



Assessment on post-harvest losses of tomato value chain in Ikire, Osun State, Nigeria

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DECLARATION

I, Oyewale Oyesuntimi John (40018059), declare that the dissertation titled “Assessment of post-harvest losses of tomato value chain in Ikire, Osun State, Nigeria”, submitted to the department of Agricultural Economics and Extension, was solely prepared by myself and has never been previously submitted by anyone at any other institution. I declare that all materials and work of others contained in the study have been duly acknowledged by means of complete references.

Signature of student.....

Date.....

Signature of supervisor(s)

Date.....

DEDICATION

I dedicate this study to God and to my parents, Mr R.O. Oyesuntimi and Mrs GT Oyesuntimi. Without their support and encouragement, this study would not have been completed on record time.

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ABSTRACT

Tomato (*Solanum Lycopersicum*) is a popular vegetable that belongs to the family Solanaceae. It is largely cultivated and consumed globally, due to its nutritional content. It is called “the poor man’s orange” because it is rich in vitamin C, marlic, and citric acids and is cheap in its price. It is a stable crop produced by small-scale farmers to meet their household needs and nutritional supplements. The purpose of this study was to assess post-harvest losses of the tomato value chain in Ikire, Osun State, Nigeria. The main objectives were to: examine the socio-demographics of farmers, post-harvest handling practices, and tomato post-harvest losses; examine determinants of farm-level post-harvest losses of tomato; and understand constraints faced by farmers at each stage of the tomato value chain. To achieve these objectives, a structured questionnaire, random sampling, and snowball selection techniques were used to collect primary data from small-scale tomato farmers. Cobb Douglas production function was used to examine determinants of farm-level post-harvest losses of tomatoes. Regarding the demographic characteristics of farmers, the results revealed that 17.5% were artisans, 13.8% civil servants, 35% full-time farmers, 8.8% public transporters and 20% traders. This is an indication that most respondents were involved in other activities not related to farming and marketing of farm products. The findings from the Cobb Douglas production function show that variables, such as education (coefficient = -0.308: $P=0.021$), size of household (coefficient = -0.255: $P<0.05$), total amount of harvest = 1.844: $P<0.05$) and selling price (coefficient -1.766: $P<0.05$) were major determinants of farm-level losses of tomatoes. Pest and diseases were ranked first by farmers as their major constraints. The study also discovered several factors that have a significant impact on fresh tomato postharvest losses among actors (farmers). Inadequate storage facilities, lack of financial support and Inadequate ready markets to sell produce were identified as major constraints faced by farmers at various stages of the value chain of tomato. Most farmers lacked training and 85% of respondents lacked storage facilities to preserve their produce. There is a need therefore, for farmers to seek technical and financial information from various institutions that provide credit facilities and technical support. There is also the need for farmers to formulate a strong pricing policy to covers losses incurred during post-harvest process as such efforts could assist in reducing and/or eliminating post-harvest losses of tomatoes as it reduces revenues and profit of farmers.

Keywords: Cobb Douglas production function; post-harvest loss; small-scale

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LIST OF ABBREVIATIONS AND ACRONYMS

GDP	Gross Domestic Product
FAO	Food and Agriculture Organisation
SPSS	Statistical Package for the Social Sciences
PHL	Post-Harvest Loss
IAR	Agricultural Research

CHAPTER ONE

BACKGROUND OF THE STUDY

Introduction

Estimates of the Food and Agriculture Organisation of the United Nations suggest that one-third of all food produced globally, is lost or discarded before consumption (Mok *et al.*, 2020). The amount of loss of foods varies between nations and is impacted by economic growth, industrialisation and levels of income (Chalak *et al.*, 2016). Most of the food and crop loss occurs in less developed nations during the post-harvest and manufacturing stage (Gustavsson *et al.* (2011), accounting for around 44% of food waste worldwide (Lipinski *et al.*, 2013). Poor business practices, technical and financial constraints, workforce shortages, and lack of adequate infrastructure for transportation and storage, are the root causes of this situation (Gustavsson *et al.*, 2011). Even in areas where food insecurity is prominent, such as Africa, around 20% of all grains, 44% of roots and tubers, and 52% of fruits and vegetables are lost between harvest and consumption (Mok *et al.*, 2020). Every year, around 1.3 billion tonnes of food are lost globally. Approximately 40% to 50% of vegetable crops produced are lost before they can be consumed, due to injuries, insect and pathogen attack, as well as decay (Kitinoja & Kader, 2002). Additionally, 30percent to 40percent of crop damages and losses are frequently reported after harvest due to reasons such as mechanical damage, pests and diseases, as well as rot caused by microbial infection or extreme temperature. (Meena *et al.*, 2009).

Despite the significant oil earnings, agriculture remains one of the most important industries of the Nigerian economy. Agriculture accounts for more than 40% of Nigeria's GDP, employs around 70% of the population, and supplies approximately 80% of the country's food needs. (Olayemi *et al.*, 2021). In agriculture, 'vegetable' refers to plants and plant parts that are edible, especially leafy, or fleshy parts usually eaten with staples as main courses or supplementary foods in cooked or raw forms. It is estimated that there are at least ten thousand plant species used as vegetables worldwide, although only about fifty are of great commercial value (Ajibade *et al.*, 2021). Vegetables are any edible and generally succulent part of a crop or part of a plant that is not a sweet fruit or seed with a savoury flavour (Blancke, 2016). Roots, bulbs, stalks, blooms, tulips, leaves, flowers, pollen and fruits are among the edible parts (Creasy, 2012). Vegetables vary in structural form, nutritional composition, and overall plant physiology. As a result, the needs and recommendations for maximal pre and post - harvest life vary depending

on the kind of vegetable species (Sudheer & Indira, 2007). All vegetables have a high moisture content by nature, making them particularly perishable. If not managed properly, a portion of high-value nutritional food can degrade and perish in a couple of days, if not, hours (Smid & Gorris, 2020).

According to Ajibade *et al.* (2021), different types of vegetables are cultivated in Nigeria, and tomato stands out as the most important, both in scale of production and level of consumption. It is grown for home consumption in most homesteads and also cultivated on a commercial level, as a cash crop for most farmers, profit organisations and industries. It is also reported that a total of over one million hectares is used for its cultivation, accounting for about 18% of the average consumption in vegetables in Nigerian homes (Nwigwe *et al.*, 2020). Most dry season market gardeners produce tomatoes as their main crop. Its cultivation is said to take up a total of one million hectares of land annually in Nigeria, and accounts for around 18% of average daily vegetable households' intake (Ajibade *et al.*, 2021). With 1.701 million tonnes of tomatoes produced annually at an average of 25 to 30 tonnes per hectare, Nigeria is the second biggest producer of tomatoes in Africa and the thirty-first largest in the world (FAO, 2010). In Nigeria, demand for most other vegetables is constrained, while the demand for tomatoes is unrestricted (FAO, 2010). Tomato, grown either as a principal or secondary crop in Nigeria by most producers, can be consumed raw in salads or processed into paste or puree, which can be used for cooking savory dishes (Ojedokun, 2020).

Tomato (*Solanum Lycopersium*) is a common vegetable in the Solanaceae family. It is largely cultivated, and the consumption rate is globally due to its nutritional content. It is referred to as the “the poor man’s orange” because it is rich in vitamin C, malic and citric acids and also cheap in its price (Abdalla *et al.*, 2020). It is an important cash and industrial crop in many parts of the world, as well as economic and nutritional value (Arah *et al.*, 2015). Its production is almost restricted to the derived savanna due to the favourable condition. However, a considerable amount of production has been recorded in some areas of lowland rainforest agroecological zones, where the yield is still below 10t ha⁻¹ average world production (Titilayo *et al.*, 2020). Tomato is a climacteric fruit and due to this ethylene triggers, the ripening process and ethylene normally is needed for normal fruit ripening. During the ripening process, tomato undergoes some changes, such as colour, texture, flavour and aroma. The changes in colour are due to the diminishing chlorophyll II pigment, which unravels pre-existing pigments, as well as the accumulation of different types of compounds, such as carotenoids (Thole *et al.*, 2020).

Tomato production in Nigeria is done on large scale. Despite the huge production observed in the country, post-harvest losses are reportedly high. These losses may occur as result of negative climatic conditions, poor processing facilities, local cultural practices, inflating cost of farm imputes, low market price and low motivation of human resources (Kitinoja *et al.*, 2019). Due to the climacteric nature of tomato, the ripening process is accompanied by a rapid rise in respiration rate termed “respiratory climacteric”. During this process, oxidation takes place through the break-down of complex substrates, resulting in ageing and deterioration. Since tomato is a fleshy fruit, it continues to lose water after harvest (Geetha & Indhu, 2020). Pathare *et al.* (2021) state that during harvesting and marketing, temperature is one of the major factors that impact the quality of tomato since it directly influences the rate of losses. The authors further posit that temperature can influence the colour, firmness, and aroma of tomatoes. Reports from previous studies have shown that storage temperature of around 10⁰C is the most appropriate temperature condition for maintaining quality and delaying the softening of tomato and that anything apart from these, will result in post-harvest loss.

