequate storage as a cause of losses, and they explained that the lack of storage is why they allow the tomato to ripen excessively on the stem, resulting in the ripeness and loss of the fruit.

6.6.2 Bad containers

According to findings in this study, 39% of respondents have identified the wrong container used as a significant cause of losses and waste during the harvest, transit, and storage of tomatoes. As discussed in 5.4.1 (Figure 5.5). Wrong container usage can result in bruising, crushing, or damage to the tomatoes, leading to a decrease in quality and market value. These containers have a rough surface which can cause bruises to the tomato. However, farmers indicated that using such containers is economical and reliable.

6.6.3 Over ripening

Over-ripening is one of the causes of tomato waste, as indicated by 23% of the frames. Farmers are forced to leave their tomatoes on the stem after they ripen. This usually occurs during the seasonal glut when farmers and markets are overwhelmed with produce. When tomatoes are left on the vine for too long, they become too ripe and deteriorate rapidly. This can happen during seasonal glut when there is an oversupply of tomatoes in the market, and farmers can only sell some of their products after it becomes overripe. Overripe tomatoes are often considered unsuitable for sale or consumption, as they may be too soft, have a mushy texture, or be prone to spoilage. As a result, farmers may have to discard these tomatoes, leading to significant food waste.

6.6.4 Bad handling

Handing practices during harvesting can lead to significant waste and loss generation. In this survey, 14% of respondents said bad handling results in tomato waste on their farms. We discussed the reasons why poor handling of tomatoes during harvest could lead to waste and loss, as well as strategies that can be employed to mitigate this issue. One of the main reasons why poor handling practices can lead to waste and loss is the weakness of tomatoes to mechanical damage. When tomatoes are subjected to rough handling, they can bruise or crack, making them more vulnerable to decay and spoilage. Additionally, mechanical damage can lead to the release of enzymes that can accelerate the ripening process, causing the tomatoes to spoil more quickly. Famers said that they employ inexperienced and non-trained personnel to harvest their tomatoes, which can lead poor handling practices resulting to waste and loss.

During harvesting, tomatoes can meet dirt, debris, and microorganisms that can cause spoilage or foodborne illnesses, especially when using inexperienced people for harvest.

6.6.5 Bad seeds and farm practices

Seeds are essential agricultural inputs, and their quality plays a crucial role in determining crop yield and quality. 32% of farmers in this survey who use fake seeds in tomato cultivation experienced significant losses in yield, which had severe consequences. Fake seeds are inferior or counterfeit seeds sold under the guise of natural seeds. Unscrupulous seed dealers often produce these seeds, prioritising profits over product quality. One of the primary reasons fake seeds can lead to losses in tomato yield is their low germination rates. The process by which a seed develops into a seedling is called germination, and a low germination rate means fewer plants will grow from the seed. This results in reduced plant density and lower yields.

6.7 Post-harvest causes of losses

Tomato farmers in Kaduna face several causes of post-harvest losses and waste, including poor transportation, lack of proper storage facilities, and limited market access. These factors contribute to significant losses for farmers, who often use old and poorly maintained vehicles for transportation, lack access to storage facilities such as refrigerators, and need help finding a market for their produce due to inadequate marketing infrastructure and distribution networks.

6.7.1 Harvesting methods

Farmers in the study area use manual picking methods, and most use wooden baskets or crates with a cutting surface to store or carry vegetables (Arab *et al*., 2015). This cutting surface usually causes mechanical injuries to the harvested fruits. Drawing from findings in the research, farmers are seen to lose about 31% of their harvest at the harvesting stage, 37% due to lack of storage on farm and at gathering and packing 20% to their tomatoes and at handling and transportation 12% (Figure 6.18).

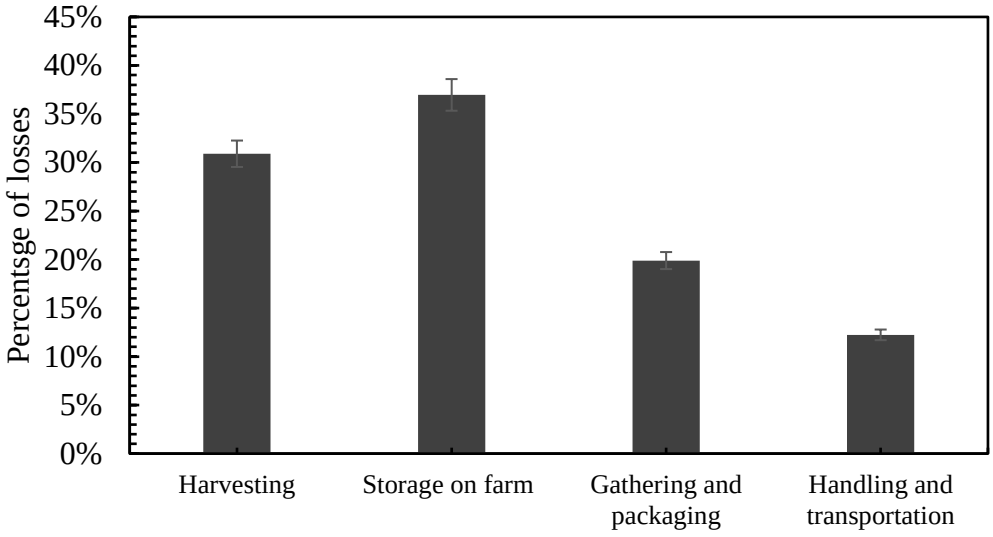

Figure 6.19: Percentages of tomato post-harvest losses at different stages identified by farmers (n=64)

6.7.2 Storage on farm

The need for on-farm storage facilities was identified as a significant problem for farmers in the study area, resulting in losses and waste of their produce. According to this study, farmers lose about 37% of their produce due to the need for storage facilities. Although the problems of preservation methods and storage facilities have been discussed in section 5.4.6, farmers in the study area have found a solution to reduce the impact on their product due to the need for more on-farm storage facilities. They use tree shades and cut branches to shelter and cover their harvested tomatoes from the sun. While using tree shades and cut branches may provide some short-term benefits for farmers, it is not a sustainable solution in the long run. Relying on natural shade and branches may not protect the harvested tomatoes adequately. Farmers may still experience significant losses in their produce. This strategy may only be effective for a limited period, and the harvested tomatoes may become unsellable shortly. As a result, farmers may miss opportunities to sell their produce to buyers unwilling to purchase damaged or unsellable tomatoes.

6.7.3 Handling and transportation

In the study area, bad roads have been identified as a significant problem for farmers, resulting in losses and produce waste. According to the study, farmers lose about 12% of their produce due to transportation and handling methods. Although the problems of transportation and handling methods have been discussed in section 5.4.8, farmers in the study area have found a

solution to avoid the problems faced on the road. They sell their produce on the farm instead of transporting it. This strategy of selling products on the farm may have benefits for farmers in the short term, but it may not be a sustainable solution in the long run. Selling produce on the farm limits the market reach and potential profits for the farmers. They may only be able to sell their produce to a limited number of customers willing to travel to their farm. As a result, farmers may miss out on opportunities to sell to buyers unwilling to travel to their farms or those who live in other areas. Secondly, selling produce on the farm may not address the underlying problem of bad roads. While it may reduce losses due to transportation and handling methods, it does not address the more significant issue of poor infrastructure. If the road conditions do not improve, farmers may still face challenges transporting their produce to other markets, even if they sell on the farm.

Figure 6.20: Bad roads in Nigeria

Source: Author

Figure 6.21: Bad roads in Nigeria

Source: Author

Once tomatoes are properly transported, they are recovered. When packaging materials fail to hold fruits in place, they move excessively during transportation, which might result in losses. Farmers should utilise refrigerated vehicles whenever possible to transport tomatoes. Covering non-refrigerated trucks with jute spreads or tarps to prevent tomatoes from wilting can help if refrigeration units cannot be used. Farmers in the study area rarely use any material to cover tomatoes while on transit. Tomatoes may also be transported in wooden or plastic crates or cardboard boxes. Even on poor roads, losses are reduced when tomatoes are transported in returnable plastic containers. When tomatoes are transported in overfilled baskets, they fall out and become damaged, decreasing the amount that can be marketed.

6.7.4 Gathering and packaging

Farmers are experiencing losses and waste due to gathering and packaging their products. The study revealed that approximately 20% of the produce is lost during this process. This is a significant problem for farmers as it directly affects their profits and food availability for consumers. The gathering and packaging issue is similar to bad container usage, discussed in section 5.4.5 and 6.6.2 of the study. In both cases, the problem lies in handling the product, resulting in damage and loss. This issue can be addressed by properly training and educating farmers on best practices for gathering and packaging produce.

6.7.5 Lack of market

The lack of market requires more sufficient customers and processing industries. The most significant contributing factor to Nigeria's PHL is the need for a market (Plaisier *et al*., 2019). Alternatives are crucial, particularly during the seasonal glut. “Famer respondent said they lack storage facilities and factories that can transform the tomato into paste and puree and make it more preservable, and consumers cannot consume all that was planted.” They lamented that it is more difficult and costly to leave the state in search of a market due to the widespread insecurity and the dearth of excellent roads.

6.8 Summary

Growing tomatoes is a profitable business in the area where the study was done. This was because at least 42.5% of the total amount invested could be turned into income. The gross and operating ratios show that the production efficiency and business are doing well. Nevertheless, the product's profitability depends significantly on how much it costs to make per hectare and how quickly it can be sold on the market. This is because tomatoes go bad quickly. So, the results of this research add to the general knowledge of production economics in the study area. They also provide a foundation for stakeholders to work together to increase production on a large scale. However, the study's results would be necessary for helping producers and traders choose factors that will help them make a profit, which is why the study is essential.

Farmers should be taught how to handle produce carefully to avoid damage and loss during gathering and packaging. They should also be provided with appropriate tools and equipment to aid the process. Farmers can be given crates and baskets the right size and shape for the produce being harvested. This will prevent the product from getting damaged or bruised during transportation. Use appropriate packaging materials and techniques to ensure the packaging is solid and protective. Regarding on-farm storage facilities, farmers in the study area need to explore alternative storage solutions to reduce losses and waste of their produce. This may involve investing in on-farm storage facilities, such as refrigeration units, or collaborating with other farmers to share the cost of building storage facilities. By investing in adequate storage facilities, farmers can extend the shelf life of their produce, reduce losses and waste, and increase their potential profits. To reduce tomato waste caused by over-ripening, farmers can take steps to ensure that their tomatoes are harvested at the right time and stored correctly. They can also explore alternative markets or value-added products, such as tomato sauces or canned

tomatoes, to use excess produce. Additionally, consumers can help reduce tomato waste by purchasing and using ripe but firm tomatoes promptly.

In summary, addressing the problems can help reduce post-harvest losses and waste among tomato farmers in Kaduna State. Strategies such as improving storage facilities, upgrading transportation infrastructure, providing market information, and increasing access to credit can all contribute to a more efficient and profitable tomato industry in the region.

Chapter 7: Intermediaries in the tomato supply chain in Kaduna state

7.1 Introduction

The tomato market in Kaduna is one of the largest in Nigeria, with a significant impact on the country's agricultural economy (Umar and Abdulkadir 2015). However, the market is predominantly controlled by intermediaries, who play a crucial role in the supply chain (Emana *et al*., 2017). These intermediaries, known as "middlemen," facilitate the transactions between farmers and consumers, but their dominance in the market has raised concerns about price volatility, exploitation, and inefficiencies. The role of intermediaries in the tomato market in Kaduna is critical as they connect farmers with consumers and other market actors. They perform various functions, including transportation, storage, sorting, grading, and marketing. Farmers typically sell their produce to intermediaries at the farm gate, who transport the tomatoes to wholesale markets in Kaduna or other cities. At the wholesale markets, intermediaries sell the tomatoes to retailers, who then sell them to consumers. The intermediaries act as "brokers" between the farmers and the markets, providing services to ensure that the tomatoes reach the consumers in good condition and at the right time (Emana *et al*., 2017). They also help farmers navigate complex market dynamics, providing information about prices, demand, and quality standards. In some cases, intermediaries give farmers credit, enabling them to produce more tomatoes and earn higher profits.

7.1.1 Dependency on middlemen

Farmers rely on intermediaries to purchase their produce “this was further discussed in 6.5.1”, leading to farm gate sales. The imperfect nature of the roads, the difficulty of loading and offloading produce on vehicles, getting access to markets and selling to consumers have all been avoided by farmers when they sell directly to intermediaries. Many farmers need more financial resources to rent vehicles to transport their goods to markets, so they prefer to sell their tomatoes at a lower price rather than keep them on their farms. Some farmers have started selling directly to customers at the farm gate, which has proven to yield high returns on their investments in the market. Even adequate handling of fruits, lack of storage, and transportation have caused significant losses for farmers, sometimes reaching as high as 90 per cent, especially when intermediaries fail to approach them for sales. While intermediaries remain a vital link between farmers and consumers, small-scale tomato farmers desire to minimize loading and unloading expenses, so they sell most of their produce at the farm gate. This

practice places the burden of transportation on intermediaries, who cover the distance between the farm and the market.

7.2 Results and discussion

Table 7.1: Socioeconomic characteristics of tomatoes intermediaries in Kaduna state

Variable	Categories	Number of participants	%
Zonal area	North	7	26%
	Central	12	44%
	South	8	30%
Gender	Female	1	4%
	Male	26	96%
Age group	18-29	1	4%
	30-39	7	26%
	40-49	9	33%
	50-59	7	26%
	60 and above	3	11%
Marital status	Married	23	85%
	Single	2	7%
	Widow/Widower	2	7%
Level of education	Arabic education	8	30%
	Nonformal education	1	4%
	Primary	4	15%
	Secondary	8	30%
	Tertiary	6	22%

Even while the number of women in agricultural business is rising, there is still a significant gender disparity in the agricultural sector (Doss, 2018). The tomato market in Kaduna is highly dependent on intermediaries, who act as brokers between farmers and consumers. These intermediaries perform various functions, including transportation, storage, sorting, grading, and marketing. Table 7.1 shows the socio-economic characteristics of tomato intermediaries in Kaduna state, Nigeria. The table indicates that 96% of the participants in this research are

males, highlighting a significant gender disparity in the agricultural sector. Women's lack of state protection is the primary source of this gender disparity, leading most women who formerly worked in agriculture to return to domestic employment. Additionally, female youth perceive agriculture as a non-lucrative business, leading them to view other business forms as more profitable. As a result, only 4% of the participants in this research are female. The research also identified the massive participation of youth as intermediaries in tomato farms. Over 59% of the intermediaries are between 30-49 and 40-49, indicating that the sector attracts individuals in their prime working age. The youth contribute significantly to agriculture, with 80% of rural youth in Kaduna found on farms after school hours and during holidays.

The level of education among intermediaries varies, with 30% having Arabic education, 15% had primary education, 30% having secondary education, and 22% having tertiary education. This indicates that intermediaries have diverse educational backgrounds, but most have at least some formal educations. The table also shows that most intermediaries are married, with 85% of participants falling into this category. The tomato market in Kaduna state heavily relies on intermediaries who perform essential functions in the supply chain. However, the dominance of intermediaries in the market has raised concerns about price volatility, exploitation, and inefficiencies. The gender disparity among intermediaries highlights the need for state protection for women in agriculture. The massive participation of youth as intermediaries indicates the sector's potential for attracting young people to agriculture.

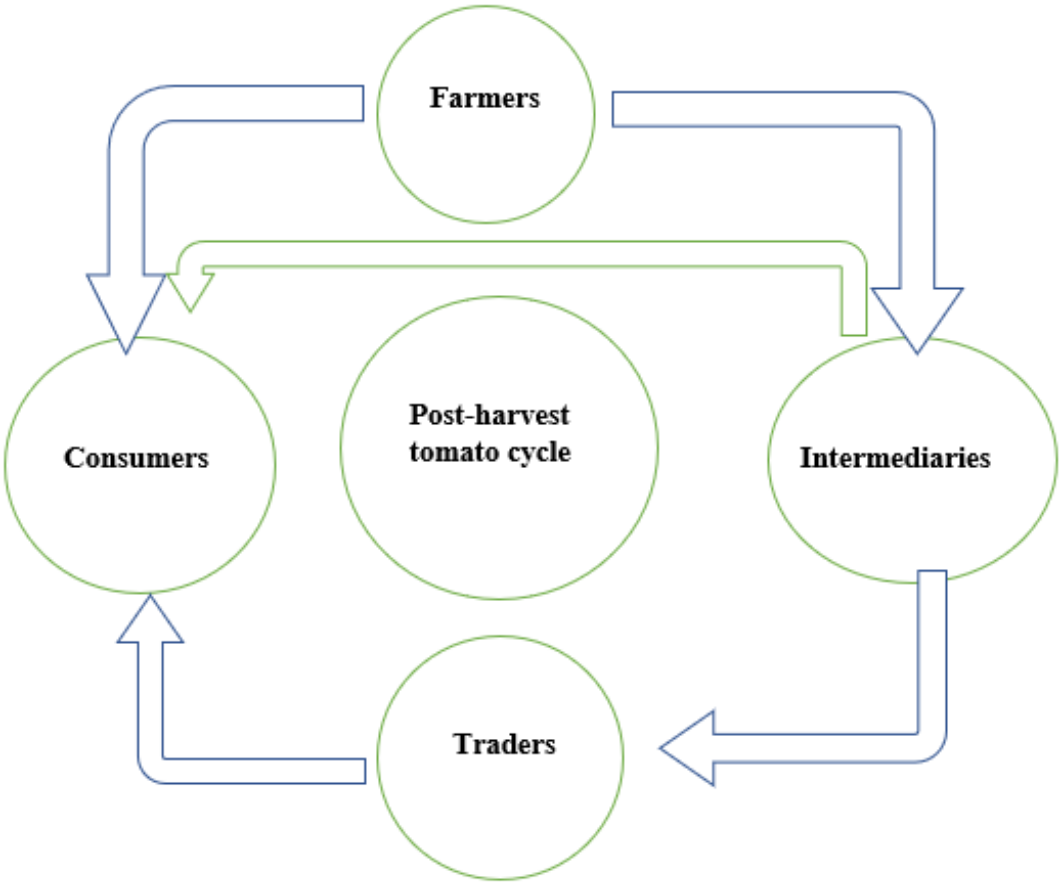

Figure 7.1: Tomato post-harvest cycle: between farmers, intermediaries, traders and consumers

Source: Author

7.3 Intermediary's transactions

Figure 7.1 above further illustrates the pattern and marketing channels through which intermediaries in the study area buy and sell their fresh tomatoes. The major ways intermediaries typically buy their products are at the farm gate. During the July-Sept season, (Dry season) the product's price reaches its peak, and as one would expect, this is when farmers produce the least quantity of tomatoes. This period sees more intermediaries buying and selling tomatoes in the tomato farms and selling at markets because of the increasing price of a tomato basket (See figure 7.2). Intermediaries appear to be in control of the markets and the supply chain because of the number of local producers and wholesalers that depend on them from within and outside the state. Drawing from the research findings, an intermediary may lose an average of 30% of his purchase under normal circumstances and up to 80% of the stock in the event of an accident or unforeseen circumstances (Figure 7.7).