Commercially, tomatoes destined for the fresh market are picked at different ripening stages, depending on the proximity between production and marketplace, and vary from green and firm to almost ripe for local markets (Thole *et al.*, 2020). Long-distance transportation of tomatoes involves storage at low temperatures to limit post-harvest losses and to extend shelf life (Abimbola, 2014). Fruits often also undergo ethylene treatment to induce colour and ripening before reaching the supermarket shelf. Artificial ripening and cold storage have, however, detrimental effects on the flavour, aroma and texture of tomatoes (Zhang *et al.*, 2016). Commercial tomato harvesting takes place at various stages of ripeness, from hard green for long-distance distribution, to ripe for local fresh-market supply (Saltveit, 2018). The degree of fruit maturity at harvest, the distance to markets, the length of storage/travel, and the planned use of the product all influence storage and transport procedures, especially temperature regimes (fresh or processed). The ideal ripening temperature range for tomatoes is between 18 and 21 °C. However, low storage temperatures (5–12 °C) are widely used to postpone ripening, reduce post-harvest losses and increase shelf life. Long-term exposure to low temperatures, however, can result in chilling damage, such incomplete or uneven ripening, early softening, uneven colour development, increased susceptibility to infections and weakened sensory features (Baldwin *et al.*, 2011; Zhang *et al.*, 2016).

The production of tomato, compared to its cultivation, is low because of production constraints and post-harvest losses. As a result, post-harvest loss can be referred to as tomato production

challenges, ranging from climatic change, pre-harvest factors, time of harvest to post-harvest handling. Thus, post-harvest losses (PHL) refer to losses that occur along the food value chain, from the harvesting period to the table of the final consumer (Njume *et al.*, 2020). According to Aghadi *et al.* (2020), losses are also encountered along the value chain in handling, storage, transportation, processing and marketing thus, resulting in the degradation of both quantity and quality, as well as in the market value of tomato produced. There is need for appropriate evaluation methods to examine possible factors responsible for major post-harvest losses and possible ways to reduce post-harvest losses, especially in tomato production.

Due to the perishability of tomatoes, producers face challenges in supplying vegetable fruits, such as tomatoes to market centres (Ugonna *et al.*, 2015). Longer distances between local farms and the assembly markets, as well as post-harvest technical management, such as grading, repackaging, warehousing, and shipping, result in a greater proportion of fruits wasted at various stages of the post-harvest value chain (Paltrinieri & Staff, 2014). According to Alidu *et al.* (2016), post-harvest losses of vegetables are caused by lack of technical assistance, inadequate market structures, improper handling of food by farmers and other players, poor transport networks, market intermediaries and consumers. The ability of packing containers to prevent perishable vegetables from physical damage, allow appropriate ventilation throughout distribution and sale, and keep their freshness, are critical in reducing post-harvest losses and improving the lives of value chain players (Kiaya, 2014). However, the traditional woven baskets widely employed in packing fresh tomatoes for distribution and sale in Nigeria do not protect against physical damage, compression, and high heat during transit and storage (Kitinoja *et al.*, 2019). Furthermore, these baskets can be used only for a limited number of times, in some cases, only once or twice. Due to losses experienced, there is need to further examine or study different ways and methods to prevent losses.

1.1.1 Agricultural value chain

The value chain (VC) refers to the sequential links that turn raw materials and resources into marketable goods (Fernandez-Stark & Gereffi, 2019). It is a collection of interconnected activities that seek to increase the value of a product; it comprises actors and actions that improve a product while connecting commodities producers to processors and marketplaces (Anastasiadis *et al.*, 2020). A value chain includes the movement of goods, knowledge, information, money, payments, and the social capital required to organise producers and communities (Masud *et al.*, 2020). The concept of a value chain allows for the integration of

multiple actors in agricultural production, processing, and marketing. It describes the various responsibilities of actors while also defining the scope and purpose of potential collaborations (Igwemeka & Ekwunife, 2020). The value chain depicts the entire spectrum of tasks that businesses and employees carry out to move a product from its conception to its ultimate usage and beyond. This covers tasks, including design, production, marketing, distribution and customer service (Kamble *et al.*, 2020). A value chain's components can either be confined inside a single business or distributed among several enterprises (Lavelli & Beccalli, 2022). Actors involved in tomato production, trade, shipping, retailing, and processing, make up the agricultural value chain in general. The value chain is examined in this study, along with the connections and interactions between the various actors, particularly between farmers and middlemen, producers, transporters, wholesalers, retailers, and consumers, as well as the full spectrum of tasks involved in the tomato post-harvest activities from farm to market.

1.1.2 Actors involved in the value chain

A farmer is a person who accepts responsibility and makes a choice in terms of gathering resources. During the process, the farmers answer the three basic economic questions which are: What to produce, how to produce it and for whom to produce it for.

1.1.3 Intermediaries/commission maker

A middleman is an individual who collects varied produce amounts from various producers and sells to large-scale dealers, processors, retailers, processors, or even exporters. The intermediary is an expert at selling a product (Mbeine, 2016). The middleman between the producer and the wholesaler, retailer, and customer, is the commission agent. He is the only vendor who is acknowledged "legally." To sell tomatoes, he searches for customers, agrees on "acceptable" rates, buys them for a profit and then gives the farmer the money. On every basket of tomatoes sold, he earns a commission for his services, which is a certain sum of money (Singh & Guleria, 2021).

Agricultural losses occur throughout the production value chain and thus is caused by insufficient facilities and supervision. Agricultural wastage can be classified as both quantitative and qualitative (Rezaei & Liu, 2017). Overall, post-harvest losses occur during the distribution of products from cultivation site to the place of sale (Aulakh *et al.*, 2013). Nutritional component, customer acceptability, and fresh food edibility losses are examples of qualitative losses. These losses are often felt in advanced economies. (Emana *et al.*, 2017).

Quantitative loss is waste in terms of a product's volume and weight. In underdeveloped countries, quantitative loss has been the main issue (Kitinoja *et al.*, 2011). According to FAO (2013), food quantity loss and undesired food are more prevalent in wealthy nations, but lower in developing ones, where more food is lost and wasted in upstream stages. Due to the perishability of these goods, producers confront challenges in supplying vegetable fruits, such as tomatoes to market centres (Rizvi *et al.*, 2020).

1.2 Problem statement

Tomato production in Nigeria is normally at its peak due to its economic and nutritional value, which helps most rural and urban dwellers as a means of obtaining excellent quality food nutritive additives. However, due to poor harvesting techniques, poor handling, and lack of processing infrastructure, post-harvest losses have been taking a high toll. As a result, reducing food losses decreases food importation, enhances availability of food, thus, increasing the welfare of tomato farmers (Balana *et al.*, 2022).

Insufficient effort has been made to decrease crop post-harvest losses, such as tomatoes, but significant resources have already been invested on vegetable cultivation, irrigation, fertilizer application, and crop safety standards (Ayandiji *et al.*, 2011). Reduced post-harvest food losses result in increased total availability of food, less food import, and improved farmer wellbeing. (Abimbola, 2014).

Continuing with these current cultural and local methods of tomato cultivation and harvesting, will lead to continuous depreciation in the quantitative and qualitative value of tomato production. Such action could also reduce the nutritional and economic standard of living of the masses, due to its undeniable importance.

There is need to develop a more efficient way of reducing the level of post-harvest losses to improve tomato production. Qualitative and quantitative approaches were used in the study to gather primary information on factors responsible for post-harvest by tomato farmers and ways to reduce such losses, if possible.

1.3 Aim and objectives of the study

1.3.1 Aim of the study

Responses to these questions will provide answers to how post-harvest losses in the tomato value chain can be reduced or eliminated, by analysing factors that affect post-harvest handling of tomatoes. It could also increase the quantity of tomato production to the global food supply chain, especially in the tomato value chain sector.

The main objective of this study was to assess post-harvest losses in the tomato value chain in Ikire, Osun State, Nigeria.

The specific objectives of the study are:

- To examine the socio-demographic characteristics, post-harvest handling practices and post-harvest losses experienced by tomato farmers.
- Examine determinants of post-harvest losses of tomato at the level of the farm; and
- Understand constraints faced by farmers at various stages of tomato value chain.

1.3.2 Research questions

The following research questions were asked in the study:

- What are the socio-demographic characteristics, post-harvest handling practices, and post-harvest losses experienced by tomato farmers?
- What are the determinants of post-harvest losses of tomato at the level of the farm?
- What are the constraints faced at the various stages of tomato value chain?

1.3.3 Hypothesis

Ho: There is no consensus among respondents' ranks.

Ha: There is consensus among respondents' ranks.

1.4 Justification of the study

Several studies have been conducted on tomato production around the world. However, there is paucity of research on post-harvest losses on tomato production in Nigeria. Farmers and buyers

of fresh tomatoes have been experiencing losses over the years thus, the need for a study to identify challenges faced by tomato farmers and possible solutions to mitigate their losses.

Tomatoes are a short season crop and very perishable, resulting in losses during the prime harvesting season. Due to the difference in supply and demand in the off season, as well as the economy considerations, it is necessary to prevent such losses (Emana *et al.*, 2017). Regardless, adopting excellent crop conservation strategies to conserve tomatoes for extended periods of time are vital, since it is necessary to enhance tomato storage period, whether fresh or processed. Estimating post-harvest losses leads to the identification of prospective post-harvest treatments that might assist in addressing significant drivers to losses along the value chain, thus, reducing losses (Befikadu, 2018).