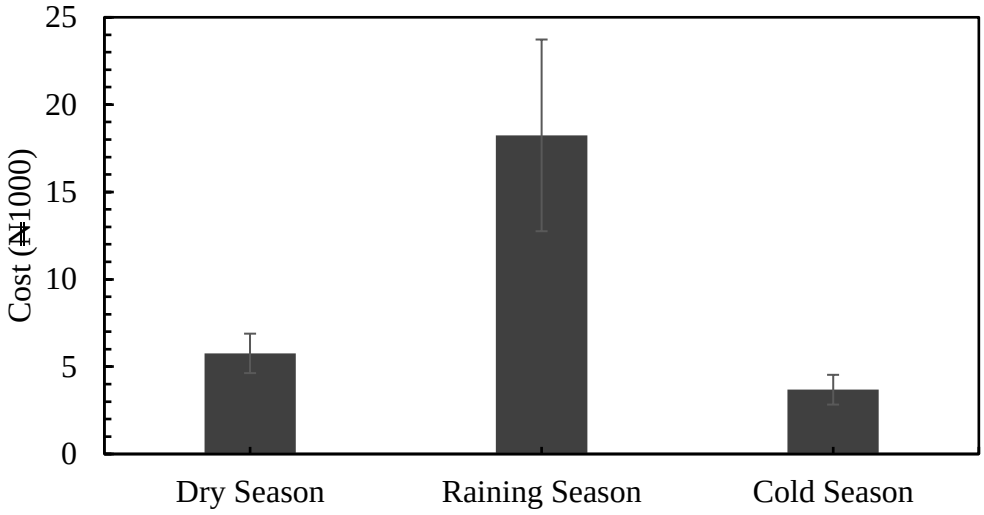

Figure 7.2: Response on the average cost of tomatoes per basket

Tomatoes for wholesalers and retailers are sold in baskets and measured per kilogram (kg) all over Nigeria (Figure 4.4). The seasonal reduction in tomato production and the subsequent increase in prices during the summer months significantly impact intermediaries in the tomato supply chain. Intermediaries, including wholesalers, distributors, and retailers, are critical supply chain components connecting farmers to consumers. The reduction in tomato production during the summer months leads to a decrease in the volume of tomatoes available to intermediaries. This scarcity of supply often drives up the prices, making it more expensive for intermediaries to acquire tomatoes from farmers. As the result in figure 7.2 indicates, intermediaries may be forced to increase their prices to consumers to maintain their profit margins. Additionally, the high temperatures during the summer months pose a significant challenge to intermediaries in the supply chain.

Tomatoes are highly perishable and can quickly deteriorate when exposed to temperatures above 25 degrees Celsius. The heat during the summer months, which can reach up to 40 degrees Celsius, means that the shelf life of tomatoes is drastically reduced. This means that intermediaries have a limited time to transport and store the tomatoes before they spoil. They survey have shown that intermediaries purchase a 65-70 kg tomato basket (Figures 6.10 and 6.11) in Kaduna are often between ₦3,000 to ₦,6000 between September and March (dry and cold season), and between ₦18,000 to ₦ 25,000 from May to July (rainy season) every year (Figure 7.2). Intermediaries get a higher price for their tomatoes during the rainy season because of the increased demand and decrease in supply.

Roman VF, UC 82-B, and Divar are the three main types of tomatoes grown in the study area (as mentioned and explained in 6.4). The Roman VF is the most popular because it is almost seedless, juicy, and has a unique flavour that people love. So, intermediaries like to do business with farmers who plant it. It can last a long time after being picked before the weather, or the baskets used to store it make it deteriorate. A 65kg to 70 kg basket is used for wholesale and is left open and under the sun, by intermediaries as shown in figure 7.3 from tomato collection markets in the study area.

Figure 7.3: Intermediaries sorting tomatoes

Source: Author photographs 2019

The intermediaries must strike a favourable deal with the farmers to make a profit because they have to sort out damaged tomatoes from good ones, and the matured green ones from the matured red ones, which may reduce the quantity of the tomatoes. They renegotiate the price when they cannot agree on a price per basket because they know it is perishable and time is running out. Echoing findings by Olaniyi (2017) intermediaries in the study area sometimes provide loans to farmers over time which get repaid at harvest time with farmers giving priorty sales to intermediaries that they have borrowed money from. Farmers in many rural areas rely on intermediaries to help them access markets for their agricultural products. These intermediaries, often known as middlemen or traders, provide various services to farmers, such as transportation, storage, and marketing. In addition to these services, intermediaries may also provide loans to farmers to help them finance their agricultural activities. These loans typically come with certain conditions attached, such as interest rates and repayment terms. In some cases, intermediaries may require farmers to repay their loans at harvest time, when they are most likely to have cash on hand from selling their crops.

To ensure that farmers can repay their loans, intermediaries may also require that farmers give priority sales to the intermediary they borrowed money from. While this lending and priority sales system can provide much-needed financing to farmers, it can also create some challenges. For example, farmers who borrow from intermediaries may be locked into a cycle of debt, as they may need to borrow more money each season to finance their activities. Additionally, giving priority sales to a particular intermediary may limit farmers' ability to negotiate prices and seek the best market for their products. Olaniyi (2017) indicates that using financial services has considerable short- and long-term effects on agriculture. One example of the short-term effects of using financial services on agriculture is that it can help farmers to manage their cash flow better and invest in inputs such as seeds, fertilizers, and pesticides. With access to credit, farmers can purchase these inputs at the beginning of the planting season, which can help to increase their crop yields and improve their income. In addition, financial services such as mobile money can help farmers quickly and easily receive payments for their products, reducing transaction costs and improving their overall profitability.

In the long term, using financial services can help farmers to build their businesses and improve their livelihoods. For example, by borrowing money to purchase equipment or expand their operations, farmers can increase production and generate higher incomes over time. In addition, by building a credit history and establishing relationships with formal financial institutions, farmers can access more significant amounts of credit at lower interest rates, which can help them to grow their businesses further and invest in new technologies and practices.

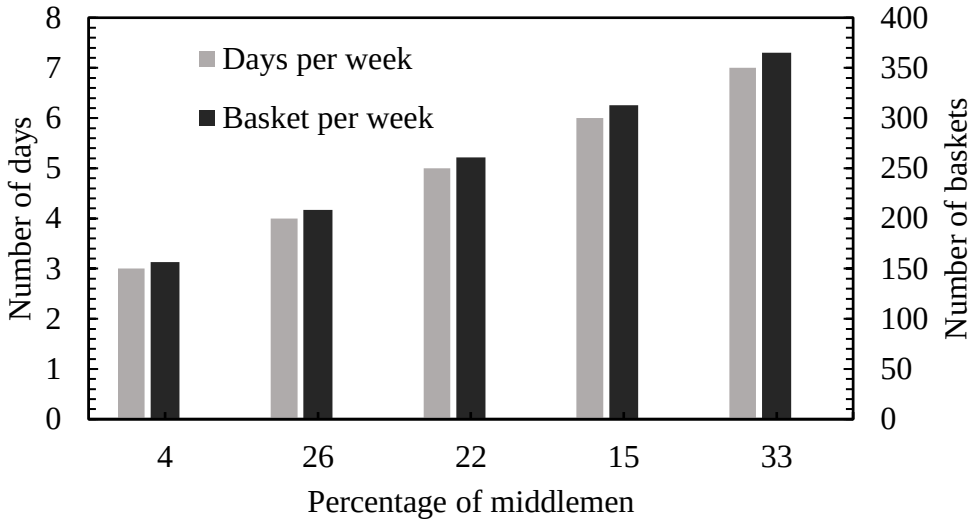

Figure 7.4: Response on their daily and weekly purchase of tomatoes (n=27)

Figure 7.4: Illustrates how many days a week the middlemen buy tomatoes and how many baskets of tomatoes are purchased in a typical week. 33% of intermediaries buy tomatoes seven times weekly, which amounts to 365 baskets weekly. 15% buy six days each week, which amounts to 313 baskets a week, whereas only 4% buy three times per week. During our inquiry with two intermediaries who purchase tomatoes three times each week, they explained that they do so because it takes them a day to harvest and get to their selling point. They also mentioned that they spent two days with their family. In their view, people who bought and sold tomatoes weekly must have daily markets to supply these products. They stated that a day without work is a significant financial loss. No respondent was observed utilising plastic crates. A few preserved their harvest under trees before transporting it to the market. Some harvesters load straight onto the transporting vehicles. Respondents noted that the transportation of the product occurred at all hours of the day. Tomatoes were transported using open pickup trucks, on top of DAF Lorries, J5 Peugeots, and buses (Figures 5.2, 5.3, 5.4, 5.5 and 5.6).

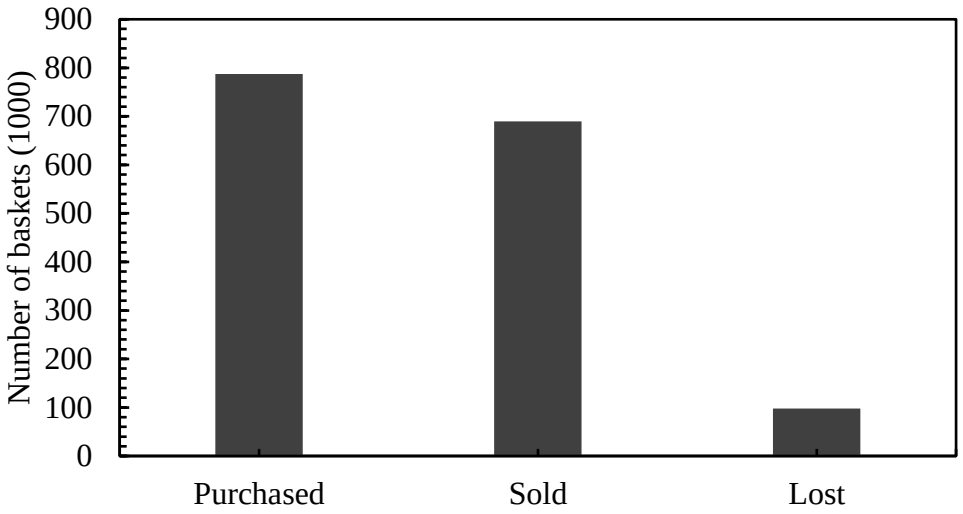

Figure 7.5: Response on middlemen annual tomato annual purchased, sold and lost (n=27)

Figure 7.6 shows respondents' annual tomato purchases, sold, and losses in the study area. Surveys from this research have shown that intermediaries purchased 787,000 baskets of tomatoes over the three seasons of the year, and they sold 669,000 baskets while they lost 97,000 baskets. These losses were due to foreseen circumstances such as excessive field heat, lack of suitable handling solutions, products bruised by the texture of the baskets, and the undulating nature of the road. Others are how workers handle the product when they load the tomato on and off the vehicles.

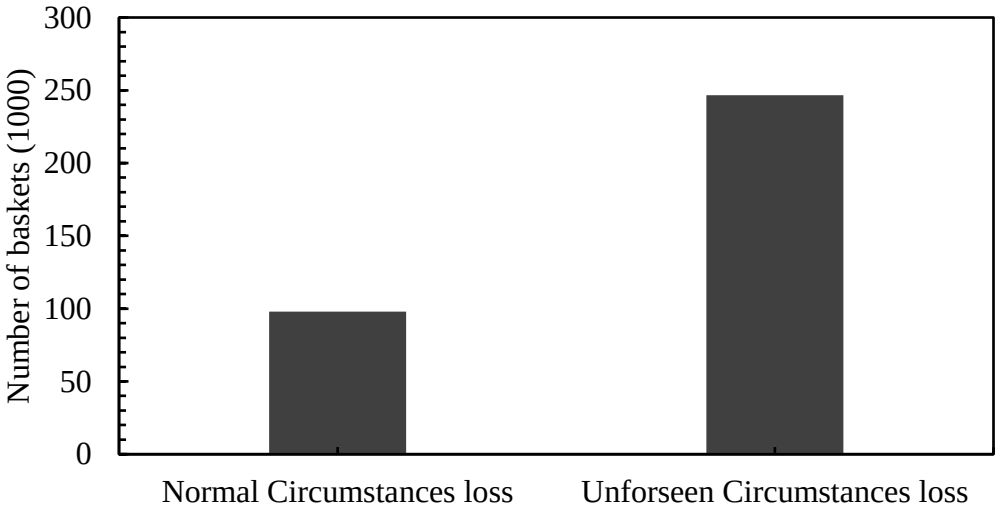

Figure 7.6: Normal and unforeseen circumstances loss (n=27)

The annual losses experienced by respondents in the study area under typical and unanticipated situations are depicted in Figure 7.7, it illustrates the losses experienced by intermediaries in the research area under typical and unforeseen circumstances. Under typical conditions, the losses amount to 100,000 baskets of tomatoes annually, attributed to natural factors. However, under unforeseen circumstances such as calamities, losses can increase to 250,000 baskets of tomatoes annually. The study participant's experience in the Lagos market highlights how accidents, poor road infrastructure, roadblocks, and lack of relevant data can lead to losses. The participant reported that he could have lost 90% of his supply due to unforeseen situations, such as delays and the deterioration of his tomatoes while waiting in a queue. The study team encountered three accidents on the highways where tomato baskets were lost, demonstrating the impact of unforeseen circumstances on intermediaries' losses.

The findings suggest that intermediaries in the research area face significant losses due to typical and unforeseen circumstances. While losses under typical conditions are unavoidable, losses under unforeseen circumstances can be mitigated by addressing factors such as poor road infrastructure, roadblocks, and lack of relevant data. The study highlights the need for better transport and logistics systems to reduce losses and increase the profitability of intermediaries. Moreover, the study provides valuable insights into the challenges intermediaries face in the tomato value chain, which can inform policymakers and other stakeholders in designing interventions to address these challenges.

A participant in the study stated, "One can lose 90% of supply due to unforeseen situations." He then told us about his last trip to Lagos, where he brought products to the Lagos “tomato mile twelve markets”. At the market, he encountered a queue; if they were all transporting tomatoes like his, it would be three days before his turn to offload them. Fortunately for him, he was the only lorry with tomatoes to sell, so everyone else had to make way for him to get rid of them when the need came for tomatoes. He claimed that his supply would have deteriorated from the excessive hit they took while travelling and queuing at the market for the next three days. Accidents, poor road infrastructure, roadblocks, a dearth of relevant data, and other similar factors can all lead to unpleasant surprises. The research team encountered three accidents on the Kaduna to Zaria highway and Kaduna to Abuja bypass road in which tomato baskets were lost (Figures 7.9, 7.10 and 7.11).

Figure 7.7: An accident along the Kaduna-Abuja highway

Author's photograph 2019

Figure 7.8: An accident along the Kaduna Road

Author's photograph 2019

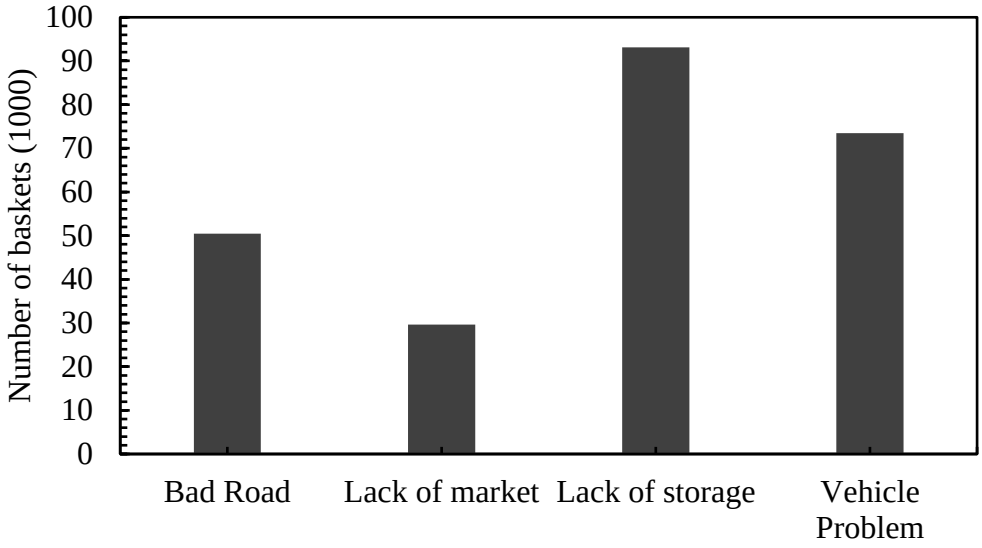

Figure 7.9: Causes of loss (n=27)

As shown in Figure 7.10, the primary causes of loss cited by intermediaries in the research area were poor roads, vehicle difficulties, lack of storage, and lack of markets. For instance, these issues are interconnected. Lack of market does not imply that the market is not physically present; instead, the issue is the market's capacity to absorb all the products supplied to the market without affecting the price and shelf life of the tomato. This might not have been lost if tomato factories were available to gather and transform these products into a form that may be preserved and enjoyed later. The National Bureau of Statistics (2016) reports that poor road conditions are Nigeria's leading cause of car breakdowns. It is common knowledge that most Nigerian roads are either in disrepair, poorly maintained or unpaved. Nigeria has the most significant road network in Africa, so, unsurprisingly, only approximately 60,000 kilometres of its estimated 195,000 road network are paved (National Bureau of Statistics, 2016). Most of the nation's road network was built between the 1980s and 1990s, and many have deteriorated due to inadequate maintenance. Even when new roads are built or maintained, they quickly deteriorate due to low-quality materials. Even though enormous annual budgetary expenditures have been committed to infrastructure development projects, it remains to be seen whether the state of the roads justifies these budgetary commitments. Even though the Federal Government should keep these roads in pristine condition, it will be observed that bandits and kidnappers can take advantage of the numerous potholes and poor surface conditions to slow down commuters. In addition, commuting on any trunk highways is typically marked by excessively

lengthy delays due to several issues, including road maintenance and accidents caused by poor road conditions. Figures 7.11 depicts the nature of some roads in the study area.

Figure 7.10: Unpaved Road in the study area

Author's photograph 2019

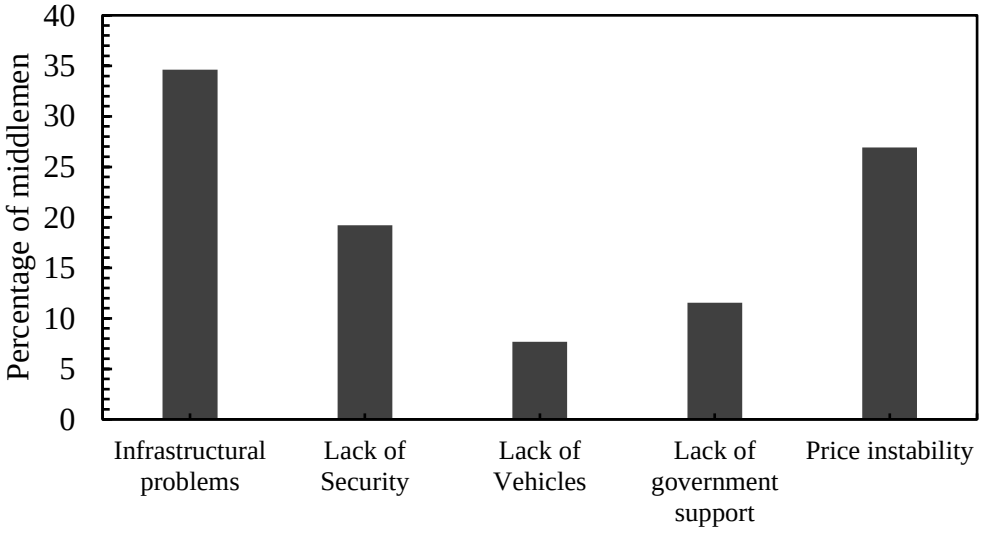

Figure 7.11: Challenges faced by intermediaries (n=27)

Marketing tomatoes requires transporting them from production to the site of consumption. Inaccessibility to markets has been a major obstacle for the tomato agricultural sector. The following are examples of the most significant obstacles to market penetration cited by respondents in the research area: 35% of respondents raised issues regarding infrastructure, including deteriorating roads, marketplaces, and supply chains. Twenty percent of respondents believed that the lack of security resulted in a decline in agricultural production in the studied area. Banditry and kidnapping are rising, making the roads unsafe for travellers and farms unsafe for farmers as respondents lament their fear of being unsafe, yet they must go out to make ends meet. Gadzama, *et al*. (2018) and Enyinnaya and Olomojobi (2022) also are of the same view of the level of insecurity in Kaduna state. Their findings uncovered that the impact of insecurity on socioeconomic growth in Kaduna showed that the security of lives and property of the people of Kaduna had deteriorated significantly in recent years, hurting both elites and the masses.

Businesses are collapsing, and closing, and parents are removing their children from schools and relocating to safer locations. No one is untouched, regardless of political standing. Tomatoes have been transported in inappropriate cars due to a lack of appropriate cold chain vehicles and a lack of enforcement by the government for the people to use appropriate vehicles to transport goods. The inappropriate vehicles used are evident in some of the images, as observed by the researcher. Intermediaries are not supported with bank loans, lack government subsidies for seeds and fertilizer, and lack control over the flow and supply of tomatoes within the local markets. This is a problem for them, particularly during times of seasonal glut.

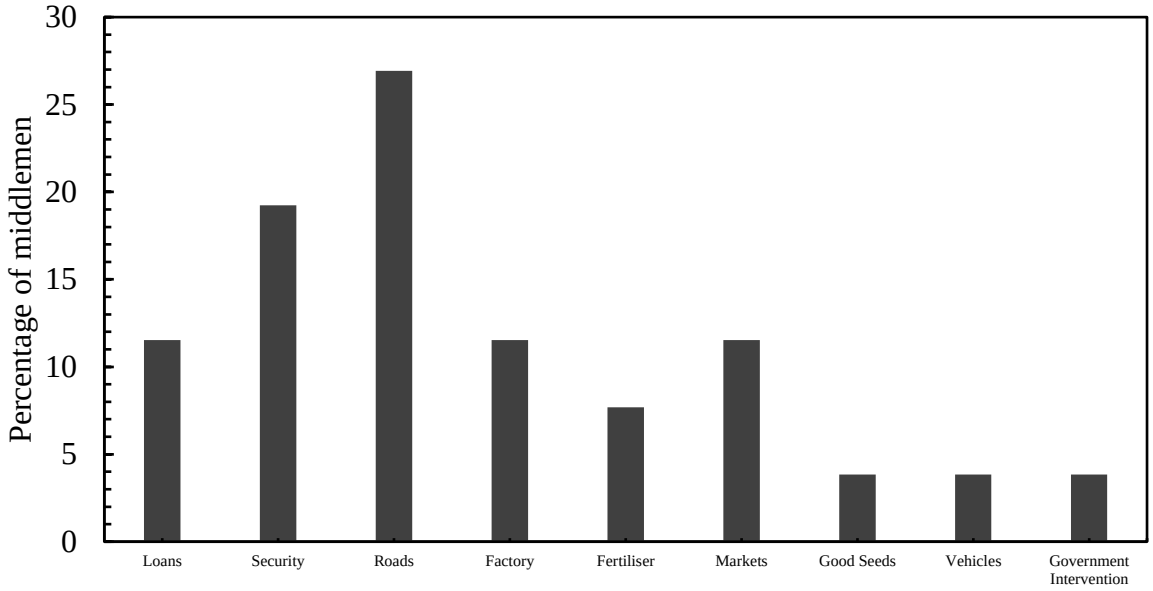

Figure 7.12: Government support required by intermediaries (n=27)

In the research area, respondents were asked what they want the government to do to minimise waste and losses in the tomato supply chain. 26% of them urged that the roads be repaired. They believe that repairing the roads will decrease the number of accidents and travel times. They lamented that poor road conditions cause car breakdowns and increase travel time. 19% of respondents believe that enhancing the area's security will inspire farmers and intermediaries who abandoned their businesses for this reason to return to their farmland and operations. Providing loans to intermediaries, tomato factories, and markets all had 11% of responders. If the government will build these storage facilities and tomato processing industries, they would have accommodated some of the tomatoes produced, particularly during the seasonal glut. These factories will minimise the number of tomatoes entering the market during the glut and stabilise the price of their products even when the supply is abundant. Good seeds, automobiles, and government intervention all had 3% of respondents. By government intervention, they say they want the government to regulate the activities of who supplies tomatoes at a given time, which markets they should supply to, and which farm these tomatoes should be collected from.

7.4 Lack of market infrastructure, congested and unhygienic marketplaces

Findings from observations during data collection show that the markets are in bad shape and lack drainage facilities and concrete floors, resulting in moody floors and floods during the rainy season, which constitutes potential health risks and problems. The poor market conditions and lack of drainage facilities highlighted in the observations could significantly impact the operations of intermediaries in the area. These challenges could make it difficult for intermediaries to transport, store, and sell tomatoes, affecting their ability to make profits and provide financing to farmers. For example, if the market floors are muddy and flooded during the rainy season, intermediaries may not find it easier to store and transport agricultural products without damage or spoilage. This could result in intermediaries having to pay higher costs for transportation and storage, which could reduce their overall profits. In addition, if the markets are not well-maintained, it could result in health risks and problems for intermediaries and other stakeholders who work in the markets.

The obstruction of the movement of vehicles into the markets due to traders turning existing road conditions into an open market could also be a challenge for intermediaries. Suppose vehicles are unable to access the markets. In that case, it could limit the amount of agricultural products that intermediaries can transport and sell, affecting their ability to meet market demand and generate profits. Intermediaries typically drive long distances to get tomatoes to the markets and need restrooms and designated parking areas within the collations markets or nearby to have some rest. However, these facilities are not available and they need such facilities within the areas of the market.

7.4.1 Price fluctuation

Tomatoes are harvested three times per year, although demand remains constant. As tomatoes are a perishable crop, the procedures for keeping them longer than five days are either unavailable or too expensive; hence, their prices fluctuate frequently, even daily. As noted earlier, the market price of fresh tomatoes fluctuates significantly between harvest and scarcity months. Seasonality is the primary cause of the fluctuation in the degree to which monthly prices deviate from the seasons. Intermediaries are less likely to reduce buying rates, and consumers are more likely to increase their consumption when costs are low. As a result, the scenario causes a rise in price until the forces of demand and supply are equalised.

7.4.2 High transport cost

The survey shows that 50% of respondents (intermediaries) cited the costs incurred during transportation as high, resulting in increased market prices of products. Quality control tax, LGA tax, and corrupt police officers' tax at numerous checkpoints contributed to the high cost of tomatoes, making the selling price higher than expected. At each tax station, the amount due was determined solely by whoever was working at the moment, including any security guards present. Many tomato transporters and truck drivers with empty trucks have declined jobs due to the high costs involved on the road. One respondent estimated he would require ₦67,000 ($286) to cover his travel costs from Kaduna to Lagos State, excluding money for fuel. To pay taxes to the Kaduna State Government alone would cost an additional ₦61,000 ($56). The intermediaries usually foot the bill for the production tax on the way to market, with the drivers covering the cost of tipping the police officers. According to one of the intermediaries, the driver planned to make a profit of ₦24,000 ($60) on the trip, but before they arrived at their destination, the driver had already spent ₦12,000 from his pocket. He observed that for this reason truck drivers do not want to transport tomatoes to other states unless they can make a substantial profit.

Taxpayers' money, intermediaries, and drivers were unhappy about this but still had to pay. They believed their money was going to the government, which refused to consider their needs, including improvements to transportation infrastructure like highways and processing plants. Findings from the research region reiterate those of Obetta, *et al*., (2020) in Enugu State about the transportation challenges faced by intermediaries.

7.4.3 Weather conditions

Various factors influence crop yields, but the three primary ones are climate and weather, pests and diseases, and soil and crop nutrition. Nevertheless, changes in environmental and biological pressures can complicate the impact of a single variable, such as a rise in temperature, on crop output. It has been demonstrated that the likelihood of degradation increases as transportation temperatures rise (Ogunsola, 2021). It is not easy for the plants to remain in good condition during their journey to the final consumers if they encounter excessive heat from the sun and the vehicle used for transporting them is unsuitable. Findings indicate a connection between the abovementioned characteristics and intermediaries' waste creation.

7.4.4 Bad transport vehicles

Good road transportation helps countries, businesses, and people in many ways. It can make it easier for goods and people to move around, create jobs, help the economy grow, improve access to education and health care, and connect people to their families and entertainment. Road transport is a crucial part of the economy so, the performance of the road transport system is vital for people's freedom of movement, business, the public good, and the economic growth and development of a country. Intermediaries in the study area complained about the poor nature of the roads and how it affects their business. There always appear to be Federal Road Safety Corps (F.R.S.C.) vehicles and police officers on the road to combat the danger of motorists overloading their vehicles. The same Nigerians who complain about poor road conditions also overload their vehicles without considering the damage to the vehicle and road.

A key obstacle hindering the success of the intermediaries in the tomato business in Kaduna is the lack of access to producing fields and markets. Many farms are located in inaccessible regions that lack modern transportation infrastructure, making it expensive and time-consuming to reach competitive markets. This research found that 90% of intermediaries in Kaduna were unhappy about the roads in the area. Tomatoes are complex, expensive, and time-consuming to transport due to the poor status of the road infrastructure that connects farms to distribution centres. On the other hand, the tomatoes will lose quality and value with each passing day between harvest and the final consumer.

7.5 Summary

The chapter describes the role of the intermediate in the tomato supply chain in Kaduna. The intermediaries in Kaduna have discovered various tomato farms in the surrounding area from which they purchase tomatoes and distribute them to Kaduna and its environs. Their vast knowledge has enabled them to recognise which farm is ready to harvest its tomatoes and which market should be supplied. This chapter examines the seasonal price volatility of tomatoes and how intermediaries perceive it. In times of scarcity, the price of tomatoes can double its typical price. Because consumers prefer Roman VF tomatoes above other varieties, intermediaries favour purchasing them over other types. The weekly and the daily number of baskets of intermediaries was also examined to determine the quantity of tomatoes they purchased and any potential waste or losses. Losses incurred by intermediaries may be anticipated or unanticipated and may be caused by poor roads, a lack of storage, vehicle difficulties, or a lack of a market.

The need for better security, price volatility, and a lack of government assistance are among the problems cited by intermediaries. They encourage the government to assist by repairing roads, providing security, constructing storage facilities, and offering loans and other government actions. To sustain tomato quality and shelf life in underdeveloped areas, intermediaries need to be knowledgeable about fundamental post-harvest procedures. Material handling processes like cleaning, pre-cooling, disinfecting, sorting, packaging, shipping, and storing must be carried out correctly to satisfy the consumer. More research is needed to consider the various places, crops, and factors that hinder losses in the tomato and other goods supply chains. Nevertheless, intermediaries are an essential part of getting fruits to market. The government must make it easy for businesses to do well and for growth to happen.

CHAPTER 8: The role of traders in the tomato supply chain in Kaduna state

8.1 Introduction

A trader is a person who buys and sells goods and services within or outside the market (Baldwin *et al*., 2020), either for themselves or another person or organisation. Traders in the study area were in three major categories. These include traders in market shops or stands with tables either inside or outside shops with benches for customers to sit on when they patronised them (Figure 8.2). The second kind is traders within roadside shops or shades. They are usually found by the roadside using an umbrella, zinc, or something as a source of shade to protect the tomato from direct contact with sunlight (Figure 8.3). The third kind is mobile traders. They were found selling from a wheelbarrow or using containers of different sizes to move tomatoes around to sell them (Figure 8.1). All three are dynamic in their activities. They have negative and positive impacts on one another. Just like the findings in this research, Shittu and Barua (2020) discovered that most tomato traders are of young adult age; they put all their time into selling tomatoes to make ends meet, as their immediate family depends on the business for their daily bread. The tomato trade industry is a critical aspect of the economy, and the different types of traders involved play specific roles in the industry's value chain. However, tomato traders face various challenges that affect their businesses profitability. For instance, shop traders face tax fees, transport costs, a lack of storage facilities, and price fluctuations peculiar to farmers and intermediaries (see 7.4). These challenges must be addressed to enhance the sustainability of the tomato trade industry in the study area.

Figure 8.1: A mobile tomato trader

Author's photograph. January 2019

The presence of mobile tomato sellers was noticed during the survey as they will approach you asking if you want to buy tomatoes. During the study, a group of mobile tomato traders said that as much as the tomatoes are not sold, they can trek up to 20 kilometres daily in search of consumers to buy their products. They are noted for having the most visually appealing tomatoes; they have time to wash and choose the large, hard tomatoes and position them in front of the wheelbarrow to attract consumers (Figure 8.1). Their tomatoes are less expensive than those sold by market traders because the traders do not rent shops or pay taxes. They enjoy roaming around looking for consumers to buy their tomatoes, and when they need to relax, they go to specific spots such as the market's entrance, exit, T junctions inside the market, and areas with a significant flow of people. They can sell to customers as few as five or ten tomatoes. They get few losses from their business as most of them buy what they can carry, which they sell quickly with a lot of persuasion and patience toward customers, especially when consumers keep negotiating lower prices. A few market shop traders requested the authorities to prohibit mobile tomato traders from conducting business in and around the markets because they stole their consumers. They promote congestion on the walkways in the markets by trading in every space they find, causing hazards on the footpaths for customers. They even accompany

consumers directly to the entrances of our shops, advertising the tomatoes we sell. Field diary notes detailing a conversation with a market trader illustrates these concerns:

> *A trader 7 in the market, is not happy about the daily number of mobile tomato traders she sees walking about in the market. She cannot afford to sell below the cost as she must pay shop rent and government tax, which they do not. She lamented, stating that "some of these mobile traders snatched my customers before my eyes." She went further, saying that the government must do something to stop these traders from doing business in the marketplace because they are sometimes forced to sell below the cost prices to avoid a lack of sales which will result in tomatoes getting bad. These mobile traders cause more harm than good, she said they stop on pedestrian paths to sell, blocking customers on the route, and on busy days they make the market so congested unnecessarily (Market trader 7).*

Figure 8.2: A market tomato trader
Author's photography January 2019

Traders in the marketplace showed interest in the research as their first impression was that we were government agents that had come to hear their problems. The study ensured that before we interacted with any respondent, they were told the purpose of our work. As observed during

the survey, the Kaduna state government has embarked on a new urban renewal programme with plans to rebuild and renovate some infrastructure in the state. This includes roads, marketplaces, car parks, bus stations, hospitals, and schools. This project had only recently started, but information from respondents indicated that all the major markets in the state capital and some critical local government areas will be demolished and rebuilt and then either sold or rented back to the people. The programme has been a significant concern for small-scale tomato traders in the state; many of whom have been in the tomato-selling business for 20-30 years and fear losing their shop or trading spot where their customers meet them. They also fear that, when these markets are rebuilt, they may be unable to pay the price to rent or purchase a space or shop.

Traders in the markets were optimistic about the daily flow of their customers, as most of the respondents know their customers and what they like. Knowing their customers helps them to decide on the number of tomato baskets to buy in a day. That gives them an edge over buying too much and suffering waste or loss as indicted in these field diary extracts:

> *"Trader 6 a tomato trader, said many of his customers like fresh and nice-looking tomatoes; they must buy matured red tomatoes. These tomatoes must be sold that same day, or you stand a chance of getting bad, due to harsh weather conditions or the maturity of tomatoes due to their short life span" (Trader 6).*

Figure 8.3: A roadside tomato trader

Author's photograph. January 2019

The tomatoes for sale on the side of the road were protected from the elements by wooden huts to keep them fresher for longer (as seen in figure 3). Tomatoes were exclusively available at roadside stalls in baskets that could hold 65 kg, 10 kg, 5 kg, or less. The bulk of traders obtain their tomatoes from nearby tomato collection markets. When merchants visited markets, they purchased fruits from intermediaries at varying costs, depending on the distance they travelled and their skill at haggling. The price of tomatoes in the market fluctuated based on the variety and availability of the product. These rates vary based on peak and off-peak seasons.

8.2 Findings from trader's survey

Table 8.1: Socioeconomic characteristics of tomato traders in Kaduna state

Variable	Categories	Number of participants	%
Zonal area	North	3	7%
	Central	32	71%
	South	10	22%
Gender	Female	17	38%
	Male	28	62%
Age group	18-29	11	24%
	30-39	9	20%
	40-49	16	36%
	50-59	7	16%
	60 and above	2	4%
Marital status	Married	30	67%
	Single	8	18%
	Widow/Widower	7	16%
Level of education	Arabic education	2	4%
	Non-formal education	8	18%
	Primary	4	9%
	Secondary	25	56%
	Tertiary	2	4%
	Adult education	4	9%

The findings from the trader's survey presented in table 8.1 provide a comprehensive overview of the socioeconomic characteristics of tomato traders in Kaduna state. Understanding the demographics of traders is crucial for policymakers and stakeholders to design appropriate policies and interventions to support traders in their business activities. The study found that most tomato traders operate in the central zone of Kaduna cities with major transportation hubs, making it easier for traders to transport their goods to other parts of the state. The low number of traders in the northern zone may be because this region is predominantly rural and needs more access to transportation infrastructure. The gender distribution of traders shows that male traders outnumber female traders. This may be due to cultural and societal norms discouraging women from engaging in trade activities. Gender disparities in access to education and financial resources may also contribute to this gender imbalance in the trading sector.

The age distribution of traders indicates that most traders fall within the 40-49 age group, followed by the 18-29 age group. This suggests that tomato trading is a popular economic activity among middle-aged individuals, who may have acquired sufficient experience and knowledge in the trade. However, the low number of traders above 60 may indicate a need for interventions that support the elderly in trade and financial resources. The marital status of traders shows that most traders are married, which may indicate that tomato trading is a means of livelihood for families. The low number of single traders may indicate a need for interventions that encourage young people to engage in the trade. The education level of traders suggests that most traders have a secondary education. However, the low number of traders with tertiary education may indicate a need for interventions that provide traders with access to higher education and specialized training in the trade.

The trader's survey findings provide valuable insights into the socioeconomic characteristics of tomato traders in Kaduna state. Policymakers and stakeholders can use these findings to design policies and interventions that support traders in their business activities, especially regarding access to financial resources, education, and healthcare.

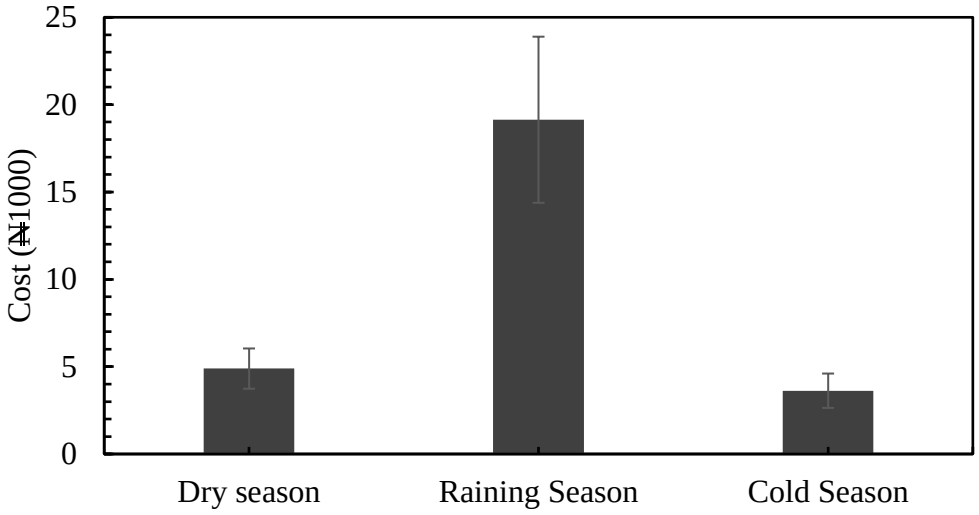

Figure 8.4: The price of tomatoes per season over a year

The survey on the cost of tomatoes in Kaduna as shown in figure 8.4 (with the mean and standard deviation) reveals that prices vary across seasons. The dry season prices range from N4,000 to N7,000, while cold season prices range from N3,000 to N5,000. On the other hand, the rainy season increases tomato prices due to product scarcity, making it difficult for local traders to secure a steady supply at reasonable prices. Traders attribute the price difference to various factors, including the variety mainly produced during a particular season, the quantity and quality of tomatoes in the markets at the time, the seasonal glut, the level of market saturation, and the demand and demand-supply flow. Intermediaries prefer to supply tomatoes to the southern part of the country during the rainy season because they can get more money, contributing to the scarcity of tomatoes in the area where they are produced.