This study is unique because it focuses on the different stages of cultural practices carried out by the local government areas for years, in order to remodify these techniques by providing a basic way forward on ways to improve the production scale of tomatoes along the value chain. The study also focuses on constraints experienced by farmers and provides basic information to rural and urban dwellers involved in tomato production, selling, and consumption through extension services on how to improve the value. The study will add to the body= knowledge by filling the gap in the literature on primary contributors and variables that influence post-harvest losses along the tomato value chain. This study will also assist farmers, distributors and retailers in the community in learning how to improve existing post-harvest procedures, to reduce post-harvest losses of tomatoes along the value chain.

Information was obtained through interaction with stakeholders and data analyzed to meet the needs of the masses in the State, country and the entire world. This research provides a platform to communicate information to the educated and uneducated on how to effectively address post-harvest losses as a problem in value chain of tomato. Such information can be used as a prototype for other perishable crops. Furthermore, the study will assist key stakeholders to develop a research-based legislative structure and plan to enhance the degradation of post-harvest losses in the tomato sector.

1.5 Structure of the study

The purpose of this study was to analyze the fundamental causes of post-harvest losses along the value chain in tomato farming, as well as the effects of farm-based remedies. The findings of the study have the potential to influence the formulation of policies by government and other

stakeholders aimed at reducing post-harvest losses. The study is divided into six chapters. Chapter One provides the introduction and background of the study. Chapter Two provides a review of the research on post-harvest losses, policies and initiatives implemented to reduce losses. The Chapter also outlines a vacuum in the literature on post-harvest losses ways to fill the gap. Chapter Three focuses on the methodology used in the study. Chapter Four provides the analysis and presentation of findings. Chapter Five is a discussion of the findings, while Chapter Six focuses on measures to reduce post-harvest losses in order to enhance tomato output across the value chain.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents a literature assessment on post-harvest losses in tomatoes harvested as fresh crops. The chapter is organized into sections as follows Section 2.2 reviews the nature and character of tomatoes; Section 2.3 provides an introduction to the fundamental concept of post-harvest losses in fresh fruits and fresh vegetables; Section 2.4 focuses on pre-harvest as well as post-harvest processes that contribute to post-harvest losses; Section 2.5 focuses on techniques used during pre- and post-harvest stages of tomatoes; Section 2.6 provides a discussion on marketing of tomatoes; Section 2.7 is based on factors that affect post-harvest losses; while Section 2.8 focuses on the estimation of losses during post-harvest activities.

2.1 Properties of tomatoes

The tomato (*Solanum Lycopersicum*) was introduced to Europe in the late 1490s by Columbus as well as other explorers, but it evolved in South and central America. It is a member of the Family solanaceae, which also contains potato, pepper and tobacco. This family's fruits and vegetables contain poisonous alkaloids. (Saavedra *et al.*, 2016). According to Anaba (2018), The Solanaceae family, which includes the subfamilies Cestroideae, Solanineae, and Solaniodeae is made up of 96 genus and around 2800 varieties spread over the subfamilies. Commercial tomato production began around 1960. It is called the “the poor man’s orange” because it is rich in vitamin C, marlic and citric acids and also cheap in terms of its price (Abdalla *et al.*, 2020). It is a valuable cash and commercial crop in many regions around the world, with economic as well as nutritional importance (Arah *et al.*, 2015). Its production is almost restricted to the derived savanna due to the favourable conditions. However, a considerable amount of production has been recorded in some areas of lowland rainforest agroecological zones, where the yield is still below 10t ha⁻¹ average world production (Titilayo *et al.*, 2020).

Tomato is a seasonal fruit; ethylene triggers the maturation process and is needed for consistent fruit development. During the ripening process, tomato undergoes changes in terms of colour, texture, flavour and aroma. The change in colour is due to the diminishing chlorophyll II

pigment, which unravels pre-existing pigments, as well as the accumulation of different types of compounds, such as carotenoids (Thole *et al.*, 2020). It is a popular vegetable crop worldwide, with over 5×10^6 hectares under cultivation, has an annual output of around 161×10^6 metric tons. It is ranked the first vegetable in the world and accounts for 14% of world vegetable production (US\$ 1.6 billion market value) (Seid *et al.*, 2015). Tomatoes mostly are cultivated from mid-August to mid-November, with harvesting taking place from December to mid-January. Tomatoes are a highly perishable crop, and half of the tropical tomato output is lost between rural and urban consumption (Khatun & Rahman, 2020).

Chishti *et al.* (2019) state that tomato is a subtropical plant, a short duration crop, grows best at a temperature range of $16^{\circ} - 29^{\circ}\text{C}$ and its colour changes at $20^{\circ} - 29^{\circ}\text{C}$. According to Joel *et al.* (2020), tomato is one of the most important vegetables produced in Nigeria and consumed in different forms due to its nutritious value. Nigeria is among the world's leading producers (ranked 13th), and also the leading producer in sub-Saharan Africa (Indabo & Abubakar, 2020). Due to its wide range of varieties, farmers in Nigeria are privileged to choose varieties of tomatoes to plant; crop types differ in their responses to a variety of meteorological conditions, soil attributes and agronomic management approaches. Tomato cultivars differ in their responsiveness to weather conditions, agronomic techniques, and nutritional management used for growth and production. As a result, it is critical to assess the responsiveness of different types tomatoes to various nutritional management strategies (Abdulmalik *et al.*, 2019).

2.2. Nutritional values of tomatoes

Tomato is a major Industrial and commercial crop in many regions around the world, not only because of its economic relevance, but also because of its nutrient content in human diet and consequent importance in human health (Ayandiji *et al.*, 2011; Willcox *et al.*, 2003). Tomato has a high concentration of vitamins, Phosphorus, carbohydrates, vital amino acids, dietary fibres, iron and minerals (Ayandiji *et al.*, 2011). It provides a source of these nutrients when consumed. The table below lists the 15 key nutrients and their respective quantities that may be received by eating 123 grams of ripe tomatoes

Table 2:1: The 15 key nutrients derived from tomatoes

Nutrients		Amounts
Calcium		1.2mg
Carbohydrate		4.7g
Copper		0.073
Dietary fiber		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 sugars		3.23g
Vitamin C		16.9mg

Source: The USDA National Nutrient Database (2010)

2.2.1 Health benefits of tomatoes

Tomatoes, which can also be considered as fruits, have several health advantages. They are, in fact, a highly flexible health product, and with similarly diverse preparation methods, there is no need to overlook tomato as part of a healthy diet (OYEBAMIJI, 2020). One of the most widely recognised dietary benefits of tomato is the presence of Lycopene. It is an important antioxidant that aids in the prevention of the development of cancerous cells, as well as other health difficulties and disorders (Salehi *et al.*, 2019). Abundant amounts of Lycopene in the body may flush out free radicals, and tomato is so excessive in this crucial antioxidant that it draws its deep red colour from it. Lycopene is thought to be the primary ingredient in tomatoes that contributes in decreasing risks of prostate cancer. (Przybylska, 2020). Research has revealed that eating tomatoes and veggie meals can lower the risk of a range of cancers, including pancreatic, pulmonary, gastrointestinal, colonic, pharyngeal, bladder, cervical and breast cancers (Kumar *et al.*, 2020).

Lycopene in tomatoes increases conception by enhancing sperm quality and swimming pace, while decreasing the quantity of defective sperm in males (Leong *et al.*, 2018). Consumption of tomatoes can help prevent age-related problems, such as Parkinson's disease, osteoporosis, Alzheimer's and dementia (Kyriazis, 2021). Tomatoes are rich in the antioxidant's vitamin C and A, which help to prevent muscle deterioration and enhance vision. When Lycopene was placed in a pre-existing cancer cell culture, it inhibited the cells from growing further. This is compelling proof that eating tomatoes has health advantages. Lycopene is present in as little as 540 milliliters of liquid tomato product. This is an indication that drinking a glass of tomato juice every day can keep a person healthy for the rest of their lives. Tomatoes are just as healthy and fresh as they are in other forms (Gonzali & Perata, 2020).

2.3 Tomato production in Africa

Africa accounts for 11.8 percent of world tomato output (Olowe *et al.*, 2022). Due to its flexibility, tomato is one of the most frequently farmed crops on the African continent, with production spanning smallholder and commercial agricultural groups. The Trend study conducted between 2014 and 2017 revealed that Egypt is still the biggest tomato producer in Africa, with Nigeria coming in second position (Dube *et al.*, 2020).

Table 2.2: Top 15 tomato producing countries in Africa

Ranking	Country	Production (tons)
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	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	188 767

Source: (FAOSTAT, 2014)

Production strategies vary across the Continent based on agroclimatic conditions, ranging from greenhouses to outdoor plains, with different application of levels of technology.

2.3.1 Challenges impeding tomato production in Africa

Tomatoes have the potential to improve the lives of small-scale local farmers in most African countries. Aside from the healing properties of tomatoes and tomato-based dishes, the crop can be a source of earnings for farmers due to its diverse purposes. Tomato business has the potential to boost foreign export earnings of African countries thus, adding to gross domestic product (GDP). In Ghana, for illustration, the tomato sector has been highlighted as a possible source of alleviating poverty, due to its potential for development and job creation (Anang *et al.*, 2013), while in Nigeria, production of the crop has improved the life of most rural and peri-urban farmers and helped the economy (Adenuga *et al.* 2013).

Though tomato can enhance the existence of rural farmers, studies have shown that the full potential of the crop has been underutilized due to a variety of problems. Due to the absence of appropriate irrigation infrastructure, most tomato cultivation in Nigeria (and most African nations) is dependent on rainfall (Adenuga *et al.* 2013). As a result, production occurs exclusively during the rainy season. Pests and diseases, inferior quality and inadequate quantity of tomatoes produced, and competition from international importation, are factors that limit tomato production in Africa (Robinson and Kolavalli, 2010).

2.3.2 Tomato production in Nigeria

Tomatoes thrive in various regions of Nigeria, although the ideal place is the Savannah agricultural production zone, where tomato diseases and pests are less prevalent. Top producing regions are located between latitudes 7.5°N and 13°N, with temperatures ranging from 25°C to 34°C. These states include Bauchi, Benue, Borno, Kano, Kaduna, Plateau and Jigawa in the North, as well as Kwara, Delta and Oyo (Osun) in the South. Tomatoes are a warm season crop and susceptible to excessive humidity and rain. Consequently, well-drained soils with sandy loam rich in humus, experience high crop yield. The planting season lasts from August through September. Where irrigation farming exists, however, the optimal time to plant is during the dry season.

According to Ebimiewei and Ebideseghabofa (2013), Nigeria was the second greatest producer of tomatoes in Africa after Egypt and the 13th in the world prior to 1990, with an output of six million tons yearly. Tomatoes are cultivated in a variety of agro-ecological regions in Nigeria, ranging from humid in the South to sub-humid in the middle belt and semi - arid regions in the North. It is grown in the country's northern areas, from latitudes 7.5°N and 13°N, and at

temperatures ranging from 25 to 34°C. According to Idah, Ajisegiri and Jiya (2007a), Nigeria produces vast quantities of fruits and vegetables, and inconsistency statistics are occasionally quoted as expected yearly production. Despite the vast and inconsistent statistics reported each year, fresh tomato fruits are inaccessible in most homes; instead, dried unhygienically processed tomatoes now function as replacement.

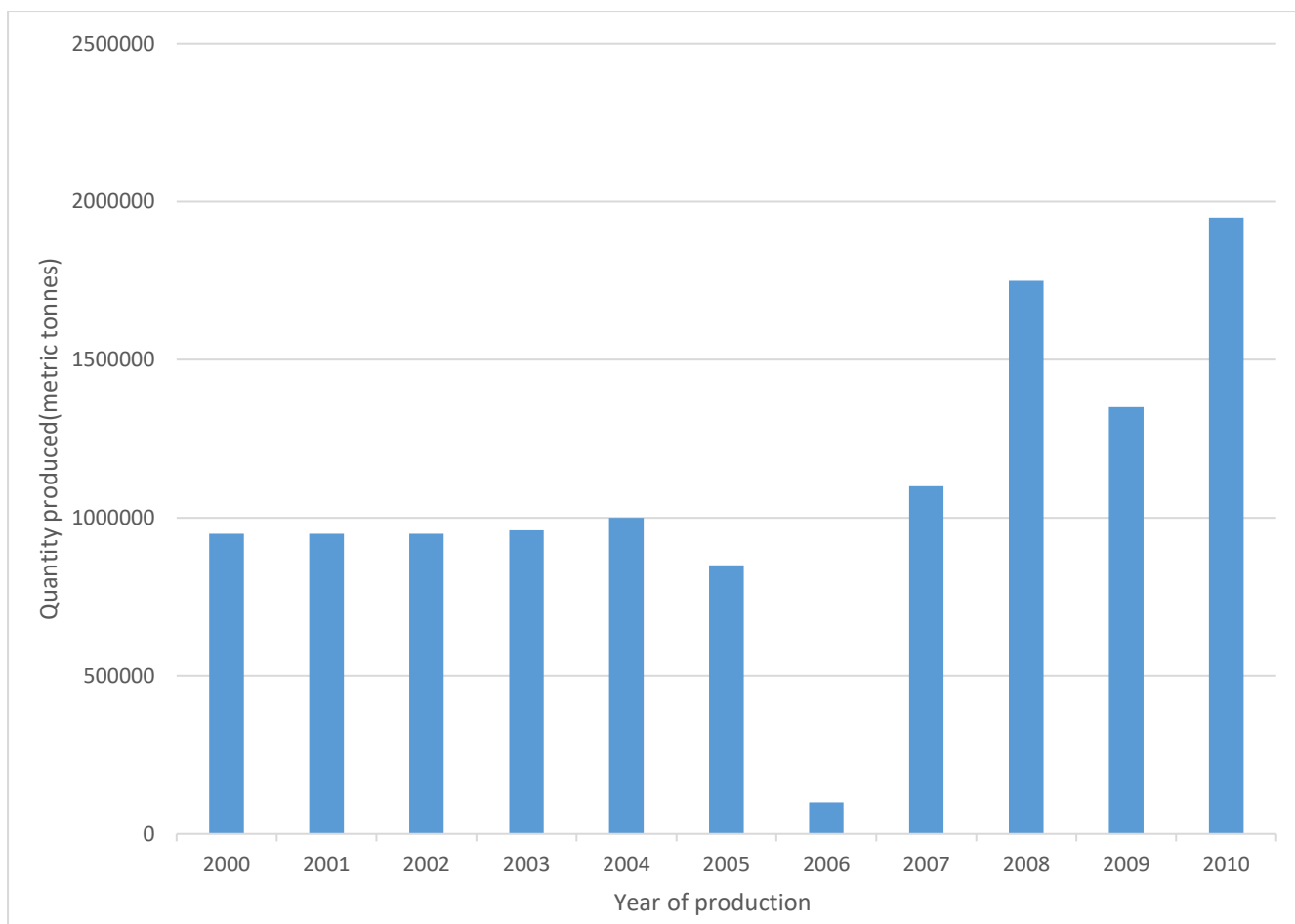


Figure 2.1: Tomato production trend in Nigeria (2000-2010)

Source: Ugonna *et al.*, 2013

Figure 2.1 above shows the development in tomato output in Nigeria from 2000 to 2010. The largest production was in 2010 and the lowest in 2006. In 2010, the total yield was 1,860,600 metric tons, estimated at \$687,610,000. Majority of tomatoes produced are for the domestic market, however, they are scarce during the off-planting season. The nationwide consumption of fresh tomatoes is around 2 to 3 million metric tons per year, resulting in a demand gap of approximately 500,000 metric tons. To close the shortage, 105,000 metric tons of tomato paste worth N16 billion was imported between 2009 and 2010 (Ugonna *et al.*, 2013).

2.3.3 Challenges hindering tomato production in Nigeria

Nigeria continues to suffer from major input shortages, lack of updated technologies, low return and profitability, significant post-harvest wastage, and inadequate marketing and processing facilities (Balana *et al.*, 2022). The demand for tomatoes and products far exceeds availability. Nigeria has a big market for processed tomato products, with a population of above 170 million

persons, an estimated national population growth rate of 5.7 percent per year, and an average economic growth rate of 3.5 percent per year over the last five years. Besides the Nigerian market, the benefits of globalisation in West Africa can boost the sale of processed tomato products in this area (Ugonna *et al.*, 2015).

Frequent issues arise in tomato production in Nigeria due to its extreme perishability. Diseases, insect pests, excessive flower drop, and nematodes all contribute to low yields and poor-quality fruits. These factors, along with inadequate harvest management, due to lack of storage facilities, marketing tactics and a sufficient road network, among others, impede full-scale tomato production. Instability in the country's agricultural policies also hampers small agricultural farmers, and the execution of unfavourable laws by government agencies over time, slowed agricultural growth (Ugonna *et al.*, 2015).

2.3.4 Tomato production season in Nigeria

Figure 2.2 (FMARD, 2014) shows the consumption patterns of tomato products in Nigeria. From January to April, fresh tomato production is abundant, hence, customers rarely utilise other tomato derivatives. However, from April to September, availability of fresh tomatoes decreases, indicating the off season, and buyers switch to alternate varieties of tomato (hybrid tomato paste). These variations cause fluctuations in the price of tomato products and has an impact on consumption patterns. During this period, imports of tomato paste, and concentrations increase in order address the gap in the demand for tomatoes during the off season. Between September and November, there is an overall decline in imports of fresh tomatoes, whereas, towards the end of the year, importation of tomato paste rises due to lack of fresh tomato supplies (Ugonna *et al.*, 2015).