The high cost of purchasing tomatoes during the rainy season could lead to lower profit margins or losses for local traders, who may have to compete with traders from the southern part of the country willing to pay more for tomatoes. This competition could make it even harder for local traders to secure a steady supply of tomatoes at reasonable prices. The survey highlights the importance of understanding the factors contributing to the price fluctuations of tomatoes in Kaduna. It emphasizes the need for local traders to explore alternative ways of sourcing tomatoes during the rainy season to avoid increasing the prices of their products and the resulting lower demand from customers. This survey observed that a big basket of tomatoes, about 65-70 kg, can cost as much as ₦25,000 and the lowest cost in this period was ₦15,000 (prices are discussed in detail in 7.4.1).

8.2.1 Security in the survey area

More recently, the scarcity of tomatoes has been attributed to insecurity within the northern region. This includes armed robbery, banditry, and kidnapping. This is one of the reasons the researcher always travelled with others when going out for a survey. According to traders, tomato prices have historically increased annually. However, this year's rise was attributed to the End SARS demonstration, terror, and the COVID-19 lockdown. Even though it was November, they were surprised that the pricing remained high. They requested that the government construct storage facilities for perishable goods to keep prices steady and always available. Some other reasonable issues identified by Ogele (2021), are getting the right tools and logistics to improve the value chain. Fresh tomatoes sold in department stores should be better packed in boxes.

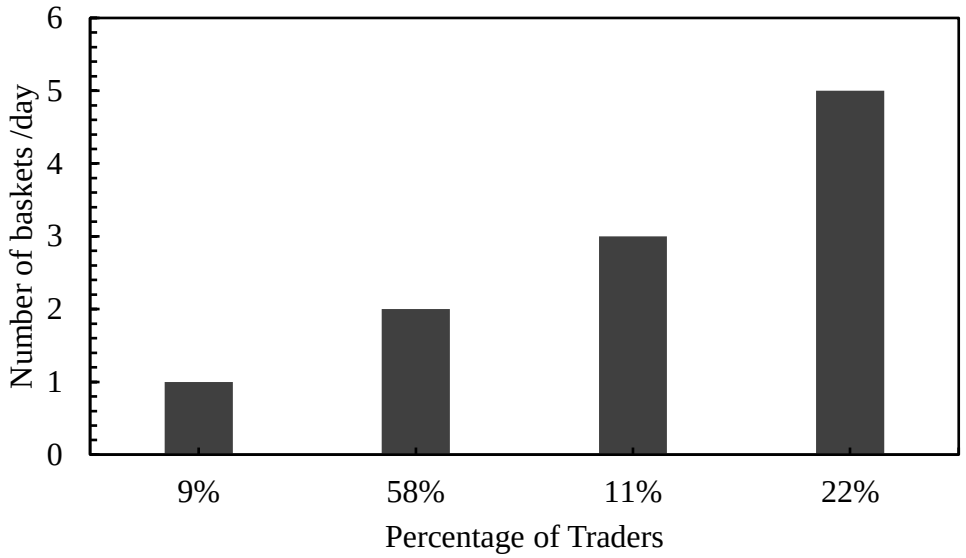

Figure 8.5: Number of baskets traders buy on a typical day (n=45)

8.2.2 Daily tomato sale

Since nearly everyone consumes tomatoes, growing and selling them can be a tremendously lucrative business. During the survey at the central market of Kaduna, traders were selling one to five 64kg baskets of tomatoes daily. They said they sell up to six baskets when the market is thriving. Furthermore, they sell at least two 64kg baskets of tomatoes when the market is weak. The survey indicates that 22% of traders in the study area buy and sell as many as five baskets of tomatoes (64kg). Only 9% of traders buy and sell one basket per day. The traders said that they make more profit when they sell tiny bits of 10kg or less to consumers. They

have customers who usually purchase as little as 5kg or less daily. 58% of traders buy two baskets of tomatoes to sell, while 11% of traders can buy as many as three baskets daily.

> *Trader 2, said those customers who buy large quantities of tomatoes only visit the market a few times a month. He said those people make him happy because he will make more profit and sometimes go home early or go on a second round of selling tomatoes. He stated that he gets more profit during the tomato glut because the tomato baskets sell at a lower cost (Trader 2).*

Figure 8.6: Number of days traders buy tomatoes in a typical week (n=45)

Tomato traders were always seen within the market daily within the survey area and markets are held on different days in different places as indicated in this field diary extract:

> *Markets days are days set aside for each town within an area where people from different places come together with their goods for buying and selling. The days are organized weekly, fort nightly, or otherwise. This is a tradition in towns around the nation and the market council of the area in question usually states market days. Although, the market days idea has evolved, most markets, especially those in cities, are now open throughout the week. Alhaji Shehu, a tomato trader who goes to the market seven days a week, said he enjoys going to the market daily since he visits different marketplaces daily. He calls these markets in the study region on their market days, and on these days, he makes more profit (field diary).*

Visits were made to different markets in the area to obtain the data in Figure 8.6. Only 9% of traders sold tomatoes seven days a week, while 4% trade two days a week, 13% four times a week, 33% five times weekly and 36% six days a week.

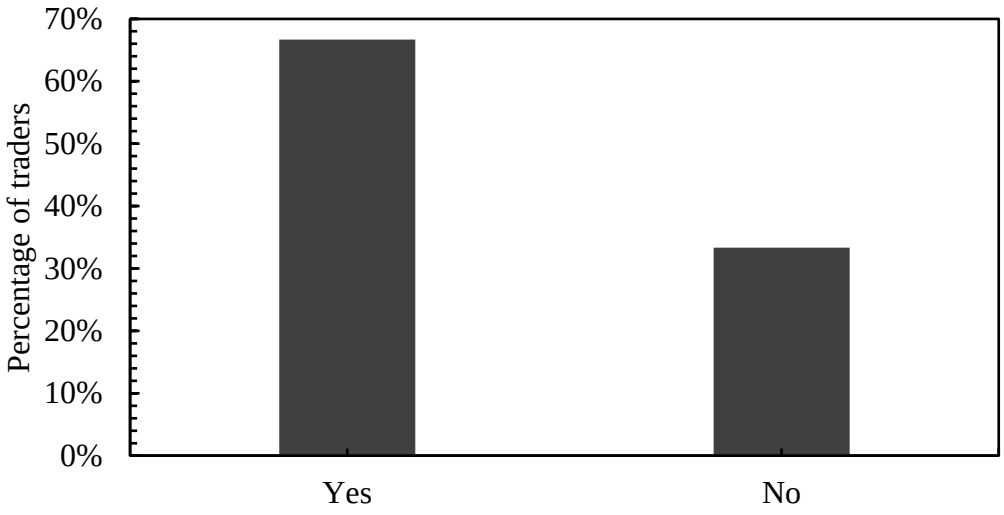

Figure 8.7; Losses and waste encountered by traders (n=45)

8.2.3 Markets post-harvest losses

When traders were questioned about their seasonal losses, 33% claimed not to have any losses while 67% mentioned encountering tomato loss or waste (Figure 8.7). Of these, 60% claimed losses between 5-10%, 4% lost between 10-20%, and 2% lost between 21-30% of their daily tomato purchases (Figure 8.8). Many respondents stated that these losses are sometimes unavoidable and can be caused by the basket used to transport the goods, overripe tomatoes or mechanical damage. Traders often discover bruises and rotting tomatoes in the base of the basket. Unsold tomatoes create problems for traders because they lack adequate storage facilities. Tomatoes usually only last for around 4 days but this may be less if they are in poor shape when purchased or have been subjected to hot weather and poor handling. Extracts from the field diary illustrate one trader's experiences of and solutions for spoiled or poor quality tomatoes:

> *Trader 3, market tomato trader, has been in the business for about 13 years. According to her, she goes to tomato collation markets five times a week to buy three 65 kg baskets of tomatoes, and she only gets losses some of the time. Some days, she gets losses, but only a few are typically found at the base of the tomato*

basket. When she gets unattractive tomato, she takes some home and gives some to beggars on the streets (Trader 3).

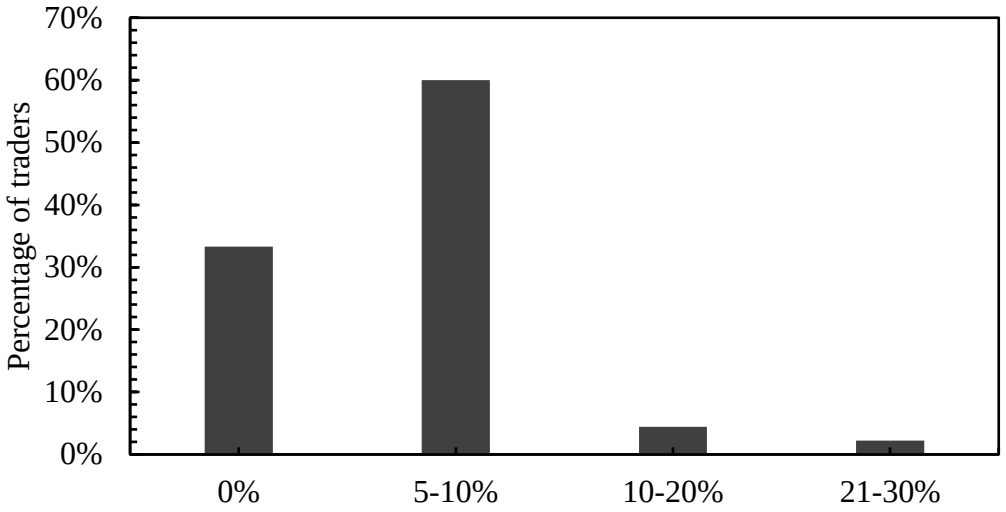

Figure 8.8: Amount of losses/waste generation (n=45)

Traders purchase quality tomatoes to minimize losses because they are less likely to spoil quickly and more likely to be in customer demand. However, even with quality tomatoes, there is still a risk of spoilage due to factors such as poor handling during transportation or storage. To reduce this risk, traders must clean and sort the tomatoes properly before selling them. Cleaning the tomatoes removes any dirt, debris, or contaminants that may be present on the surface of the fruit. Sorting the tomatoes helps identify any damaged, bruised, or overripe, which can then be removed to prevent them from spoiling the other tomatoes. By cleaning and sorting the tomatoes, traders can ensure that they offer their customers high-quality products that are less likely to spoil, reducing their losses and increasing their profit. Echoing research by Gemeda *et al*., (2023), traders of tomatoes asserted an understanding of food safety, hygiene, and the risks of uncooked tomatoes. However, tomato traders' primary concern regarding vegetables' safety was soil contamination.

8.2.4 Bad tomatoes

Figure 8.9 below shows that 23% of traders have complained that the tomatoes they were given were terrible, especially the ones at the bottom of the basket. One possible reason for the poor quality of tomatoes at the bottom of the basket is that they were crushed or damaged during transportation. Another possible cause of poor-quality tomatoes is improper storage. Tomatoes

are sensitive to temperature changes and can spoil quickly if not stored properly. If the tomatoes are stored in a warm or humid environment, they are more likely to spoil quickly, leading to poor-quality produce. Moreover, the issue of poor-quality tomatoes could also be attributed to poor harvesting practices (as further discussed in 6.7.1). Findings in this study bear some similarities to research by Nofiu *et al*., (2021) and Ugonna *et al*., (2015). Both suggest that traders buy red tomatoes, which is what this research shows. Traders must buy red, ripe tomatoes to get people to buy their goods. The amount of tomatoes sold affects both the price and the supply.

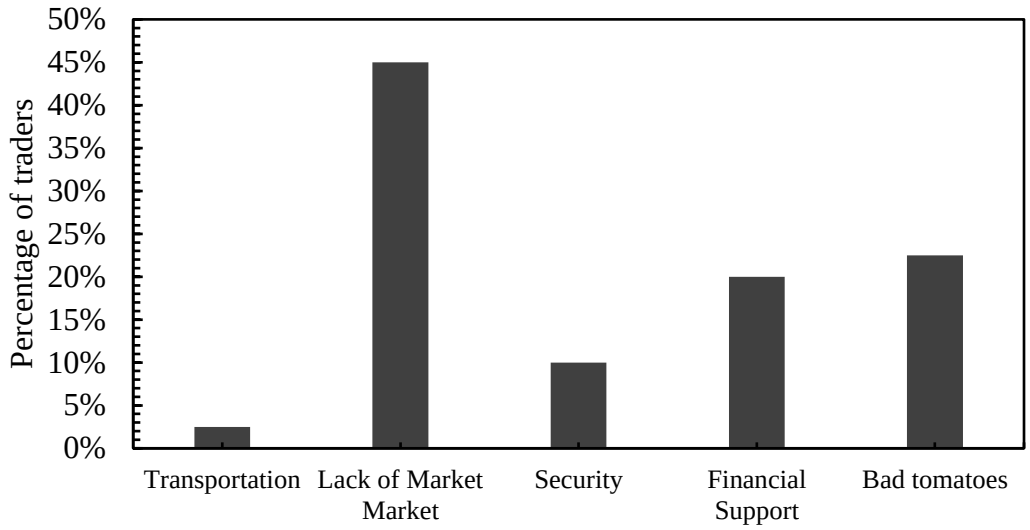

Figure 8.9: Challenges faced by the tomato traders (n=45)

8.3 Transport and packaging

Most traders in the research area only drive short distances to get tomatoes, and only 3% of dealers cited transportation as a challenge. Usually, traders acquire commodities from their suppliers (intermediaries) or go a short distance to the closest tomato wholesale market to purchase them. The traders operate in areas with a high concentration of tomato farmers, allowing them to access a local supply of fresh produce quickly. Most traders have established relationships with reliable suppliers who can deliver the tomatoes to them. Furthermore, only 3% of dealers cited transportation as a challenge could indicate that there are efficient transportation networks in place, such as well-maintained roads or reliable transportation services, that allow traders to move their goods efficiently within the city and the distance they travel to purchase tomatoes. Depending on the season and the quantity of tomatoes being supplied, the intermediaries utilized a variety of vehicles to transport tomatoes to the traders.

Most of the farm-gated produce is packed and transported in wooden baskets. During the survey, a group of traders showed the research team where they kept the plastic boxes provided to them in the past that they no longer use. Plastic crates have significant implications for both traders and customers. Firstly, they increase the cost of tomatoes and create challenges in storage and transportation. Traders face several challenges when using plastic crates, such as the need to pay for the crates when purchasing tomatoes, limited storage and transportation due to the crates' size and shape, and the intermediaries' refusal to lend them the crates, forcing traders to purchase them. On the other hand, customers also need help purchasing large quantities of tomatoes. They must buy multiple plastic crates to transport the tomatoes, requiring more vehicle space and challenging carrying the tomatoes. Additionally, traders' use of plastic bags to sell to customers creates an inconvenience for customers buying more than 30 kg of tomatoes.

The implications of plastic crates and bags are significant for traders and customers. Traders may charge higher prices to cover the additional costs of using plastic crates, which could discourage customers from buying the products and lead to declining sales. Furthermore, the use of plastic bags creates an inconvenience for customers, particularly those buying large quantities of tomatoes. So, the plastic crates were rejected despite the fact that the smooth inside of nestable plastic crates keeps tomatoes from getting damaged while moving or handling. The sharp edges and other flaws in the raffia baskets were to blame for the high amount of tomato damage. Furthermore, they said many of the losses in the supply chain from the collection centre to the consumer are caused by damage to packaged tomatoes while in transit. Traditional raffia baskets and also plastic crates were used to pack tomatoes for road transport from Kano state to Lagos. When moving tomatoes from the north to the south of Nigeria in raffia baskets, mechanical damage was estimated to be an average of 41.12%. Plastic crates reduced this high level of damage during shipping to an average of 4.92 %.

The last thing these traders worried about was transportation. Only 15% of those who answered the survey wanted the government to solve the transportation problem (Figure 8.10). Many traders walk a short distance from the market to their shops or other places where they sell their goods. Even though the price of tomatoes is affected by how much it costs to ship them, traders say this only affects the consumer. These findings echo those of Coste (2014) and Akujor *et al*. (2022) but contrast with the findings of Mani *et al*. (2018), who saw the price of the tomato fluctuating because of the product’s availability.

8.4 Market-based challenges

Market traders elect a group of individuals to manage and oversee the markets on their behalf; this group is known as the market council for that market. The members of these market committees face significant challenges, as observed during the survey. They cannot effectively manage the few existing facilities in the markets, let alone the essential anticipated facilities, utilities, and amenities proposed for these areas. In-depth interviews with market council members showed they were not overseeing basic amenities like trash cans, cleaning market surroundings, and monitoring parking spaces and public restrooms. Nevertheless, council members have been quite effective in improving the social welfare of local market traders who need financial and in-kind assistance. According to the survey results, 45% of the traders identified problems with the market that act as constraints to their tomato business. Many lacked access to essential utilities such as piped water, available organized parking spaces, and toilets in the markets. They are forced to buy sachet water from traders selling in the marketplace to keep their tomatoes clean.

All the marketplaces that the researchers visited had a market union with a leader. Traders typically select these leaders. They serve for between one and three years, during which they attempt to maintain market stability. The market union leaders are also responsible for the market's growth and ensuring that it has the necessary infrastructure and services. They are also responsible for collecting taxes and fees from market sellers and sending them to the local or state government. The heads of market unions and market organisations collaborate closely to accomplish these objectives. Market organisations, such as the tomato traders' association and other associations, are comprised of individuals who sell or supply commodities or services. Leaders of market associations establish prices and assist traders of comparable goods and services in getting along.

Regular washing is necessitated by the dust created by the high volume of people in the market and the tendency of potential buyers to feel the tomatoes before purchase. In addition, the presence of free-roaming animals at the market and live chickens sold close to tomatoes and other vegetables act as a source of microbial contamination for foodborne pathogens. Most of the study's participants had heard of people getting sick after eating raw tomatoes from contamination caused by salmonella so they washed their tomatoes regularly to keep them looking them fresh and clean. As traders work long hours at markets, they would benefit significantly from improved access to things like storage, electricity, clean water and

bathrooms. Occasionally, due to the lack of structured parking space at the marketplaces, some buyers would park their automobiles in spots that made it impossible for other vehicles to pass once they returned after their transactions. This occurs because traffic management in the markets needs to be improved.

The researcher observed that all the marketplaces visited were in poor condition and required repair. Many of them have never been renovated previously. It was encouraging to learn that the Kaduna state government has begun a campaign to improve the cities. Within this programme's scope, several urban and suburban markets were to be redeveloped. They will achieve this with the Market Development and Management Company (KMDMC) (Koko, 2018). They will collaborate with private investors to construct and renovate some markets and business hubs throughout the state. During the survey, the researcher witnessed the demolition of some markets and interacted with some government contractors confirming the findings of (Koko, 2018), who said these market developments would occur as soon as possible. However, not all traders think this is a good idea, particularly those at the Kasuwan barchi market. This group of traders got a court ruling against the state government for demolishing their stores at the Kasuwan barchi market in the Tudun Wada neighbourhood of Kaduna. During our survey, we were granted an interview with the leaders of this Kasuwan barchi market. He said they are pleased with the new development, but it must be executed more effectively.

Among their complaints against the government is the absence of appropriate documents for store owners. They fear losing their shops, and some argue about their store's size and location and ask how large the stores will be when reconstructed? One trader stated that temporary commercial space has yet to be provided while the market is reconstructed. Moreover, they were not given a timeline of how long the rehabilitation would last, or any guarantees that all traders would receive their shops back, or information on the rates at which the shops would be sold or rented.

8.4.1 Security

During the field survey, 10% of respondents showed concerns over the security provided in the market. We talked to some traders and found that some have tried to improve how the markets are run. For example, some shop owners hired security guards to monitor their stores at night. The presence of security guards can help deter criminal activities such as theft, vandalism, and burglary. They also hired people to clean up around their shops and put solid waste in the trash

cans that are available in the markets. This measure can reduce the chances of accidents or health hazards that could occur due to unclean environments. Some people saw a need for solar security lights inside the markets and dug boreholes to get water to sell. Installing solar security lights can provide adequate lighting and help deter criminal activities during the night. At the same time, market interactions and trading relationships between groups that might otherwise be at odds with each other also help bring them together. People from different sides of a dispute may need to work together to keep their jobs. From the perspective of market traders, it would be helpful for policymakers to know more about trade-related conflicts and the need to give poor people better access to markets.