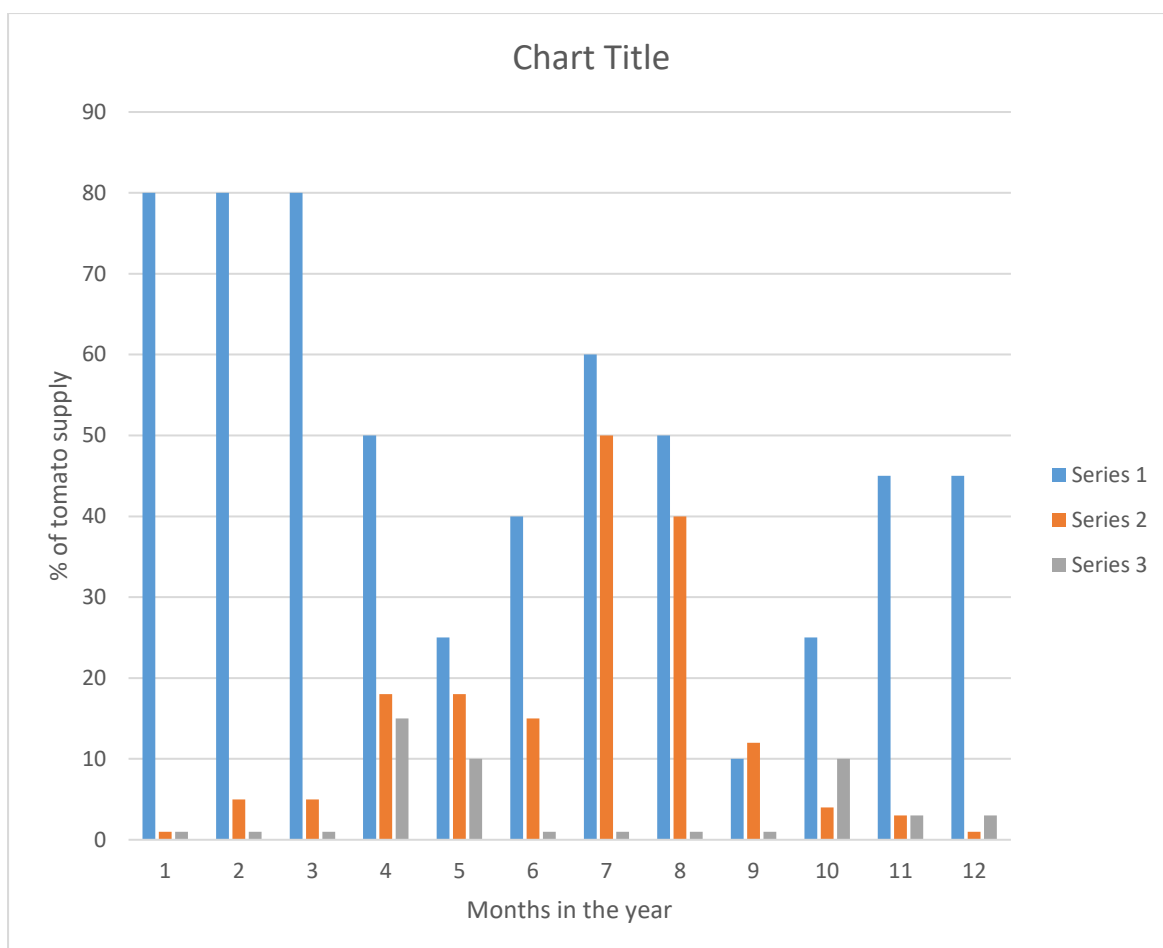


Figure 2.2: Seasonality of tomato production

Source: Federal Ministry of Agriculture and Rural Development, 2014

2.3.5 Varieties of tomatoes cultivated in Nigeria

There are several types of tomato cultivars, which are classified as follows: Sun Gold; Pear Drops cherry; and Napa Grape tomatoes. These different types have the classic delicious tomato flavour and are ideal for salads and snacking overall. These are the earliest to mature since the fruit is tiny. Sauce tomatoes, such as Roma, Amish Paste and Big Mama, have a stronger flavour and less water than other types. They are ideal for spaghetti sauce. Mortgage Lifter, Cherokee Purple, and Brandywine beefsteak tomatoes, offer the largest fruit and the widest variation of flavour and shape. The better types are eaten as an apple and sliced for sandwiches or salads. In Nigerian markets, sauce tomatoes (Roma) are the most popular (FAO, 2006). There are around 7500 tomato varieties in the world. Heirloom tomatoes are becoming extremely prevalent, especially within gardeners and local farmers since they provide more unique and savoury fruits and are disease resilient. While all commercial tomato types are red, certain

cultivars, particularly heirlooms, yield fruit that is green, yellow, black, brown, ivory, white, orange, pink and purple (Sharma *et al.*, 2022).



Figure 2.3: A Tomato variety in Nigeria

Source: FAO, 2006

The superior tomato cultivars depicted in Figure 2.3 produced for industries by the Institute for Agricultural Research (IAR), Ahmadu Bello Institute, are still in use in Nigeria (FAO, 2006).

Table 2.3: Varieties of tomatoes available in Nigeria

Name of variety	Original name	National code	Origin source /	Developing institution	Outstanding characteristics	Year of release
SAMT OM-1	CIRIO-56	NGLE-91-1	Introduction from Steziona Agaria Sperimentale, Bari, Italy	IAR, Samaru Zaria	High yielding, good paste Qualities, field Tolerance to leaf diseases and Moderately tolerance to Fusarium race 1.	1980
SAMT OM-2	MARAN I	NGLE-91-2	Stazione sperimentale, Parma, Italy	-do-	-do-	1980
SAMPT O-3	PIACENZA 0164	NGLE-91-3	Institute Nazionale Gertical Rome, Italy	-do-	High yield under heavy leaf spot disease pressure, good taste qualities	1980
SAMPT ON-4	Harvester	NGLE-91-4	FMG Corp, California U.S.A	-do-	High yield and some heat tolerant; good paste qualities	1980

			Peto, Italian, Parma Italy, USDA, Beltsville USDA			
SAMPT ON-5	CHICO	NGLE- 91-5	Texas- A&M Weslaco	-do-	High yield and good paste qualities	1980
SAMPT ON-6	La bonita	NGLE- 91-6	-do-	-do-	Uniform size, round and attractive fruits with skin suitable for salad	1980
SAMPT ON-7	Roma- VF	NGLE- 91-7	Royal sluis, Enkhuizen, Holland	-do-	Combines high yield with good paste qualities, good processing tomato	1980
SAMPT ON-8	Gamad	NGLE- 91-8	Hazera seed Ltd, ItafaIsreal	-do-	High yield and good paste qualities, good processing	1980
SAMPT ON-9	Gamad-F	NGLE- 91-9	Hazara seeds Ltd., HaltaIsreal, Dizing of W.A.(Nig)	-do-	Similar, to SAMTOM - 8, but also resistant to fusarium yield 42,100-	1980

			Itd, Apapalagos		45,600kg/ha	
SAMPT ON-10	Ife-1	NGLE- 97-10	Faculty of Agriculture O.A.U. Ile Ife, Nigeria.	Faculty of Agric O.A.U. Ile Ife, Nigeria	Skin good for salad, medium size, round and attractive	1980

(Source: NIHORT, 2014)

2.4 Definition of post-harvest system

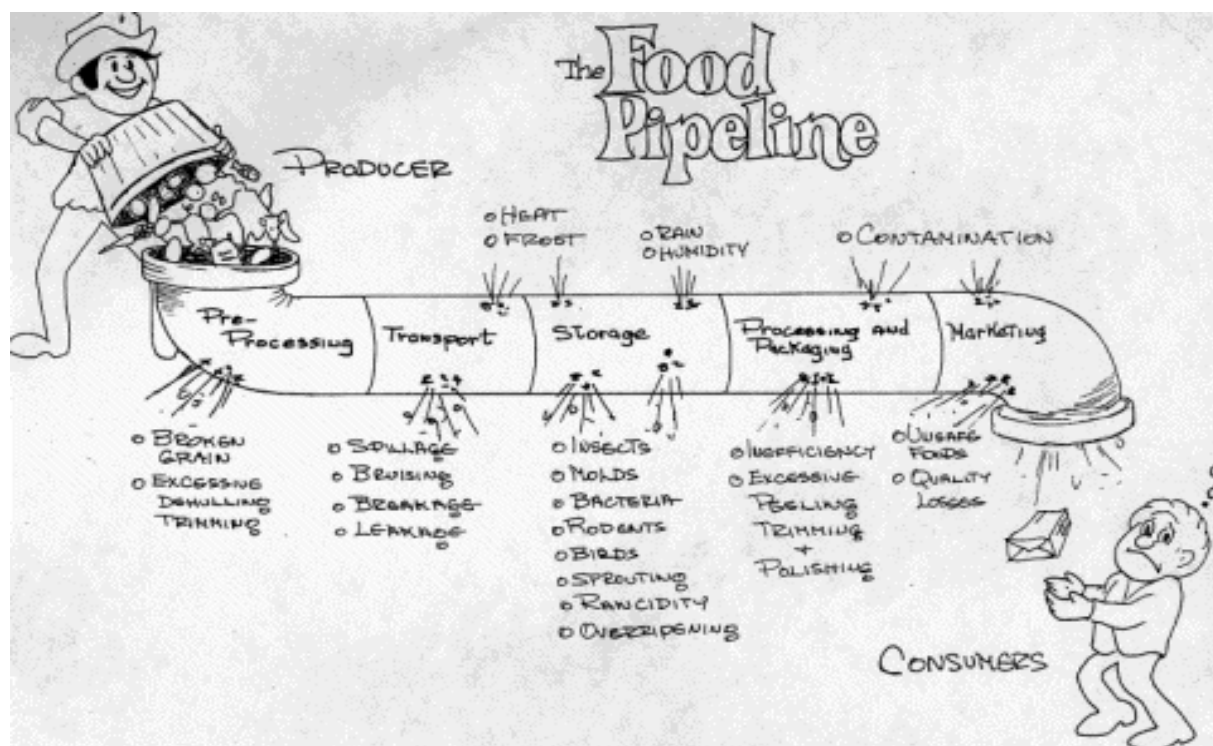


Figure 2.4: Post harvest pipeline

Source: (FAO, 2006)

"When carefully studied", Spurgeon writes, "the post-harvest system should be seen as involving the transport of a crop from the specific moment of harvesting to the specific moment of consumption, with lowest wastage, maximum productivity, to maximize benefits for all stakeholders" (The Hidden Harvest, 1976). The term "system" refers to a continuous, complex collection of inter - linked functions or activities within a given field of activity. The terms "chain" and "pipeline" emphasise the chronological sequence of numerous processes while ignoring their intricate interrelationship (Jennifer *et al.*, 2019). Harvesting may be viewed as a fulcrum or crest between the pre-harvest gradient, which corresponds to production processes, and the post-harvest pistle, which extends from harvesting to consumption.

2.4.1 Post-harvest loss

2.4.1.1 Concept of post-harvest loss of food

Post-harvest losses (PHL) are wastes that occur along the food supply chain, from harvesting to the table of the end consumer. Losses occur along the value chain, including handling, storage, transportation, processing, and marketing, resulting in a loss in quantity and quality, as well as the market worth of agricultural commodities (Bradford *et al.*, 2020). Post-harvest losses (PHL) can also be considered as losses of crops after harvest and at all stages of the onward supply of produce to the market (Post-Harvest Loss Chain). It is often used as a reference to the quantitative loss of food that was originally intended for human consumption, particularly in the context of food security in developing countries (Kok *et al.* (2019).

Post-harvest losses have several severe economic and environmental consequences (Ali *et al.*, 2021). The size of these losses and their influence on farm revenue varies considerably from place to place and it is, sometimes, difficult to measure because losses are frequently connected to cultural practices, incorrect temperature management, insufficient physical facilities and low market pricing, among others (Adewoyin *et al.*, 2022; Hodges *et al.*, 2011). Reduced post-harvest losses and food waste provide a significant avenue for providing and improving the nutritional content of food, alleviating poverty, and achieving better market prices through optimum harvesting, sorting, grading, storage, packing, transport and marketing (Affognon *et al.*, 2015; Odeyemi *et al.*, 2021).

Inadequate logistics and quality control operations are major causes of high PHL. Poor demand forecasting, ineffective inventory management systems (Kaipia *et al.*, 2013), and lack of supply chain coordination (Priyadarshi *et al.*, 2020), are typical examples of insufficient logistics

control that contribute to PHL. Inadequate temperatures, humidity, and atmospheric condition control (Kasso & Bekele, 2018) insufficient packaging (Kaipia *et al.*, 2013; Kitinoja *et al.*, 2019), and poor product quality control (Macheke *et al.*, 2017) are examples of inadequate quality control activities that contribute to PHL. Farmers encounter pests and illnesses, as well as low soil fertility, on the farm, which they manage using pesticides and fertilizers, respectively (Ngosong *et al.*, 2015; Ngosong *et al.*, 2018).

2.4.2 Post harvest losses of tomatoes

Vegetables have the highest post-harvest losses of any cereal crop. Such losses are related to highly perishable vegetables, with tomatoes being one of the vegetables that deteriorate faster after ripening. Tomato post-harvest losses might be quantitative or qualitative. Fresh tomato losses of 20-50 percent have been documented in tropical nations during harvest, transportation and consumption (Ahmad *et al.*, 2021; Pila & Gol, 2010). Roads in most developing nations, including Nigeria, are inadequate for transporting horticulture crops, and delivery trucks and other means, particularly those appropriate to short shelf-life perishables, such as tomatoes, are few. Furthermore, pre-harvest circumstances and field activities, such as varietal and soil conditions, crop management methods, unfavorable weather variables, insect pest control programs, and harvesting, as well as packing and handling procedures, have a substantial impact on the level of losses (Oyedele *et al.*, 2021).

In some cases, post-harvest loss of vegetables, such as tomatoes, is attributed to socio-demographic and organizational factors. These factors also include weak marketing information and assistance programmes, insufficient transportation infrastructure, unpleasant government regulations, incapability to incorporate laws and legislation, absence of suitable technology and materials, lack of professional expertise, and a poor servicing heritage for established resources and amenities (Ayandiji *et al.*, 2011; Melomey *et al.*, 2022). Post-harvest losses are also induced by rodents and birds, particularly in veggies, such as tomatoes, as indicated by Singh and Sharma (2018). However, such losses for vegetables are often minor compared to damages caused by rough handling, inadequate packaging and qualitative losses induced by temperature pressure (Mai & Pathare, 2021).

2.4.3 Pre-harvest and post-harvest activities enhancing tomato losses

2.4.3.1 Harvesting

The tomato maturation process concludes with harvesting, and it starts with a variety of key processes that guarantees clients receive products in the right condition. According to Huang *et al.* (2020), harvesting is an essential component of horticultural activity. Harvest maturity is a crucial factor in determining storage life as well as final fruit quality, flavour, juiciness and texture. Immature fruits have low quality and are usually incapable of ripening; immature fruits eventually degenerate and disintegrate. Fruit and vegetable harvesting delays, on the other hand, can dramatically increase the chance of fruit damage, resulting in severe post-harvest loss (El-Ramady *et al.*, 2015).

According to Li *et al.* (2019), tomato harvesting is labor-intensive and should be done when the fruits are still green to avoid becoming overripe during transit to distant marketplaces. The authors suggest picking tomatoes only when they are vine-ripe and when there is a perfect market. Planters often pluck fresh tomatoes by hand; however, this varies per producer. Since fresh tomato fruits are fragile and easily crushed, picking is done in smooth-edged plastic containers (Kitinoja *et al.*, 2019).

2.4.3.2 Application of pesticides

Application of pesticides in tomato planting is very vital as it helps to drastically reduce losses encountered due to pest invasion (Pattnaik *et al.*, 2020). To offset these pest-related losses, growers use insecticides at greater doses than tomatoes, which may impact growth and productivity (Thomson & Hoffmann, 2019). Pesticide residue issues in vegetables and fruits are caused by the widespread overuse of pesticides on vegetables and fruits, which eventually harms human health (Narendran *et al.*, 2020).

(Guedes & Siqueira, 2013) suggests specifications on the use of insecticides. Pyrethroid pesticides that breakdown readily should be used to treat vegetables by spraying it on the field, two weeks before harvesting (Danquah *et al.*, 2009) As a result, they advocate for the correct use of pesticides such as Diazinon, Dimethoate, or Sumithium in the organophosphorous group, or Karate in the pyrethroid order. (Danquah *et al.*, 2009). Spraying should be done at the proper time (Guedes & Siqueira, 2013). Because the presence of chemicals such as pesticides on

produce influences its quality. When used, several pesticides have both immediate and long-term effects on crops. (Steinmetz *et al.*, 2016).

According to Asante *et al.* (2013), the extensive use of pesticides in tomato farms appears to deliver pleasant and best quality fruits at market sites and produces good bargains for both farmers and vendors. However, this appears to have contributed to a rise in dietary risks, which are responsible for 200 diseases in humans, ranging from diarrhea to cancer and diabetes (Organization, 2015). To decrease the danger of pesticide contamination in food and the socioeconomic burden of disease, the European Union (EU) has developed pesticide residue guidelines that fulfill the conditions for a healthy diet. In addition, biological control employs bugs that are not harmful. Retailers and consumers of harvested vegetables have little or no information.

2.4.4 Variety of tomatoes grown

There are around 7500 tomato varieties in the world (Ugonna *et al.*, 2015). Tomatoes, one of the Heirloom varieties, are gaining popularity, particularly among farmers, gardeners and organic growers, since they provide more unique and flavourful crops and thus, are disease resilient (Deppe, 2010). While almost all commercial tomato types are red, certain cultivars, particularly heirlooms, yield fruits in a variety of colours, such as green, orange, brown, yellow, white, pink, black, ivory, as well as purple (Dwivedi *et al.*, 2019).

In Nigeria, various tomato cultivars are cultivated. However, their availability is often limited to specific sections of the nation (Jaiyeoba & Raji, 2012; Ugonna *et al.*, 2015). The three most frequent tomato cultivars on the market in Southwestern Nigeria are Ibadan-Local, Roma-VF, and Ife-1 (Jaiyeoba & Raji, 2012; Sibomana *et al.*, 2016). Among the tomato cultivars available in the Southwestern Nigeria market, is Ibadan-Local, a variation with better fruit output and longer fruiting propensity that has received little or no substantial attention due to the preference of other cultivars for it (Ajibade *et al.*, 2021).

Tomato variety is a key contributing reason to losses experienced by many tomato growers (Cherono & Workneh, 2018). The majority of the variants discovered by the researchers were of foreign or unknown origin, indicating that they should be examined for adaptability to the local areas before being adopted by farmers. Additionally, the usage of such experimental tomato varieties frequently results in genetic and environmental production limits (Adu-Dapaah & Oppong-Konadu, 2002). This is attributable to shortage of adaptation to the new ecology or

stressors, such as high temperatures, drought, disease and pests. Crop varieties can also impact the efficiency of postharvest of tomato plants (Nyamah, 2020).