8.4.2 Financial support

Most traders who participated in this study are educated and open to growing their businesses. The lack of money was felt to be a serious obstacle to achieving this by 20% of respondents. According to the sampled traders, funding from the government and commercial banks was insufficient to allow them to carry out their plans. There was never enough to go around for everyone. Most of the time, traders struggled to repay their debts as commercial banks no longer lend to them without collateral because of previously low levels of loan repayment. Traders also lamented the lengthy procedure before a client can access loans which requires one to travel a considerable distance and visit the bank several times. Figure 8.10 demonstrates that 41% of traders believe they will receive a loan from the government, despite having a cooperative society in charge of disbursing loans to traders. A field diary extract indicates why traders may prefer government loans:

> *Mr trader 4 claims that because government loans are typically higher than those from local cooperatives, traders choose to obtain them. He also emphasised how he had benefited from the government's good act. Those traders who previously received loans from the government but could not repay them had their debts pardoned (Mr trader4).*

The local cooperative loans are generated from the traders in the area, so when a loan is taken from them, there is no chance of the trader being forgiven if they can’t pay it back.

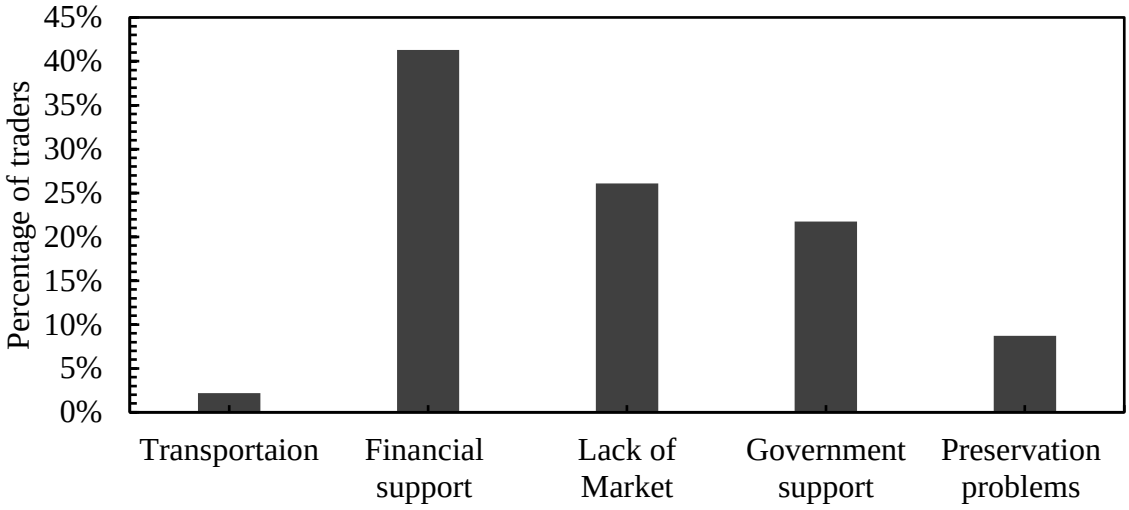

Figure 8.10: Government help required by traders (n=45)

8.4.3 Government support and preservation problems

The 22% of traders who want government to support their business and 9% of traders who have preservation problems were alluding to a list of requests to the government for assistance. A change in government policy is sought with the hope that it will affect the entire value chain of tomatoes. To get people to use locally grown tomatoes, they need the government to ban the importation of tomato paste. To sell perishable commodities, the markets require cold storage facilities. They requested that the government improve training on the planning of tomatoes, provide certification processes to uphold standards, and set up suitable marketing structures. Additionally, fresh tomatoes should be better wrapped in upgraded boxes for sale in department shops and transformed into well-packaged and professionally managed items for storage and processing. Obtaining the necessary tools and logistics to enhance the value chain presents the most significant difficulty.

8.5 Summary

The capacity to trace commodities within national borders can help shed light on inefficiencies and difficulties in global supply networks. Kaduna state has a severe problem with tomato loss. It is also important to note that fruit is perishable and spoils quickly. The rate at which it is consumed makes the market active and lucrative for traders. Traders in the study area suggested that the active supply chain of tomatoes needs to be improved and made more efficient due to the absence of a cold supply chain, which is vital to the supply of tomatoes. During the seasonal glut, it is challenging to sell tomatoes because people may only purchase the quantity they need. This tomato goes to waste yearly due to a need for more processing facilities and storage

space. This issue should be resolved as quickly as possible. These suggestions parallel those of Arah *et al.* (2015) and Ugonna *et al.* (2015) who argue that Nigeria should not be importing tomato paste because it is the second-largest tomato producer in Africa. When they cannot sell, traders cannot earn a substantial profit. There are situations where sellers lose more than fifty per cent of their purchase because the tomatoes they sell need to be more attractive.

The lack of political will to build alternate methods to preserve tomatoes was identified as the most significant concern by respondents, emphasising the importance of active post-harvest procedures. Traders are the final link in the supply chain that leads to the consumer, so it is essential that the food produced reaches consumers in good condition. The private sector needs to conduct post-harvest loss management schemes with government backing. More research is required to account for the diversity of geographical locations. Nigeria's agricultural sector needs more funding, particularly for research and development. Post-harvest losses are hard to deal with because there needs to be more information about agriculture. There needs to be more research on post-harvest losses in different value chains, especially with tomatoes.

CHAPTER 9: Consumer in the supply chain

9.1 Introduction

Tomatoes are goods that are widely utilised in daily life, both at home and in the workplace. In addition, tomatoes are essential to satisfy the vitamin and mineral requirements of the human body (see 5.2). Tomato products have a unique flavour and qualities not present in other food items. Tomatoes undergo lengthy processes before reaching customers and becoming consumable. The objective of the tomato's planting, sorting, harvesting, collecting, packaging, grading, distribution, and transportation is to satisfy the consumer. These stages may result in losses owing to mechanical and physiological damage caused by incorrect handling and treatment, followed by waste generated from the farm, on transit, even after it gets to the consumer's table. The consumer concludes the supply chain as they purchase a good or service for their own use. However, when the tomato eventually gets to the consumer, he or she has a choice of consuming or wasting the product.

9.2 Findings from consumer survey

Although data collection for all stakeholders was being done almost concurrently, the consumer survey started in February 2020, just before the covid 19 pandemic began. The survey was conducted face-to-face, and covid 19 restrictions did not allow face-to-face contact at the time. As such, consumer data collection had to halt. This resulted in a notable decrease in the proportion of consumer respondents the research intended to cover.

Table 9.1: Socioeconomic characteristics of tomato consumers in Kaduna state

Variable	Categories	Number of participants	%
Zonal area	North	7	18%
	Central	23	61%
	South	8	21%
Gender	Female	29	76%
	Male	9	24%
Age group	18-29	16	42%
	30-39	11	29%
	40-49	8	21%
	50-59	2	5%
	60 and above	1	3%
Marital status	Married	19	50%
	Single	14	37%
	Widow/Widower	4	11%
	Engaged	1	3%
Level of education	Non-formal education	3	8%
	Primary	4	11%
	Secondary	8	21%
	Tertiary	23	61%

Table 9.1 above illustrates that most sampled consumers were based within the Kaduna metropolis due to covid 19 related mobility restrictions. Cheaper tomatoes are available in the Kaduna metropolis and other local government areas within Kaduna state compared to other parts of the country due to farmers' fear of spoilage, seasonal gluts, and lack of suitable storage facilities (Mani *et al.,* 2018). The survey was a convenience one collecting information from respondents, during which we came across an anonymous respondent who had been operating her local restaurant for more than ten years.

> *"I use tomatoes in almost every meal I prepare to sell to my customers, and it seems they cannot get enough of it. Seeing the satisfied looks on their faces when they take their first bite is one of the most rewarding feelings as a cook. It is not just about*

the taste - tomatoes are also incredibly versatile. They add a burst of colour and flavour to any dish. I can use them in stews, sauces, salads, and garnish. After I lost my husband. I have been relying on the earnings from my restaurant (mama put) to take care of my household and pay for my children's school fees. It is not easy to be a single mother, but cooking has always been my passion, and I am grateful that it is also my source of income. Using tomatoes in my cooking may seem small, but every ingredient counts. The attention to detail and the love I put into my food keep my customers coming back. And knowing that my cooking helps support my family keeps me going" (Restaurant owner 1).

As indicated in Table 9.1, 76.3% of the respondents are females. Females are highly concerned with food safety issues. This is not surprising, as females do most cooking. Similarly, while it may be true that females cook most in some households, this is not always the case and can vary by cultural and familial traditions. The age group of sampled respondents between 18 to 29 years is 42%, indicating that most respondents are young. The age group alone does not provide sufficient information to make this assumption. Additionally, the fact that the age group of sampled respondents is primarily young does not necessarily mean that they can all share relevant experiences related to tomato issues, causes of losses, and hidden challenges faced in their homes and restaurants. The marital status of respondents stood at 50% married and 37% single, with some of the single respondents still living with their parents. Widow/Widowers were 11%, and engaged respondents stood at 3%. 55.3% are well educated to the levels of tertiary education; only 7.9% had no formal education but related well to the questions asked. The survey questions were clear and unbiased, and all respondents understood the questions and were able to provide accurate responses. Some respondents may have misunderstood or misinterpreted the questions, which could affect the accuracy of the survey results.

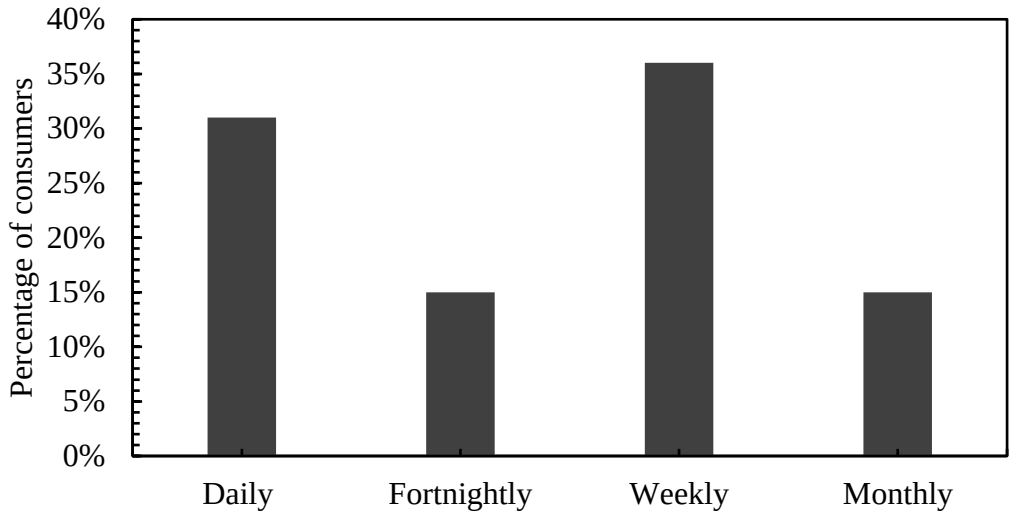

Figure 9.1: Response on how often consumers buy tomatoes (n=38)

According to a survey, the most common method of purchasing tomatoes among consumers is weekly, as 36% of the respondents say they do. Purchasing tomatoes weekly offers several advantages. It enables cost savings as buying in larger quantities often results in a better price per unit than buying smaller amounts more frequently. This translates to savings on grocery bills in the long run. Buying tomatoes weekly helps in reducing food waste. By planning meals, one can avoid buying more than what is needed, leading to a reduction in spoiled or unused produce and consequent savings. It reduces the need to make frequent trips to the grocery store, saving time and money. Proper storage in a cool, dry place or refrigerator can extend their shelf life. Lastly, buying tomatoes weekly contributes to sustainability. It reduces the amount of packaging and transportation required for frequent trips to the store, thereby minimizing the carbon footprint and promoting a healthier planet.

Furthermore, during interactions with the researcher, some 31% of respondents mentioned buying tomatoes daily because they cannot afford to buy them monthly or weekly. Due to factors already identified in chapter 6, tomatoes can be expensive in some regions or at certain times of the year as discussed in 7.41. Respondents may need more money to buy tomatoes weekly because their income is too low. They said: "we do not have a steady electricity supply, so we can only buy what we can consume on the same day". This echoes the research of Sambo *et al*. (2016), who identified a lack of infrastructure development as a problem for perishable agricultural produce in Kaduna state.

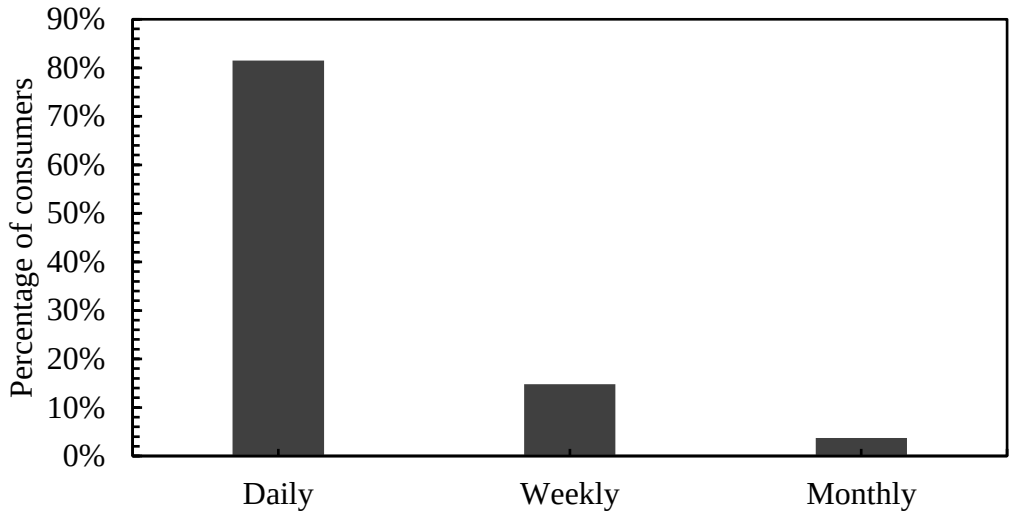

Figure 9.2: Response on how often consumers plan their meals (n=38)

Meal planning helps enhance time management. According to the survey, 81% of respondents plan their meals daily, 15% have a weekly meal plan, and 4% have a monthly meal plan. Meal planning is an effective way to reduce tomato waste.

> *Consumer 1: "In the past, I have discarded tomatoes that had gone bad because I bought too many and needed to use them in time. However, since I started planning my meals, I have noticed a significant waste reduction. Planning meals helps me become more organized and less likely to acquire unnecessary foods impulsively. This has also helped me cut spending, save money, energy, and time, and become more aware of my food expenses. Meal planning also ensures that I have fresh tomatoes on hand when I need them. Buying and storing them weekly extends their shelf life, saving me money and ensuring that I always have fresh produce for my meals".*

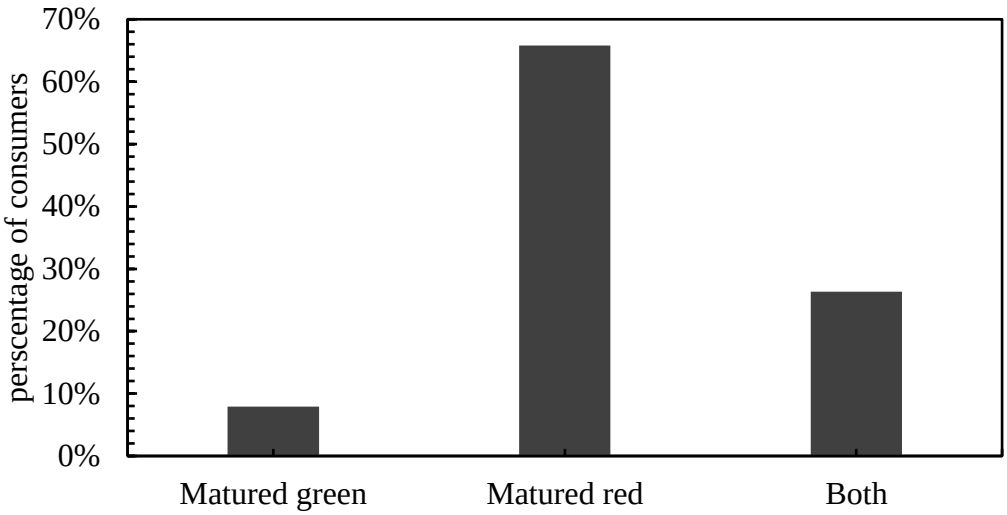

Figure 9.3: Response on how mature the tomato are that consumers buy (n=38)

Visual appearance, dry matter content, organoleptic chemicals, texture and hardness, and health-influencing components are commonly considered to contribute to the quality of tomato fruit (Verheul *et al*., 2015). Most participants utilised fresh tomatoes in dishes such as Jollof rice, stew soup, and other home-cooked meals. The respondents utilised both fresh and processed tomatoes although 66% preferred to buy mature red tomatoes. Almost all said that they liked the idea of freshness and healthiness associated with fresh tomatoes and viewed the purchase of fresh tomatoes as a pleasurable experience that would improve their quality of life. A few participants disliked tomatoes that were pre-packaged on foam trays as they felt that it was vital for them to be able to handle and examine the tomato before making a purchase. Most participants opted for fresh tomatoes over canned tomatoes. Some consumers viewed tomatoes on the vine as an indicator of freshness. More than half stated they felt more comfortable purchasing fresh tomatoes with unique colours and shapes because they could speak with the farmers and taste samples before purchase. Despite this, only a few respondents were willing to purchase conventional varieties of tomatoes in the supermarket, such as round and Roma. This reluctance could be due to a perceived lack of freshness or concerns about the quality of products sold in supermarkets.

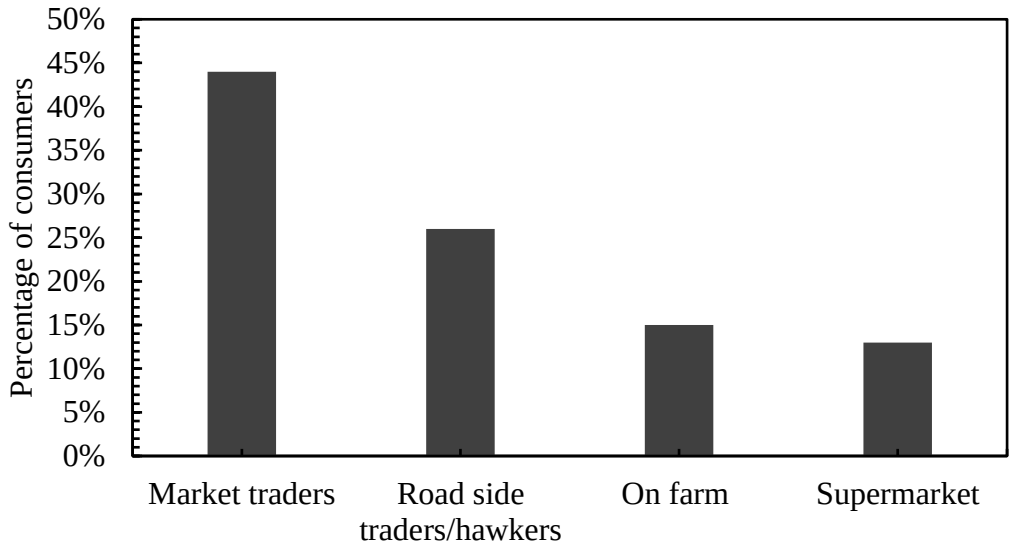

Figure 9.4: Consumer response on the source of tomato purchased (n=38)

Some participants prefer to get their tomatoes within walking distance of their houses, with 26% of respondents buying them from roadside traders or hawkers. 44% buy them from the market, which they feel is safer because they trust the source that their market traders buy from. However, the markets may offer a limited range of tomato varieties, and the quality of the tomatoes available may be subpar. As a result, the prices of the available tomatoes may be higher than what consumers are willing to pay. Moreover, particularly humid conditions can reduce production during the rainy season. This can lead to a seasonal scarcity of tomatoes, which can further drive-up prices. A seasonal shortage of high-quality tomatoes affects poor urban people more severely at this time of year.