2.4.5 Sorting and grading concept

Sorting and grading are the most important activities in the post-harvest processing of agricultural goods, whether fresh or in another form (Rajapaksha *et al.*, 2021). This is because sorting and grading is an earlier action in material handling that determines the subsequent handling procedure (Liadakis *et al.*, 2022). Based on this idea, the concept of sorting may be characterized as a set of operations to separate the material in various ways to acquire items that meet requirements. Grading is the practice of separating foods based on quality factors, such as size, weight and quality (Pokhrel, 2020).

The majority of post-harvest losses occur during transportation, storage, handling, and processing, and these inevitably contribute to secondary loss causes. (Okonkwo & Onu, 2018). Physical handling of fruits during sorting and grading when preparing fresh fruits for the market causes bruising and mechanical damage, resulting in losses. Inadequate transportation also makes crops more susceptible to decay and microbial growth (Arah *et al.*, 2016; Barbosa-Cánovas, 2003). After harvesting, poor post-harvest handling procedures induce bruising and pathogenic contamination of freshly harvested fruits, especially when the fruits come into contact with contaminated soil. Procrastinating cultivation and grading promote thermal create on farms, resulting in quicker ageing (Sudheer & Indira, 2007; Zhao *et al.*, 2020).

2.4.6 Concept of packaging

An effective packing method should protect the commodity against diseases, natural predators, moisture loss, extreme temperatures, crushing, deformation and bruising (Gaur & Goyal, 2016). Large green leaves, clay pots, braided cane baskets, wooden crates, cardboard crates, cardboard boxes, plastic buckets, nylon sacks, jute sacks and polythene bags are some of the most prevalent packing materials used in poor nations (Arah *et al.*, 2016). The bulk of these packing materials does not allow for enough aeration within the boxed tomatoes, resulting in heat accumulation due to respiration (Arah *et al.*, 2016).

Processed tomato products are available in a variety of packaging options, allowing consumers to select the package that best meets their needs. One of the roles of packaging is communication, which allows a product to be identified, aids in sales through marketing, and provides customers with information on the product's usage and handling (Samoggia *et al.*,

2021). Through marketing methods, packaging plays a crucial role in drawing customers' attention and influencing their purchasing decisions. A product packaging may be utilized as a source of information and recognition in this context, as well as to convey extrinsic quality and brand image (Lo *et al.*, 2017; SUNG, 2021).

The packaging of fresh tomato fruits is very important in preventing waste. Mechanical damage, unwanted physiological changes, and pathological degeneration are factors that can be averted when crops, such as tomatoes are carefully packed throughout storage, transit and marketing. With appropriate packaging, Quality vegetables and fruits can be stored for extended periods of time (Sudheer & Indira, 2007; White & Lockyer, 2020).

2.4.7 The role of transportation

Transportation refers to any forms of transportation used to transfer products from the point of manufacture to the point of consumption. Because tomato fruits are perishable, mishandling and transportation can cause mechanical damage to fresh tomatoes. (Duarte *et al.*, 2019). According to Arah *et al.* (2016), To reduce heat accumulation and rain, tomatoes should be conveyed in ventilated vehicles. According to MBACHO (2021), when tomatoes are transported on terrible roads in tropical places, they decay quicker than when transported on excellent roads in relatively chilly areas.

Most tomato producers do not offer their tomatoes directly to customers in an organised marketing route (Chaboud & Moustier, 2021). Several intermediates conduct various marketing activities between producers and customers (Sampaio *et al.*, 2018). Wholesalers and retailers are the marketing channel's intermediates. The marketing channel in Nigeria is chaotic due to the perishability of tomatoes and the weak transportation system. Farmers will occasionally reject intermediaries and sell their products straight to consumers or to shops (Britwum, 2013; Robinson & Ngeleza, 2011).

2.4.8 Benefits of transportation to tomato production and marketing

The transportation network is a crucial foundation for the Nigerian economy since it plays an important role in enhancing agricultural production, particularly in the field of tomato cultivation (Oke *et al.*, 2020). In marketing channels, transportation serves as a direct link between producers and the ultimate customer (Adesoga & James, 2019). The importance of transportation cannot be overstated. It is a stage in the manufacturing process that cannot be completed until the commodity reaches the ultimate customers.

Accessibility of transportation facilities is a significant investment element that promotes economic growth by increasing accessibility, efficiency and effectiveness (Cook *et al.*, 2017). This is because the source of food and other economic items must be sufficiently proximate to markets and industries through transportation in order to have economic worth. As a result, a suitable transportation network and specific undertaking service operation are necessary ingredients for the efficient and physical distribution of agricultural goods (Todorovic *et al.*, 2018). According to Ajiboye and Afolayan (2009), transportation improves the quality of life of farmers, develops markets for agricultural output, allows contact across economic and geographical regions and opens up new areas for economic approach. Increased efficiency in transportation will encourage farmers to work harder in rural areas to increase production, add value to their products, reduce quality deterioration and waste, equip farmers, and have a hopeful impact on their productivity, revenue and work opportunities. It also helps in eradicating levels of poverty in rural areas as it will be easier to move inputs and workers to farms as well as products to markets and agribusiness industries (Deichmann *et al.*, 2016).

2.4.9 Storage of tomatoes

Water holding sheets are applied to minimize the water content of tomatoes, making them appealing to customers. Vegetables that are Packaged have a longer lifespan than unpackaged produce (Oliveira-Bouzas *et al.*, 2021; Sudheer & Indira, 2007). These researchers found that tomatoes clothed in proof lignin film will lose weight by 25% less than unwrapped tomatoes in impermeable cellulose fabric sustaining fresh tomatoes in the absence of refrigerating facilities in subtropical and tropical zones may be more difficult than in cold zones; thus, tomatoes in tropical zones must be delivered to market centers faster than in cold zones (Adarkwa, 2011). According to Iwuchukwu *et al.* (2017), In Nigeria, farms and retail marketplaces lack storage facilities, and those that do have warehouses, lack refrigeration and ventilation.

Tomatoes are climacteric fruits with a limited shelf-life in humid storage (Ashenafi & Tura, 2018), but they retain their flavor and are quite constant as long as they are not picked, are not harmed by sickness and are not consumed by insects or other animals (Zhong *et al.*, 2021). Quality deterioration occurs when tomatoes are isolated from their natural source of nutrient, which is caused by a natural process that begins when the biological cycle is broken by harvesting (Mai & Pathare, 2021). To increase the life span of tomatoes, several deteriorative processes, such as limiting ethylene synthesis and activity, must be deferred (Ebrahimi *et al.*, 2021).

2.4.10 Market facilities

Tomato marketing entails transporting the produce from the place of production to the site of usage. In order to supply items that best fit the demands of the consumer, marketing must be considered as part of the total strategy, not only the final stage of handling fresh food (Abera *et al.*, 2020). Lack of access to markets is a key limitation in the tomato sector (Geoffrey *et al.*, 2014). The following are some of the key hurdles to market penetration: insufficient road infrastructure; expensive transportation costs; significant market price fluctuation; inadequate or non-existent storage facilities; and existence of market monopolies (Geoffrey *et al.*, 2014).

Nigeria's transport network, particularly its rural roads, is in disrepair. Thus, the need for government, at either the national or local level, to upgrade road infrastructure to facilitate transportation of tomato produce from producing regions to market destinations (Olojede *et al.*, 2019).

2.5 Marketing of tomatoes in Nigeria

According to Nwuba and Nwaizugbo (2020), agricultural marketing refers to "all actions that help in the flow of commodities from farmers to customers, including an assembly of items, storage, transportation, processing, grading and financing of all of these activities". According to Emanu *et al.* (2015), in a typical vegetable marketing, shops were seen selling both tomato and onion at the same time, along with other vegetables, such as hot pepper, sweet pepper, cabbage, salad and, in some cases, chilies pepper. Tomato marketing is primarily characterised by seasonality and perishability, among other issues (Wosene & Gobie, 2022). According to Roelofs (2021), the federal state, and local governments of Nigeria have historically given little attention to the marketing of vegetables, such as peppers, tomatoes, onions, garden eggs, okra, and green vegetables, although they require spatial marketing infrastructure. Improper packaging and handling exacerbate the losses. Many fruits and vegetables lose 40-50 percent of their value in the marketing chain due to deterioration caused by improper handling, insufficient transportation and lack of chilling facilities. The net returns to plantain marketing were impacted by marketing expenditures and selected personal characteristics of marketers.

Tomatoes can be sold in Nigeria through a variety of channels (Ugonna *et al.*, 2015). According to Ganiu (2019), the "fresh tomato marketing channel" refers to the many channels available for transferring tomatoes from the grower to the end user customer. A marketing chain links each distribution channels, which is made up of any middlemen that carry out different tasks. The

marketing network refers to the multiple gateway intermediaries (like farmers, distributors, traders, and retailers) who often perform various actions in the process of transferring the product to the end customer.

Farmers' marketing channels for fresh tomatoes should be able to supply tomatoes to customers in the required format and for a lower cost compared to other links. Orzolek *et al.* (2006), illustrates that there are six marketing alternatives available to tomato growers: pick-your-own businesses; mini marts stalls; stores; partnerships; wholesale marketplaces; and industrial firms. When post-harvest management is properly maintained, additional profits on fresh or processed tomatoes can be obtained (Arah *et al.*, 2015).

Intermediate duties include selecting, grading, packing, loading, offloading, transportation, warehousing, and distribution (Yeboah, 2011). Though tomato farmers have access to a variety of markets, location and availability of markets are the primary factors of which market, tomato farmer in Nigeria chooses. The quandary in selling freshly harvested tomatoes might be ascribed in part, to the crop's fragile nature and perishability and the limitations enforced by "market chiefs" in the selling of tomatoes at the country's major tomato wholesale markets (Robinson & Kolavalli, 2010).

2.6 Empirical studies on factors that affect post-harvest losses

2.6.1 Results of models

According to Ayandiji *et al.* (2011), who stated that the employment of vans or trucks for hire as the mode of transportation with the maximum throughput may not necessarily increase post-harvest losses compared to motorbikes and bicycles, and in the case of head loads. This implies that good transportation will decrease quantity losses to a bare minimum. According to the findings, the quantity of fresh fruit lost rose as the distance between the farm and market increased. It was caused by tomatoes being overcrowded and packed for an extended amount of time. Post-harvest losses were influenced by the amount of time spent in the field or on the vine after maturity, as well as the quantity of baskets of tomatoes harvested. With a determination coefficient of 0.95, the impacts of independent variables were significant at a 5% level of probability. The age of tomatoes during harvest increases losses owing to fruit ripening and softening, and they become more prone to mechanical damage and fermentation as they age. As the farm develops in size, so does the quantity lose owing to poor management and a lack of sufficient storage facilities.

Aidoo et al. (2014) discovered that a farmer's sex (female), farm size, and days of storage were positively associated to post-harvest losses, but participation in a farmer-based association, household size, and cultivar type were adversely connected to post-harvest losses. The F-Statistics was 1% significant, indicating that all regression coefficients had a significant impact on tomato post-harvest loss.

Experience, fruit age at harvest, The amount gathered (crates), household size, and degree of education were discovered to be essential. (Alidu *et al.*, 2016). According to their findings, all explanatory factors have a negative significant influence on post-harvest loss, with the exception for amount collected, resulting in a substantial favorable influence on loss. Regarding regression, the researchers found that Prob. > F = 0.000, R² = 0.761, indicating that the entire model is fit, an indication that the explanatory factors explain, indicating that the full model is fit, and R² = 0.76127 is the Estimates of post-harvest loss.

2.7. Estimates of post-harvest loss

Post-harvest losses in vegetable crops may be divided into two types: quantitative and qualitative losses (Rajapaksha *et al.*, 2021). According to Kader (2004), reduction in quantitative loss is a top priority in underdeveloped nations, whereas, reduction in qualitative loss is a top goal in developing countries. Kader (2004) further states that determining qualitative loss is more difficult than determining quantitative loss.

In general, loss of weight, hardness, deterioration, locules per fruit, test weight, total soluble and storage life of tomato fruit may be used to determine its quality (Kader, 2004; Zulkifli *et al.*, 2020). The authors compared the overall look of various tomato varieties (Akoma, Cal J, Pechtomech, Power and Royal). General appearance (GA) of fruit was evaluated on the fruit's general appeal to the purchaser and was graded by sheer quality. It was dependent on the selection on an 8-point multi-item scale, with zero indicating bad (very faulty), 2 indicating acceptable (defective), 4 indicating good (slightly flawed), 6 indicating very good (somewhat flawed) and 7 indicating exceptional (not defective). Weight loss (WL) is a mathematical expression for the loss of both quantity and quality of fruits.

$$WL = \frac{FW - IW}{IW} \times 100$$

Where WL = Weight loss

FW = Final weight

IW = Initial weight

Egyir *et al.* (2008), indicated that there is a universally acknowledged approach to estimate post-harvest loss of freshly harvested crops, but the approach used is dependent on circumstances. The researchers also claim that if losses are not appropriately measured while reviewing the current marketing operation, a problem may arise. Losses may be substantial, but statistics to support these losses may be unavailable due to: Records are lacking; if they are available, they do not span a sufficiently enough time; The statistics available are simply educated guesses from several observers; Records may not accurately reflect the current condition; for example, losses could have been computed only when they were particularly high or low; loss estimates may have been purposefully inflated or underestimated for business or other purposes to earn advantages or avoid humiliation (Egyir *et al.*, 2008).

Egyir *et al.* (2008) outlined various basic methods as guidance when assessing these losses:

Step 1: Calculate the quantity of commodity (j) retained (tq) and wasted (qi) at each level of the chain as indicated by respondents. The commodity (j) possessed at the beginning of a chain is reported per unit in this study (eg 50 kilogram sack of pepper; 100 kilogram acks of cereal, mean tubers of yam etc).

Step two: Determine the average quantity (TQij) retained and wasted per commodity at each ith link in the chain (given n number of respondents) (j).

Hence,

$$TQ_{ij} = \frac{\sum tq}{n}$$

$$TQ_{ij} = \frac{\sum q}{n}$$

Step 3 Calculate the loss ratio as the proportion of mean quantity lost to starting mean amount held at each link of the chain per commodity (QL).

Hence,

$$QL = \frac{Q_{ij}}{TQ_{ij}}$$

Step 4: Calculate the raw percentage loss per commodity by taking the average of the total of loss ratios for all links in the value chain for each commodity analysed.

Hence,

$$TQ_{ij} = \frac{\sum \frac{Q_{ij}}{TQ_{ij}}}{N} \times 100$$

Where,

%TQL= post-harvest loss as a percentage of commodities along the supply chain.

Q_{ij} = mean proportion wasted at each i th level of the j th commodity's value chain.

TQ = average complete quantity at the start of the distribution of the j th commodity

N = Overall number of channels in the chain.

In addition, a functional analysis was performed by Nag *et al.* (2000) to explore factors that influence crop after harvesting fruits and vegetables. The following multiple linear regression functions (2) were included:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \dots + \beta_7X_7 + \mu$$

Where,

Y = post-harvest tomato losses in kg per hectare.

X_1 = level of education of respondents (number of years of schooling).

X_2 = average yearly income of respondents (Naira).

X_3 = total tomato production in quintals.

X_4 = sale price of tomatoes (Naira/kg).

X_5 = farming experience (years).

X_6 = rainfall dummy with a value of '1' if rainfall occurs during harvest and a value of '0' otherwise.

X_7 = packaging dummy that takes the value '1' if the packaging is appropriate and the value '0' otherwise.

a = intercept.

$\beta_1, \beta_2, \dots, \beta_7$ = coefficients of the corresponding variable; and

μ = 'Random-error'.

CHAPTER THREE

METHODOLOGY

This section provides a description of the research approach used in the study, and methods used to collect and analyse data. Primary and secondary data were used in the study. Primary data was obtained structured questionnaires. To ensure that farmers understood the questionnaire, the items were explained to extension officers, who have experience working with tomato producers.

This chapter is divided into different sections as follows: Sections 3.2 and 3.3 present the theoretical background as well as the data analysis strategy: Section 3.4 focuses on the methods used to data; while Section 3.5 presents the study's scope and limitations

3.1 Data analysis

The Statistical Package for the Social Sciences (version 21) and Microsoft Excel 360 were used to re-code, arrange, and analyse the raw data from the survey questionnaire. Mathematical computations and assumptions were performed when needed. Descriptive statistical analysis (means standard deviation, percentage, and Chi-square) was performed to describe socio-demographic characteristics, post-harvest handling practices and post-harvest losses incurred by tomato farmers. A functional method was used to examine determinants of farm-level post-harvest losses in tomato. Kendall's Concordance Coefficient (W) was utilized to identify the constraints that role players experience at various levels of the tomato value chain.

3.1.1 Socio-demographic characteristics, post-harvest handling practices and post-harvest losses experienced by tomato farmers

The objective of this design was to compute the demographic characteristics of tomato farmers, wholesalers and retailers in relation to post-harvest handling practices responsible for Post-harvest losses throughout the value chain. The raw data from the survey questionnaire was re-coded, organised and analysed using SPSS (version 21) and Microsoft Excel 365. Relevant mathematical computations and inferences were used accordingly.

Descriptive statistical analysis (means \pm standard deviation percentage and Chi-square) was used to describe socio-demographic characteristics, post-harvest handling practices and associated post-harvest losses experienced by tomato farmers. The age and size of family of

respondents, major source of income, sex, marital status, level of education and connection with tomato post-harvest losses were also measured. The major demographic variables used to assess working capacities of respondents were age and sex.

3.1.2 Determinants of post-harvest losses at farm level

A functional method was used in this study to examine determinants of post-harvest losses at the level of the farm, as explained by Nag, Nahatkar and Sharma (2000), Khatun *et al.* (2014) and Kaysar *et al.* (2014). The Cobb-Douglas type multiple linear regression function was used as indicated below.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_9 X_9 + \mu_i,$$

Where, Y = Postharvest loss of tomato (kg/farm),

α = Constant term,

X_1 = Total harvested amount (kg/farm),

X_2 = Education (year of schooling),

X_3 = Total family member (no.),

X_4 = Farming experience (year),

X_5 = Selling price (Tk/kg),

X_6 = Dummy type of vehicle (pulled van=0, others = 1),

X_7 = Packaging dummy (traditional packaging=0, improved packaging = 1),

X_8