> *Consumer 2: "I buy my tomatoes in the market because I will see plenty of them there, and most times, it is cheaper to buy from the market, especially when I have a customer who sells cheaper for me. Aminu said that he could not buy his tomato from elsewhere because of their bond with his roadside trader. He sells so cheap and even sells to me on credit when I do not have money. The good part is that he never asks for his payment. I will pay him when I get the money".*

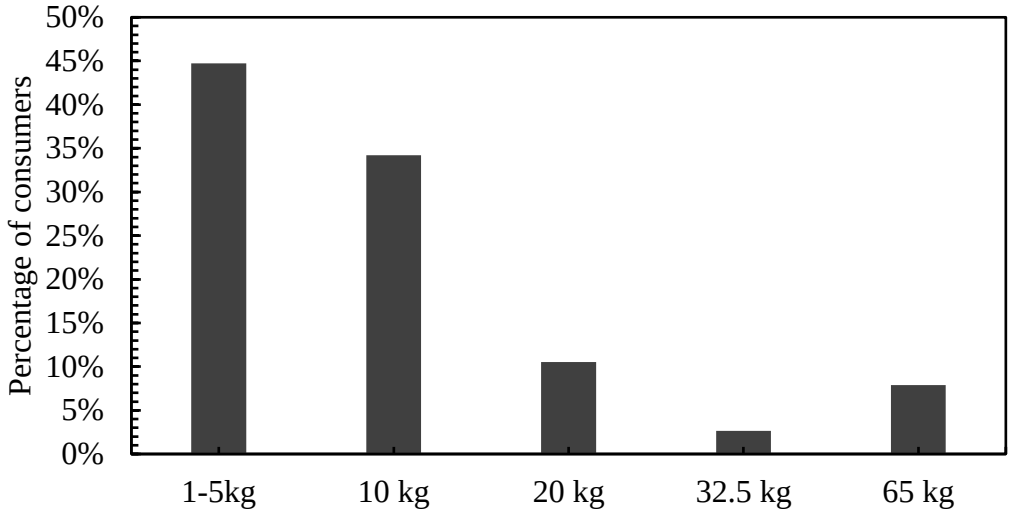

Figure 9.5: Consumer response on the quantity of tomato purchased (n=38)

The amount of waste and loss depends on the quantity of tomatoes respondents buy: 45% buy between 1 kg and 5 kg of tomatoes in a typical shopping trip. Of the people who answered the survey, 8% said they buy a whole basket of tomatoes on a typical day. Respondents also said it is not daily. 10kg of tomato is the most common quantity consumers like to buy, with 34% of respondents buying this amount daily. This could be attributed to the fact that men in Kaduna marry more than one person. One can find a man living with his four wives and children in the same house.

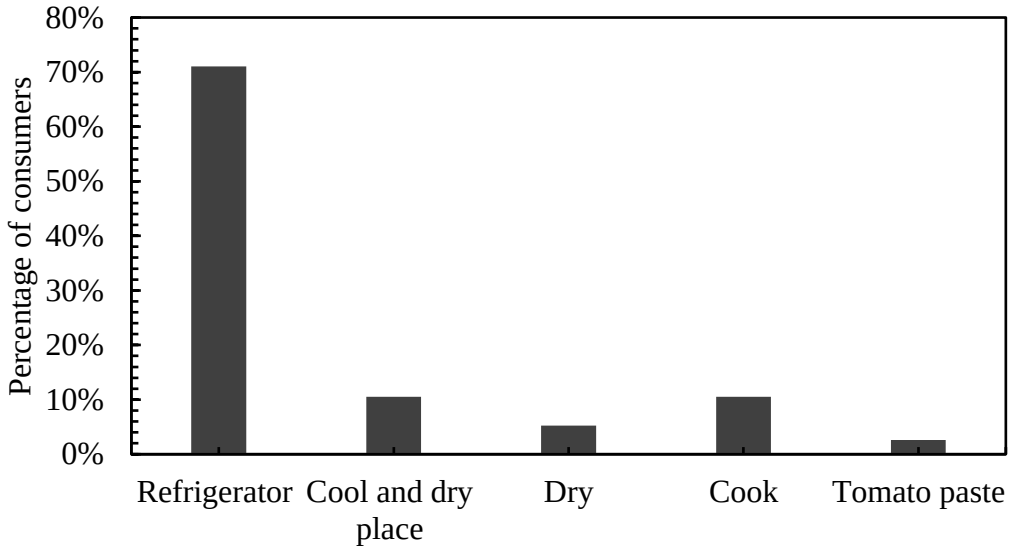

Figure 9.6: Tomato storage and preservation methods (n=38)

While purchasing tomatoes, respondents buy undented, unbroken, and preserved fresh tomatoes. Also, they must be ripe. If they are unripe, they must ripen before eating. During a period of scarcity, consumers consume dry tomatoes other than fresh ones. According to them, it has the same flavour as fresh ones. However, only 5% of consumers used the drying method to preserve their tomatoes, whereas 71% of consumers refrigerated their tomatoes, and 11% of the participants cooked the tomatoes to preserve them. To prevent waste, tomatoes can be stored in dry, cool, dark, well-ventilated areas, boiled or doused with oil or pureed and chilled. With the preservation methods applied above, the tomatoes can last for as long as four weeks or as little as two days depending on the method used and the availability of electricity. Respondents who said the tomatoes could last for two weeks and above used alternative storage methods to refrigerators. For example, traditional open-air storage: In many rural areas in Kaduna, tomatoes are stored in traditional open-air structures known as "Mattan". These structures are typically made of bamboo, and the tomatoes are stored on racks inside them. The mattan provides shade and ventilation, which helps to keep the tomatoes cool and dry. Smoking is a traditional way of preserving tomatoes in some parts of Kaduna. This method involves smoking the tomatoes over a low fire until they are dry and shrivelled. The smoked tomatoes can be stored in airtight containers for several months.

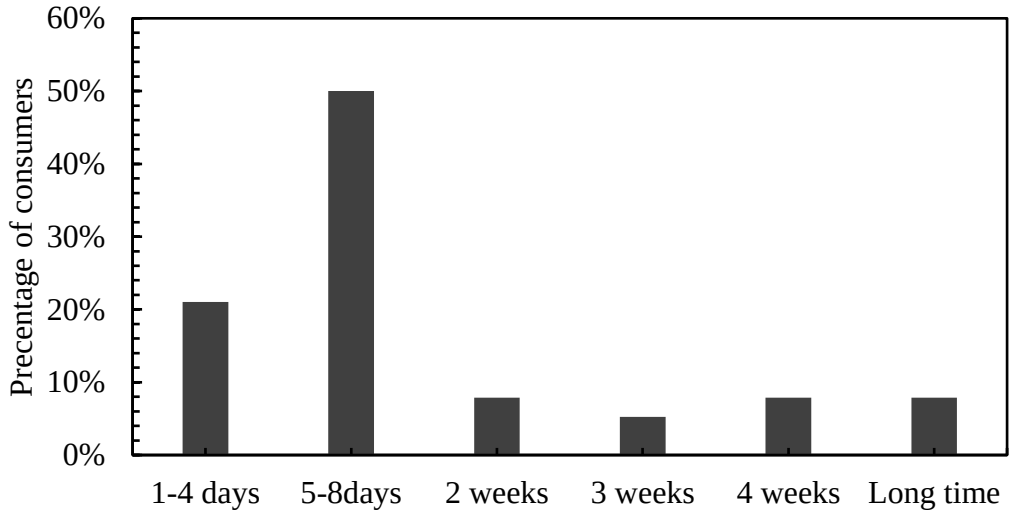

Figure 9.7: Consumer response of tomato shelf life using the above storage methods (n=38)

The life span of the tomato depends on the consumer's ideas, or the method applied to preserve the tomatoes by the consumer. Suthar *et al*. (2018) and Saini *et al*. (2019) warn that damaged

tomatoes are hazardous to one's health because they may cause food-borne infections, food poisoning, and diarrhoea. 50% of the consumers surveyed agreed that tomatoes would remain fresh for 5-8 days and should be consumed in their entirety and when still safe. 21% of respondents believe that tomatoes are no longer fresh after four days, and that damaged or bruised produce is susceptible to rot and illness as the imperfections on the surface of the tomatoes are good entry points for bacteria.

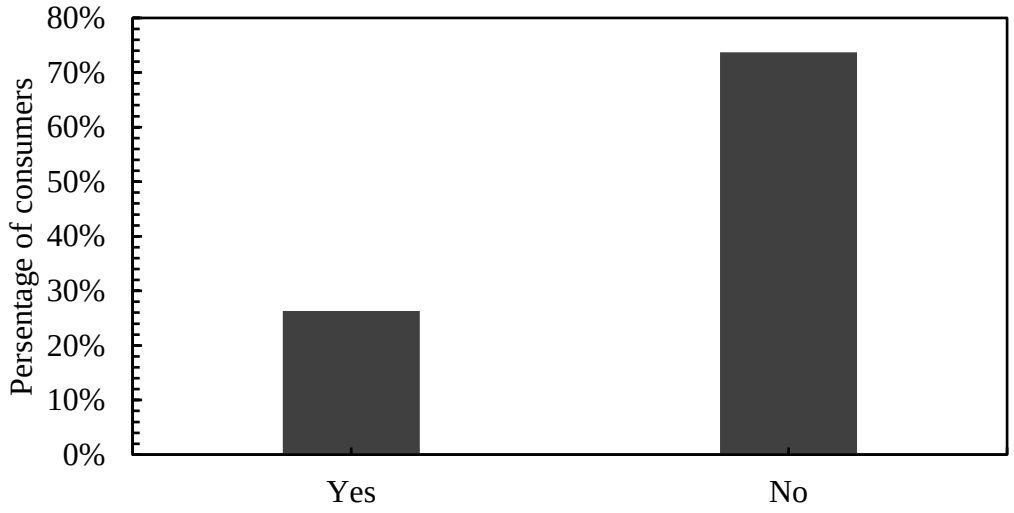

Figure 9.8: Consumers who generate losses of tomato daily (n=38)

In Kaduna, unlike those in the UK and other developed countries, they need the luxury of a reliable food supply chain, a cold supply truck, or adequate storage to keep tomatoes fresh longer after harvest (Xue, *et al*., 2021). However, Kaduna's consumer population has little to no tomato waste. According to the results, most customers (74%) do not waste tomatoes, although a sizable minority (26%) do. During the survey, we had the opportunity to speak with a resident of the kawo region in Kaduna state, who suggested that there is never any wasted food in the home since there is always someone that can be helped. Furthermore, he pointed out that many people are asking for money or food and he always gives them whatever is left, as much as he does not need.

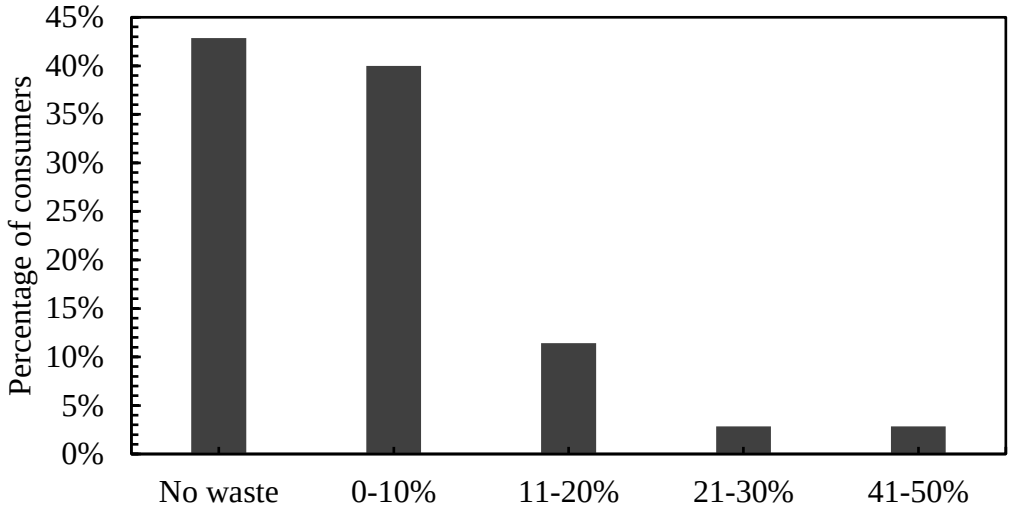

Figure 9.9: Response to weekly tomato waste (n=38)

In contrast to the UK and EU where up to 65% of tomatoes are wasted by consumers (Li Xue *et al*., 2020), consumers rarely throw away tomatoes in the study area. This is clear from the fact that 43% of respondents had no waste. 40% of the consumers tomatoes have 0-10% waste, and 11% have 10-20%. The main reason for wastage was a lack of proper storage and electricity. One respondent said that she usually buys whole baskets of tomatoes so that she does not have to go to the market as often. Nevertheless, when the power goes out, she looses almost all the food in her fridge.

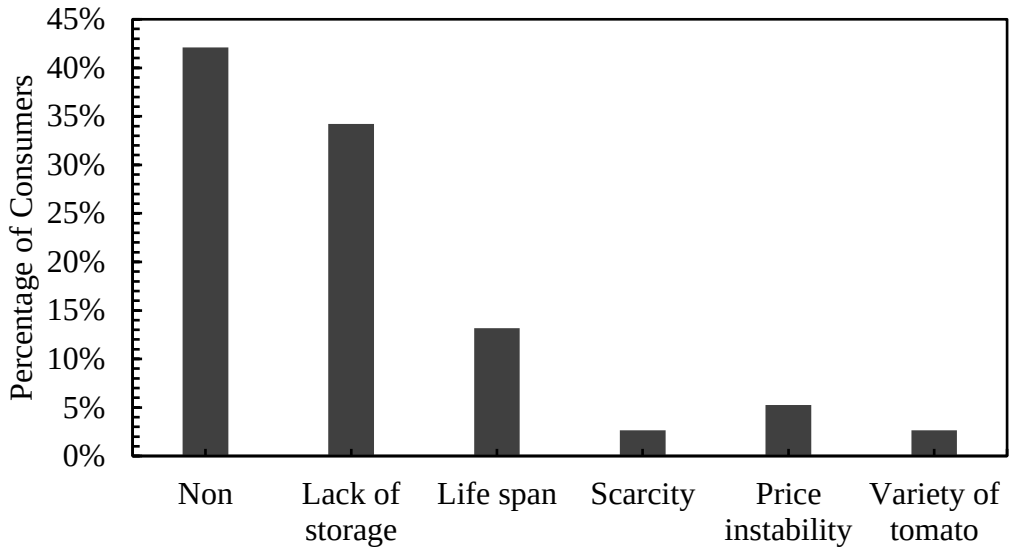

Figure 9.10: Response to the challenges faced by consumers at home (n=38)

Figure 9.10 shows the challenges consumers face at home with tomatoes. 42% of respondents to the survey responded that they have no issues with tomatoes in their homes because they often purchase only what they can consume. Moreover, when they have leftovers on their plates, they distribute them to the homeless. 34% of respondents stated that unreliable storage, typically caused by power fluctuations, is one of the most significant challenges they face when storing tomatoes at home. Most consumers would prefer to purchase a larger quantity of tomatoes to store at home to prevent frequent trips to the market, but they cannot do that due to power outages. Due to the perishable nature of tomatoes, their shelf life is short. As reported by 3% of participants, product scarcity may also be a problem. During times of scarcity, people must use alternatives such as canned or dried tomatoes to avoid purchasing fresh ones, which have become expensive. 5% of respondents indicated that the unstable price of tomatoes per basket is their primary concern.

Manager 1: A restaurant proprietor in the southern part of Kaduna city, noted that the volatility of tomato prices makes it impossible for her to maintain a profitable business. She stated that the price modification of the basket has caused her to raise the price of a plate of food, resulting in the loss of some of her customers (manager 1).

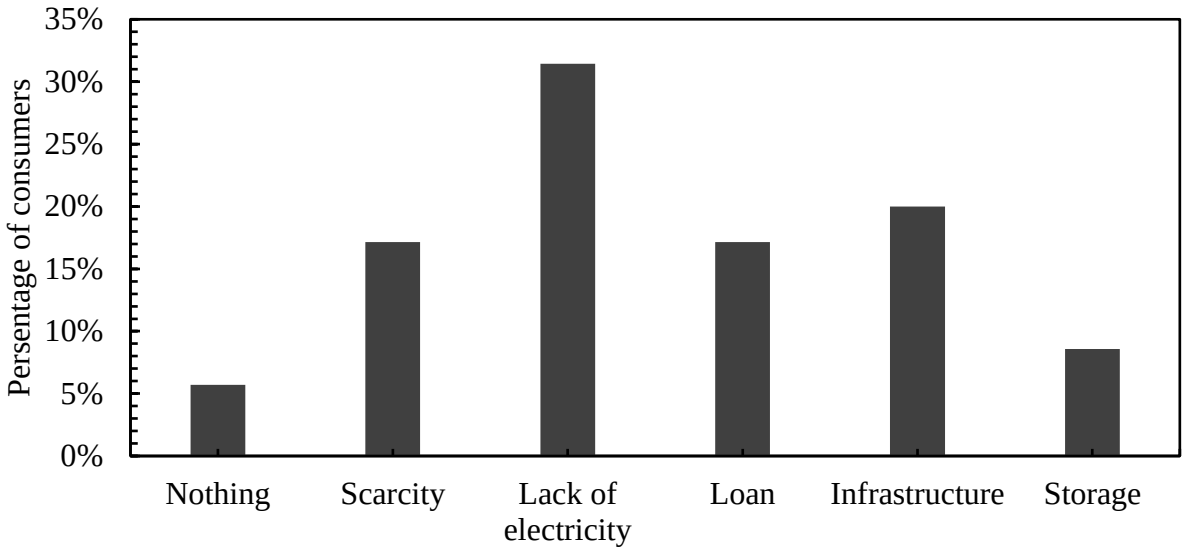

Figure 9.11: Ways government can reduce loss/waste of tomatoes (n=38)

Figure 9.11 indicates consumers' request for the government to find a solution to reduce the loss/waste of tomatoes in their households. A lack of electricity was the most frequent response, as might be expected from responses to some of the questions discussed earlier. Alternative means to generate electricity, like power generators and solar panels, are challenging to purchase for individual households. 20% of respondents indicated a general problem coded to infrastructure. Consumers said some markets are not conducive to doing business as the footpaths are not cemented, unpaved footpaths in markets can have several negative impacts on both vendors and customers. They can create discomfort and challenges for customers to navigate, especially for those with mobility challenges. This can lead to reduced foot traffic and sales for vendors. Additionally, the uneven surface can make it challenging for vendors to set up their stalls and display products effectively, impacting sales and overall customer experience. Unpaved footpaths can also pose safety risks to vendors and customers, such as slipping and falling on muddy or uneven surfaces. To improve market functionality and accessibility, alternative footpath materials that are comfortable, functional, and safe should be considered, such as concrete or paving stones.

Markets should also be designed and maintained with the needs and preferences of vendors and customers in mind to create a welcoming environment that fosters economic growth and community development; there are no toilets and rest areas, and they do not have security cameras. Some 17% of respondents are appealing to the government to improve the availability of the tomatoes as scarcity of it makes it more expensive. Some 9% of consumers believe that

government should provide storage, such as cooling plants that can be positioned at strategic locations that can be accessed by people selling perishable goods.

9.3 Summary

This chapter highlighted findings on customer purchases and waste in the supply chain. The consumer represents the end of the supply chain. He or she can do as they please with the tomatoes. The entire process, from the farms to the intermediaries and traders, is designed to meet customers' needs. If the consumer wastes the tomatoes supplied to him or her, all efforts to ensure that the food arrives in acceptable condition are useless. To an extent, individual attitudes and social environments influence consumers' attitudes regarding tomato waste; however, in contrast with countries such as the UK, waste is something that consumers seek to minimise. Many consumers experience zero or low-level tomato waste or losses as ‘surplus’ purchases are often not wasted but given to others including the homeless. Most customers buy tomatoes regularly due to their family size and the limited availability of storage systems. Over sixty per cent of consumers prefer to purchase red tomatoes. Power and electricity shortages present significant difficulties for customers: as most people keep their tomatoes in refrigerators, it is crucial to have a constant energy source to maintain the tomatoes' shelf life.

Chapter 10: Conclusion

The tomato supply chain in Kaduna, Nigeria, is vital to the local economy, providing income and employment opportunities for small-scale farmers and traders. However, the supply chain faces several challenges, including poor infrastructure, inadequate storage facilities, and post-harvest losses due to pests and diseases. These issues can lead to reduced quality and yield of tomatoes, which ultimately affect the profitability of the entire supply chain. Commodity chain analysis provides a valuable framework for understanding the complex interactions between global economic forces and local food systems. By tracing the journey of tomatoes from farm to plate, researchers can identify points of vulnerability and opportunities for intervention. For example, improving infrastructure and storage facilities could reduce post-harvest losses and increase the quality of locally produced tomatoes. This could be achieved by investing in transportation networks, cold storage facilities, and post-harvest technologies, such as packaging and processing.

In addition, supporting policies and programmes prioritising local food systems over global commodity chains can help protect the livelihoods of small-scale farmers and traders in Kaduna and beyond. This could include tariffs on imported tomato products to protect the local market, subsidies to support local production, and funding for research and development in tomato cultivation and processing. However, post-harvest research and management of food waste in the tomato supply chain should also consider the geographic context of production, processing, and consumption. The climatic conditions of a region can affect the timing of harvest and the degree of maturity of the fruits, which can impact the quality and yield of the tomatoes. Therefore, post-harvest management strategies should be adapted to each region's specific climatic conditions and tomato varieties.

Moreover, the geographic location of processing facilities and markets can impact the transportation and storage of tomatoes and the availability and affordability of post-harvest technologies and services. For example, tomato losses may occur in regions with limited transportation infrastructure and low-income levels due to inadequate handling and storage facilities, lack of access to market information, and limited capacity for value addition. On the other hand, tomato losses may occur in regions with advanced transportation infrastructure and high-income levels due to strict food safety regulations, consumer preferences for uniformity and appearance, and the high cost of post-harvest technologies and services. Therefore, to

reduce tomato waste and improve the food system's sustainability, researchers and practitioners must critically analyse the challenges and opportunities that arise from the geographic context of production, processing, and consumption. This requires developing targeted interventions and policies that address the specific needs of each region, such as investing in transportation networks, cold storage facilities, and post-harvest technologies, as well as supporting local production and value addition. By doing so, they can improve the overall efficiency and profitability of the tomato supply chain while protecting the livelihoods of small-scale farmers and traders in Kaduna and beyond.

10.1 Contribution to the knowledge

The study highlights several gaps in the literature on food waste and the need to fill these gaps through specific studies. One of the main issues is the ambiguity in food waste definitions, making it challenging to document the total volume of food waste generated worldwide accurately. This is further compounded by the fact that research on food waste has been split along economic and development lines, with different causes and effects of food waste being studied separately. The study notes that post-harvest losses are studied in developing nations, while post-consumer waste is more prevalent in middle-income and wealthy nations. Similarly, fruits and vegetables suffer the most significant decline among all food groups, particularly in low-income nations. The lack of research on post-consumer waste in low-income countries means less data on post-harvest losses. To fill these gaps, the study conducted crop- and region-specific studies on post-harvest losses, including the consumer, by tracing the tomato value chain from farm to consumer table in Nigeria.

The analysis of the tomato supply chain as a system revealed major regions, actors, linkages, operations, governance systems, and the combination of variables and processes that resulted in losses. The case and context specificity of commodity chain analysis allowed for evaluating the vertical and horizontal chain elements. In particular, the role of gender in the activities of actors was investigated. The study showed that significant losses occurred during harvest and after the farm gate, affecting the participants' lives in those areas. The study also demonstrated the significance of analysing local supply chains as global food chains have resulted in longer food chains that have superseded shorter ones. It also advocated for using the 'follow the thing' concept to monitor the tomato's voyage outside the farm gate: in transport, the marketplace, and the consumers' homes. In addition, the study revealed that tomato is an economically

significant crop for individuals and society and that the tomato business represents an unexplored possibility in Nigeria.

The study also examined post-consumer waste by concentrating on the fruit preferences of consumers, which showed that consumers in developing countries are like western consumers in that their choices for quality traits determine their purchase and waste habits. The study took a multi-method approach and utilised questionnaires, images, interviews, observations, internet surveys, and a research diary to track the journey of the tomatoes from farm gates to the consumer's table. The purpose and aims of the study informed the choice of methodologies, and the combination of these methods gave a comprehensive grasp of the study problem. Overall, the study significantly contributed to food waste knowledge by addressing specific literature gaps and demonstrating the need for further research on local supply chains and post-consumer waste in developing countries.

The tomato supply chain in Kaduna involves some key stakeholders. The research identified these stakeholders as farmers, intermediaries, traders, and consumers. Each stakeholder plays a distinct role in the tomato supply chain, contributing to tomatoes' overall production, distribution, and consumption. Farmers form the backbone of the supply chain as primary producers. They cultivate and harvest tomatoes, employing various agricultural practices to ensure quality and quantity. Depending on their resources and capabilities, these farmers may operate on a large-scale or small-scale basis. Intermediaries or wholesalers act as middlemen between farmers and traders. Their role involves purchasing tomatoes in bulk from farmers and aggregating them for further distribution. By consolidating the produce, intermediaries help streamline the supply chain and facilitate the movement of tomatoes from farms to markets.

The trader's role in the supply chain is to purchase tomatoes from intermediaries or farmers. They are responsible for the distribution of tomatoes to various marketplaces. Traders operate in local markets, regional markets, and even export markets, depending on the scale and reach of their operations. Their activities ensure that tomatoes reach consumers efficiently and effectively. Consumers represent the end-users of tomatoes in the supply chain. They include households, restaurants, food processing companies, and other entities that purchase and consume tomatoes. Consumers drive the demand for tomatoes and influence the supply chain dynamics through their preferences and consumption patterns. It is important to note that the composition of stakeholders in the tomato supply chain may vary in different contexts and

regions. Other stakeholders that could be involved include transporters, processors, input suppliers (such as seed and fertilizer providers), government agencies, and regulatory bodies.

This research has identified farmers as the supply chain's primary generators of tomato waste. The high volume of waste can be attributed to several factors, including seasonal glut, inadequate pre and post-harvest handling practices, farm mismanagement, and limited market access. These combined factors contribute significantly to the substantial losses experienced by farmers throughout the tomato production process. Intermediaries in the tomato supply chain encounter tomato waste primarily due to sorting and grading processes, transit-related challenges involving using containers for transportation, and the uncertainty surrounding available markets for the produce. These factors contribute to substantial losses experienced by intermediaries during the handling and distribution of tomatoes within the supply chain. Traders within the tomato supply chain typically encounter a minor waste, which occasionally manifests as smashed tomatoes found at the base of the baskets. This limited waste is primarily due to incidental damage during handling and transportation. In the study area, consumers are observed to have a small amount of tomato waste. This waste can be attributed to two main factors: tomato spoilage caused by electricity failures and occasionally due to leftovers on plates. The lack of a consistent electricity supply increases the risk of tomato spoilage, as inadequate refrigeration leads to accelerated deterioration.

Additionally, when tomatoes are left uneaten on plates, they contribute to the overall waste generated by consumers in the study area. Tomato waste contributes to several environmental challenges, including energy consumption, biodiversity impact, resource depletion, and greenhouse gas emissions. These challenges arise due to inefficient handling and disposal practices associated with tomato waste. Addressing these issues is crucial to mitigate the environmental impact of tomato waste. In conclusion, several approaches have been identified to mitigate tomato waste in the supply chain effectively. Using plastic crates instead of traditional baskets offers improved protection during transportation, reducing the chances of damage and waste.

Additionally, investing in road infrastructure repairs can reduce travel time, ensuring quicker and more efficient delivery of tomatoes from one point to another, thus minimizing spoilage and waste. Furthermore, intermediaries can play a vital role by developing routines that promote even produce distribution throughout the year. This strategic market circulation can

help prevent oversupply or undersupply, reducing the potential for waste. Supporting farmers with appropriate farm tools and equipment encourages consistent year-round production, contributing to stabilized prices and the availability of tomatoes.

This research provided valuable insights into the challenges different stakeholders face within the tomato supply chain and has offered potential approaches to address and reduce tomato waste. By identifying the specific challenges encountered by farmers, intermediaries, traders, and consumers, the study has highlighted the different factors contributing to tomato waste generation at various supply chain stages. The findings emphasize the importance of targeted interventions and strategies for each stakeholder. For farmers, implementing improved farming practices, such as efficient irrigation systems, integrated pest management, and proper post-harvest handling techniques, can minimize losses and enhance overall productivity. Intermediaries and traders can benefit from better storage facilities, transportation logistics, and market coordination to reduce waste and optimize distribution. Furthermore, consumer awareness and education play a crucial role in reducing waste at the consumer level. Responsible consumption habits, such as proper storage, meal planning, and utilization of imperfect but edible tomatoes, can significantly reduce waste. The suggested approaches to waste reduction in the tomato supply chain align with broader sustainability goals and circular economy principles.

By implementing these measures, significant economic losses can be prevented, and environmental impact can be minimized. Reducing waste in the supply chain contributes to resource conservation, decreases greenhouse gas emissions associated with waste disposal, and helps preserve the integrity of ecosystems and natural resources. Policymakers, industry stakeholders, and relevant organizations need to collaborate in implementing these approaches. This requires creating an enabling environment through policy support, investment in infrastructure, knowledge dissemination, and capacity-building initiatives. Continuous monitoring, evaluation, and adjustment of strategies will be essential to ensure their effectiveness and long-term sustainability. By addressing the challenges identified within the tomato supply chain and adopting the suggested approaches, a more sustainable and efficient tomato supply chain can be established in Nigeria. This benefits the stakeholders involved and contributes to the achievement of broader developmental goals, including food security, environmental conservation, and economic growth.

10.2 Recommendations

The recommendations mentioned are related to improving tomato farming practices in Kaduna State, a region in Nigeria known for its agricultural activities. The region's geography, climate, soil type, and topography are crucial in determining the success of tomato farming in the area. The recommendations focus on improving the efficiency and productivity of tomato farming in Kaduna State while promoting sustainability and reducing the negative environmental impact. The region's agricultural potential can be harnessed by adopting best practices and using appropriate technology and inputs, including high-quality seeds, irrigation, pest management, and fertilizer use. These recommendations can help farmers in Kaduna State optimize their crop production and contribute to the region's sustainable and productive tomato farming system.

There are several recommendations to consider to improve tomato farming in Kaduna State. Firstly, providing credit facilities to tomato farmers can significantly improve their farming practices and increase their yields, profitability, and market access. This investment can benefit everyone involved and contribute to the economy's growth, creating a sustainable agricultural system. Policies and programmes that support and incentivize smaller farms can promote sustainable farming practices, provide employment opportunities, and support local economies and communities. Encouraging small-scale tomato farming can improve efficiency, reduce environmental impact, and limit the acquisition of large tracts of land for industrial agriculture. Direct marketing channels can also be established to promote small-scale tomato farming. Choosing appropriate seed types is crucial for optimizing tomato yield and efficiency in Kaduna. High-quality, well-suited seeds can lead to better plant growth, disease resistance, and higher yields.

Encouraging farmers to adopt appropriate seed types can improve tomato yield and efficiency while benefiting public health and the environment. Pretraining farmers on best practices such as irrigation, pest management, and fertilizer use are crucial for improving tomato yield and efficiency in Kaduna. Farmers can optimize crop production and contribute to the region's sustainable and productive tomato farming system. Farmers can consider sun-drying a traditional and cost-effective method of preserving tomatoes, but they must be aware of potential contamination and nutrient loss. Other methods, such as canning or freezing, can also be considered. Early harvesting of tomatoes can benefit farmers by reducing the risk of damage from pests and diseases, improving quality control, and extending shelf life. However, farmers

must be careful to pick tomatoes at the right stage of ripeness to prevent spoilage or loss of flavour. The practice of cool storage can extend the shelf life of tomatoes by slowing down the ripening process.

Building storage facilities and tomato processing industries can stabilise prices, reduce waste and losses, create new jobs and economic opportunities, and provide a reliable source of income for farmers and intermediaries during periods of oversupply. This can also stimulate economic growth and improve the overall economic well-being of the community. Regulating the supply of tomatoes can ensure that the supply chain operates efficiently and reduce waste and losses. Farmers in Kaduna can consider composting tomato waste, using it as animal feed, and exploring other waste reduction techniques such as mulching. Solar-powered cold rooms, known as Cold Hubs, can also be used as a cost-effective mobile storage solution. Encouraging farmers to sell their produce directly to consumers through farmers' markets or online platforms can diversify the tomato supply chain and benefit farmers and consumers. By bypassing intermediaries, farmers can sell their products at a higher price and increase their profits.

Additionally, consumers can access fresh, locally grown produce at affordable prices, which is particularly important for those needing more accessible access to fresh produce. Farmers may need training and support on marketing and business skills to facilitate direct sales, such as product presentation, pricing, and customer service. Infrastructure support, such as space for farmers' markets or online platforms, may also be necessary. By diversifying the supply chain and reducing the dependence on intermediaries, farmers can have greater control over their profits, and consumers can benefit from improved access to fresh and affordable tomatoes. Investing in tomato storage and transportation infrastructure, such as cold storage facilities and refrigerated transportation, is crucial for maintaining the quality and freshness of tomatoes and reducing spoilage. This can extend their shelf life, reduce food waste, increase farmers' profits, and improve consumers' access to fresh tomatoes.

Therefore, governments and private investors should consider investing in these critical infrastructure components to support the tomato industry and promote sustainable development. Roman VF tomatoes are known for their taste, nutritional value, and longer shelf life, making them more marketable and profitable. Encouraging the cultivation of Roman VF tomatoes can increase the supply of tomatoes, reduce their cost, and provide intermediaries with a profitable crop. Training on best practices, access to high-quality seeds and inputs, and financial support or incentives to intermediaries help promote their cultivation. Training

intermediaries on best practices for tomato handling is crucial for improving tomato quality and quantity in the study area. Agricultural extension programmes and collaboration with local universities or research institutions can provide access to knowledge and expertise on tomato cultivation and post-harvest handling. This training can include pest management, irrigation, fertilisation, and new technologies to prolong tomato shelf life.

Encouraging alternative tomato packaging, such as sealed plastic bags or containers, can help reduce spoilage, extend shelf life, maintain quality and freshness, and increase marketability. This could benefit farmers and consumers by reducing waste, increasing profits, and providing visually appealing, high-quality tomatoes. Enhancing security in tomato production areas can increase tomato supply, stabilise prices, improve worker safety, and reduce waste and losses in the tomato supply chain. Measures such as increasing police presence, improving surveillance, and addressing underlying issues can be taken, along with providing training and resources to farmers and intermediaries to protect themselves and their businesses from security threats. The government can establish a central market system to control the flow of tomatoes and ensure that prices remain stable even during periods of oversupply. Alternatively, a licensing system can regulate the number of tomatoes produced and traded, ensuring supply matches demand and preventing oversupply. Both approaches can streamline the supply chain, reduce inefficiencies, and ensure that all actors receive a fair return for their efforts.

A comprehensive quality control system can ensure that the tomatoes are of the highest quality. Regular quality checks throughout the tomato supply chain, including at the farm, during transportation, and at the point of delivery to traders, can minimise the risk of spoilage, damage, and contamination. These checks should include inspecting for damage or spoilage, monitoring temperature and humidity levels, and conducting lab tests for harmful bacteria or chemicals.

10.3 Challenges and limitations

The challenges and limitations faced during the research study can significantly impact the accuracy, validity, and generalizability of the research findings. These challenges can arise due to various factors, including environmental, social, and methodological factors. The first challenge faced during the research study was the weather. As stated in the text, the research was carried out during the rainy season, and it rained almost every day during data collection. This made it difficult to reach some areas and collect data, which could have affected the representativeness of the data collected. For instance, certain areas may have been excluded due to accessibility issues, resulting in incomplete or biased data. The impact of weather on

research is a common challenge, and researchers must consider this when designing their studies.

The second challenge faced during the research study was getting farmers' attention. As stated in the text, farmers were busy working and going about their businesses, and it took much work to get their attention. Some farmers even demanded payment for providing information, which could have resulted in biased data. This challenge may have been due to the nature of farming activities and the farmers' perception of research activities. Researchers must find ways to incentivize participants to participate in research activities without compromising the collected data quality. Thirdly challenge during the research study was the fear of traders answering some questions due to the Kaduna state government's urban renewal programme. As stated in the text, some traders declined to answer certain questions, fearing that they might lose their market if they disclosed their challenges. This could have resulted in incomplete data, as some traders declined to answer certain questions, resulting in missing or biased data. Researchers must find ways to establish trust with participants and assure them of the confidentiality of the data collected to minimize such fears.

Fourthly challenge faced during the research study was the limitations of the research methodologies used, such as the sample size, which was limited due to the Covid-19 pandemic. As stated in the text, data collection had to stop due to the Covid-19 pandemic, and the sample size was limited. This limitation could affect the generalizability of the research findings, as a larger sample size may have provided more insights into post-harvest losses in the tomato supply chain. Researchers must consider the potential limitations of their research methodologies when designing their studies and take steps to mitigate these limitations. During the research study was capturing quantitative data. This challenge highlights the importance of establishing reliable data sources and collecting accurate data to ensure the accuracy of the research findings. As stated in the text, not all supply chain stakeholders recorded the number of baskets of tomatoes they produced, bought, or sold daily.

It should be noted that although the data collected represent the quantities of tomatoes produced, bought or sold, there could be some variability due to the challenges aforementioned. Finally, the difficulty in identifying farmers, intermediaries, and traders due to the lack of maps specifying their positions, and language barriers may also result in data variation.. Researchers must find ways to overcome these challenges, such as working with local partners who understand the local context and can assist with data collection activities. The challenges and

limitations faced during the research study could have some implications for the research findings'. Researchers must acknowledge these limitations and take steps to mitigate their potential impact on the research findings. This can include using a mixed-methods approach, working with local partners, establishing reliable data sources, and ensuring the confidentiality of the data collected.

10.4 Future research

Geography is critical in understanding commodity chains and the challenges related to post-harvest management and food waste. Commodity chains are geographically dispersed, and their processes and activities involve various actors, including producers, processors, distributors, retailers, and consumers, located in different regions and countries. Therefore, future research on post-harvest management and food waste should consider the specific geographies of the commodity chains for different crops. This means identifying the geographical locations of the actors involved in the supply chain, the geographical patterns of trade flows and distribution networks, and the geographical factors that affect post-harvest losses and waste.

For instance, in the case of tomato waste, the research could begin by identifying the key production areas for tomatoes and mapping the trade flows from these areas to processing and consumption locations. This could involve conducting spatial analyses to identify the geographic patterns of production, transportation, and distribution of tomatoes, as well as the geographical factors that contribute to post-harvest losses and waste, such as poor infrastructure, lack of storage facilities, and unfavourable climatic conditions. The research could also investigate the socio-economic and cultural factors that influence post-harvest management practices and consumer behaviour in different regions. For example, cultural practices related to food preparation and consumption can vary significantly between regions and countries, affecting the demand for different tomato varieties and the extent of waste generated at the consumer level.

Case studies of specific commodity chains for tomatoes in different regions could provide valuable insights into the challenges of post-harvest management and waste reduction in different geographic and socio-economic contexts. This could involve identifying the factors contributing to post-harvest losses and waste at each stage of the chain, including production, harvesting, transportation, processing, distribution, and consumption. Ultimately, the goal of research on the geography of commodity chains and post-harvest management should be to

develop targeted interventions that are tailored to the specific geographic and socio-economic contexts of different commodity chains. By considering the unique challenges and opportunities associated with different regions and commodity chains, stakeholders can develop effective and sustainable strategies to reduce post-harvest losses and food waste.

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Appendices

Appendix 1

Farmer's questionnaire

Survey of losses and waste in tomato post-harvest supply chain

This survey is conducted to gather information on post-harvest losses and waste of tomato. The survey cut across tomato farms to reveal the hidden social and cultural factors affecting tomato farmers and the causes of losses and waste along the value/supply chain. The questionnaire seeks to gather information on the quantity and quality of fresh tomatoes loss on farm, on transit and in households.

A. Identification

Name of research assistant	
Date of interview	
State	
Local Government Area	
Village	
Name of respondent	

B. Demographic data

1. Gender?

   a) Male [ ] b) Female [ ]

2. Age group?

   a) 18-29 [ ] b) 30-39 [ ] c) 40-49 [ ] d) 50-59 [ ] e) 60 and above [ ]

3. Marital status: a) Single [ ] b) Married [ ] c) Widow/Widower [ ]

4. State of origin? (Hometown)

   Town _ _ _ _ _ _ _ _ LGA_ _ _ _ _ _ _ _ _ State_ _ _ _ _ _ _

5. Where is your Place of birth?

   Town _ _ _ _ _ _ _ _ _ LGA_ _ _ _ _ _ _ _ _ State_ _ _ _ _ _ _

6. Level of education?

   a) No formal education [ ] b) primary [ ] c) Secondary d) Tertiary [ ]

   e) If tertiary please explain _

   f) Others please specify _

C. Production

7. What other type of crops and vegetables do you grow?

_ _

8. How long have you been growing tomatoes?

_ _

9. How did you acquire your farmland? a) Inherited [ ] b) Purchased [ ]

c) Rent [ ] d) Others [ ] Please specify _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

10. What is the size of your farm in hectares?

a) <- 1 hectare [ ] b) 1-4 hectares [ ] c) 5-9 hectares [ ]

d) 10 hectares and > [ ] e) I don't know [ ]

11. Do you usually use mechanized equipment to prepare your farmland?

_ _

a) If yes, please explain the benefits _

12. Do you use irrigation for your tomato farm? a) Yes [ ] b) No [ ]

a) If yes, what is the estimated yield with irrigation? _ _ _ _ _ _ _ _ _ _ _ _ _

b) If no, what is the estimated yield without irrigation? _ _ _ _ _ _ _ _ _ _ _ _

_ _

13. Do you use fertilizer for tomato production? a) Yes [ ] b) No [ ]

a) Where do you get fertilizer from? _

b) Does it improve productivity? a) Yes [ ] b) No [ ]

c) Estimate the improved productivity? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

14. Do you use hired labour for harvesting tomato? a) Yes [ ] b) No [ ]

a) If yes, does it improve harvesting speed?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

b) If no, why?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

15. How do you normally measure your harvested tomatoes?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

a) What is the total amount of tomatoes you harvest in a season?

_ _ _ _ ___ _ _ _ _ _ _ ___ _ _ _

16. Estimate the amount of tomato you produced in the last three seasons?

a) Season 1 _ _ _ _ _ _ b) Season 2_ _ _ _ _ c) Season 3 _ _ _ _ _ _ _

17. What do you do with tomatoes harvested form your farm?

_ _ _ _ ___ _ ___ _ _ ___ _ _ ___ _

a) If sold, where do you sell them?

_ _ _ ___ _ ___ _ _ _ _ _ _ _ ___

b) If not sold, what do you do with it?

_ _ ___ _ _ _ _ _ _ ___ _ _ _ ___ _

18. What is the average distance from your farm to the market? _ _ _ _ ___ _ _ _ _ _ _ _ _

a) What type of vehicle do you use to transport the tomatoes? _ _ _ _ ___ _ _ _ _ ___ _ _ _ _ _ ___ _ _ _ ___ _

b) How much does it cost you per trip? _ _ _ _ _ _ _ _ _ _ _ ___ _ _ _ _ ___

D. Post-harvest losses and waste

19. How do you determine the maturity of your tomato?

_ _ _ _ _ ___ ___ _ _ _ _ _ _ _

20. How many months after planting do you commence harvesting your tomato?

_ _ _ _ _ _ _ ___ _ _ _ _ ___ _ _

21. Do you encounter losses and waste? a) Yes [ ] b) No [ ]

a) If yes, what causes the loss and waste? _ _ _ _ _ _ _ ___ _ _ _ _ ___ _

b) Which stage of harvest does loss/waste occur? _ _ _ _ _ _ _ _ _ _ ___ _ _

22. Give us an estimate of your losses based on percentage in the last three seasons?

a) Season 1 _ _ _ _ _ b) Season 2 _ _ _ _ _ c) Season 3 _ _ _ _ _ _

23. Use the table below to identify produce and losses on each stage of the supply chain for a season of harvest.

	Stages	**Produce (%)**	**Loss (%)**
Farm level losses	Harvesting		
	Storage		
	Grading and packaging		

	Handing and transportation		
	Others		
	Total Farm produce and losses		

d) What do you do to prevent the loss and waste in subsequent seasons?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

24. How do you preserve the tomatoes? _ _ _ _ _ _ — _ _ _ _ _ — _ _ — — — — _ _

a) How long do the tomato last with your method of preservation?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

25. What kind of container do you use to store and transport your produce?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

a) Does the container cause damage to the tomatoes? _ _ _ _ _ — —

26. How much money do you spend on tomato production in a season?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

27. How much profit do you make in a season? a) 0-100% _ _ _ _

b) Non [ ] c) I don't know [ ]

28. Are you participating in any FG/State/NGO projects that promote tomato production?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

a) How do they impact on you? a) Positively [ ] b) Negatively [ ] c) Not sure [ ]

29. Are you a member of any tomato cooperative society or association of tomato farmers?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

a) If yes, how long have you been a member?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

30. What are the challenges you face in your tomato farm?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

31. What do you think the government can do to help farmers?

_ _ _ _ _ — _ _ _ _ _ — _ _ _ — — — _ _ _ _

Appendix 2

Intermediary's questionnaire

Survey of losses and waste in tomato post-harvest supply chain

This survey is conducted to gather information on post-harvest losses and waste of tomato. The questionnaire seeks to gather information on the quantity and quality of fresh tomatoes lost, on farm, post-harvest in transit and in the market.

A. Identification

Name of research assistant	
Date of interview	
State	
Local Government Area	
Village	
Name of respondent	

B. Demographic data

1. Gender?

   b) Male [ ] b) Female [ ]

2. Age group?

   b) 18-29 [ ] b) 30-39 [ ] c) 40-49 [ ] d) 50-59 [ ] e) 60 and above [ ]

3. Marital status: a) Single [ ] b) Married [ ] c) Widow/Widower [ ]

4. State of origin? (Hometown)

   Town _ _ _ __ _ _ _ _ LGA_ _ _ __ _ _ _ _ _ _ State_ _ _ _ _ __ _ _

5. Level of education?

   a) No formal education [ ] b) primary [ ] c) Secondary d) Tertiary [ ]

   e) If tertiary please explain _ _ _ _ _ _ _ _ __ _ _ _ _ _ _ __ _ _ _ _ _

   f) Others please specify _

C. On transit post-harvest losses

6. Where do you get your tomatoes from? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

   a) How many baskets of tomatoes do you buy in a month? _ _ _ _ _ _ _ _ _ _ _

7. What type of vehicle do you use to transport the tomato? _ _ _ _ _ _ _ _ _ _ _ _ _

8. Have you had any problems with car breaks down while transporting tomatoes before?

a) Yes [ ] b) No [ ]

a) If yes, why? _____

9. What is the distance you cover to where you sell your tomatoes? a) 0-20km [ ]

b) 21 - 40km [ ] c) 41- 60 km [ ] d) 61-80 km [ ] e) 81-100 km [ ]

f) Others please specify _ _ _ _ _ _ _ _ _ _ _

10. Do you encounter losses on a single trip? a) Yes [ ] b) No [ ]

a) 0-10 % [ ] b) 11-20 % [ ] c) 21-30 % [ ] d) 31-40 % [ ] e) 41-50 % [ ]

e) Others please specify _ _ _ _ _ _ _ _ _ _

11. How much has the cost of a unit or basket of tomatoes in the last three seasons?

a) Rainy season _ _ _ _ _ b) Dry season _ _ _ _ _ c) Rainy season _ _ _ _ _

12. What is the reason behind the fluctuation of tomato prices from the years above?

_ _

13. Do you make a profit from trading tomatoes? a) Yes [ ] b) No [ ]

a) If yes, what is the profit made in percentage? a) 0-20% [ ]

b) 20-40% [ ] c) 40-60% [ ] d) 60% and above [ ] e) I am sure [ ]

f) Others please specify _ _ _ _ _ _ _ _ _ _ _ _

14. What are the challenges face in your tomato trade?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _

15. What do you want government to do to reduces the amount of tomato waste in the supply chain?

Appendix 3

Trader's questionnaire

Survey of losses and waste in tomato post-harvest supply chain

This survey is conducted to gather information on post-harvest losses and waste of tomatoes. The questionnaire seeks to gather information on the quantity and quality of fresh tomatoes lost, on farms, post-harvest in transit and in the market.

A. Identification

Name of research assistant	
Date of interview	
State	
Local Government Area	
Village	
Name of respondent	

B. Demographic data

1. Gender?

   a) Male [ ] b) Female [ ]

2. Age group?

   a) 18-29 [ ] b) 30-39 [ ] c) 40-49 [ ] d) 50-59 [ ] e) 60 and above [ ]

3. Marital status: a) Single [ ] b) Married [ ] c) Widow/Widower [ ]

4. State of origin? (Hometown)

   Town _ _ _ __ _ _ _ _ LGA_ _ _ __ _ _ _ _ _ _ State_ _ _ _ _ __ _ _

5. Level of education?

   a) No formal education [ ] b) primary [ ] c) Secondary d) Tertiary [ ]

   e) If tertiary please explain _ _ _ _ _ _ _ _ __ _ _ _ _ _ _ _ __ _ _ _ _ _

   f) Others please specify _ _ _ _ _ _ _ _ __ ___ _ _ _ _ _ _ __ _ _ _ _ _ __

C. Markets and Sales.

6. How long have you been selling tomatoes?

   a) 0-3 years [ ] b) 4-10 years [ ] c) 11-15 years [ ] d) 15-20 years [ ]

   e) 21-40 [ ] f) 41 years and above [ ]

7. From where do you normally buy your tomatoes?

a) Farm [ ] b) Tomato Market place [ ] c) Others Please _ _ _ _ _ _ _ _ _ _ _ _

8. How matured is the tomato you buy?

a) Matured red [ ] b) Matured green [ ] c) Both [ ] d) Others please specify _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

9. How long does the tomato last before it gets unsaleable? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

10. What is the cost of a basket of tomato in the last two seasons?

a) Dry season 1 _ _ _ _ _ _ b) Raining season _ _ _ _ _ _ _ _

11. What is the reason for the variation in the seasons above?

_ _

12. How many baskets of tomatoes do you buy on a typical day? _ _ _ _ _ _ _ _ _ _ _

a) 1-5 [ ] b) 6-10 [ ] c) 11-20 [ ] d) 21-30 [ ] e) Above 31 [ ]

13. How many times do you buy tomatoes in a typical week? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

14. Do you encounter losses and waste transporting tomatoes? a) Yes [ ] b) No [ ]

a) If yes, where does the waste occur? _ _ _ _ _ _ _ _ _ _ _ _ _ _

14b. What is the amount of tomato lost/wasted on a typical day?

a) 0-10 % [ ] b) 11-20 % [ ] c) 21-30 % [ ] d) 31-40 % [ ] e) 41-50 % [ ]

e) Others please specify _

15. Do you make a profit from trading tomatoes? a) Yes [ ] b) No [ ]

a) If yes, what is the profit made in percentage? a) 0-20% [ ]

b) 20-40% [ ] c) 40-60% [ ] d) 60% and above [ ] e) Others, please specify _ _ _ _ _ _ _ _ _ _ _ _ _ _

16. What other challenges do you face in the tomato trade?

_ _

17. What do you think should be done by the government to help traders?

_ _

Appendix 4

Consumer's questionnaire

Survey of losses and waste in tomato post-harvest supply chain

This survey is conducted to gather information on post-harvest losses and waste of tomato. The questionnaire seeks to get information on the quantity and quality of fresh tomatoes lost from farm to market to consumer.

A. Identification

Name of research assistant	
Date of interview	
State	
Local Government Area	
Village	
Name of respondent	

B. Demographic data

1. Gender?

   b) Male [ ] b) Female [ ]

2. Age group?

   b) 18-29 [ ] b) 30-39 [ ] c) 40-49 [ ] d) 50-59 [ ] e) 60 and above [ ]

3. Marital status: a) Single [ ] b) Married [ ] c) Widow/Widower [ ]

4. State of origin? (Hometown)

   Town _ _ _ __ _ _ _ _ LGA_ _ _ __ _ _ _ _ _ _ State_ _ _ _ _ __ _ _

5. Level of education?

   a) No formal education [ ] b) primary [ ] c) Secondary d) Tertiary [ ]

   e) If tertiary please explain _ _ _ _ _ _ _ _ __ _ _ _ _ _ _ __ _ _ _ _ _

   f) Others please specify _

C. Buying habits.

6. How often do you buy tomatoes?

   a) Daily [ ] b) Fortnightly [ ] c) Weekly [ ] d) Monthly [ ] e) Others please specify _ _ _ _ _ _ _ _ __ __ _

7. Where do you buy from?

a) Roadside traders [ ] b) Market traders [ ] c) On Farm [ ]

d) Supermarkets [ ] e) Other please specify _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

8. How many baskets of tomatoes do you buy on a single shopping day? _ _ _ _ _ _ _ _

9. How mature is the tomato you buy?

a) Matured red [ ] b) Matured green [ ] c) Both [ ] d) Others, please specify _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

10. How do you store your tomato when you buy it from the market? _ _ __ __ _ _ _

11. How long does it last with the above storage method? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

12. Do you need help with the above storage method? a) Yes [ ] b) No [ ]

If yes? What is the quantity loss/waste? _ _ _ _ _ _ _ _ _ _ _ _ _

D. Food Loss in the house.

13. How many are you in your household? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

14. Do you plan your meals at home? a) Yes [ ] b) No [ ]

14a) If yes, is this: a) Daily [ ] b) Weekly [ ] c) Monthly [ ] d) Others

please specify _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

15. How often do u use tomato in your meals?

a) Every meal [ ] b) Twice a day [ ] c) Once a day [ ] d) Once a week [ ]

e) Others please specify _ _ _ _ _ _ _ _ _ _ _ _ _

16. Do you encounter losses and waste with the tomatoes you buy? a) Yes [ ] b) No [ ]

a) If yes, where does the waste occur? _ _ _ _ _ _ _ _ _ _ _ _ _

14b. What is the amount of tomato lost/waste in on a typical week?

a) 0-10 % [ ] b) 11-20 % [ ] c) 21-30 % [ ] d) 31-40 % [ ] e) 41-50 % [ ]

e) Others please specify _ _ _ _ _ _ _ _ _ _ __ _ _ _ _ _ _ _ _ _

17. What other challenges do you face with tomato at home?

_ _ _ _ _ _ _ _ _ _ _ _ _ _

18. What do you want government to do to reduces the amount of tomato waste in your household?

Appendix 5

Interview Questions

Survey on post-harvest losses and waste in tomato supply chain

This survey is conducted to gather information on post-harvest losses and the waste of tomatoes. The survey cut across tomato farms to reveal the hidden social and cultural factors affecting tomato farmers and the causes of losses and waste along the value/supply chain. The questionnaire seeks to gather information on the quantity and quality of fresh tomatoes lost on farms, in transit and in households.

Name of Organization	
Date of interview	
State	
Local Government Area	
Name of enumerator	
Name of respondent	

1. How long have you been planting tomato? _ _

— – – — — – – — – – — – – – – – —

2. What is the total size of your tomato farms?

– – — – – — — – – — – — – – – – —

3. What is your total tomato production capacity in a season?

– – – – – — – — – – – — – – – – – — – – — — —

4. What is the total amount of tomatoes produced annually?

– –

5. How are the tomatoes packed?

– – — – – — — – – — – — – – – – —

6. What is the size of the container?

– – — – – — — – – — – — – – – – —

7. How do you transport your tomatoes?

– – — – – — — – – — – — – – – – —

8. Where do you sell your tomato too?

– – — – – — — – – — – — – – – – —

9. Does the government invest in local farmers, and how much does it invest?

– – — – – — — – – — – — – – – – —

10. Do you or the government monitor tomato post-harvest losses?

_ _

11. How will you describe your farm's tomato losses and waste?

_ _

12. Do you have data on the number of tomato losses and waste at the post-harvest stage along the supply value chain?

_ _

13. Identify the stages that cause losses and waste annually in the tomato supply chain.

_ _

14. Do you have a good supply chain? Could a cold supply chain for fresh and perishable farm products?

_ _

16. What problems do you encounter in your tomato business?

_ _ — _ _ — — _ _ — _ — — _ _ _ _ _ _ _ _ _ _

15. What can be done to improve the supply chain and reduce losses and waste?

_ _

Appendix 6

Tomato companies

Survey on post-harvest losses and waste in tomato supply chain

This survey is conducted to gather information on post-harvest losses and waste of tomatoes. The survey cut across tomato farms to reveal the hidden social and cultural factors affecting tomato farmers and the causes of losses and waste along the value/supply chain. The questionnaire seeks to gather information on the quantity and quality of fresh tomatoes lost on farms, in transit and in households.

Name of Company	
Date of interview	
State	
Local Government Area	
Name of enumerator	
Name of respondent	

1. When was your tomato paste company established?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

2. How did you acquire your company? a) Inherited [ ] b) Purchased [ ]

c) Rent [ ] d) Others [ ] Please specify _ _ _ __ _ __ _ _ _ __ _ __

3. What motivated you to build the tomato paste company?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

4. What is the size and capacity of your company's production?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

5. Where do you get your raw material from?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

6. Is your company funded by any local or foreign investor?

_ _ __ __ _ _ _ _ _ _ _ _ _ __

7. Are you able to mobilise adequate finances to cover your operations?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

8. Do you involve local tomato farmers for supplies?

_ _

9. Do you get the required quantity needed for your production from local farmers?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ __ _ __ _ _ _ _ _

10. How will you grade the supply of local fresh tomato to your factory?

a) Very good [ ] b) Good [ ] c) Okay [ ] d)Bad [ ] e)No comment [ ]

11. Do you have records of quantity purchase and amount of loss within the supply chain?

_ _ _ _ _ _ — _ _ _ _ _ _ _ _ — _ _ — _ _ _ _

12. Do you generate losses on your daily operation?

_ _ _ _ _ — _ — _ _ _ _ _ _ _ _ _ _ _ — _

13. What is the amount of waste generated on a daily base?

— _ _ — _ _ _ _ _ _ _ — — _ _ _ _ _ _ — —

14. What is the amount of loss generated by your factory annually?

a) 50 - 100 kg [ ] b) 100 - 200 kg [ ] c) 200 - 500 kg [ ] d) I do not know [ ]
e) Others, please specify _ _ _ _ _ — _ _

15. State the stages involved and losses or waste within the supply value chain of tomatoes in your company in a good season.

_ _ _ _ _ — _ _ _ _ _ _ _ _ — _ _ _ _ _ — _ _ _ _ _ _ — _

16. In a few words, how can we improve supply chain management to reduce waste?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _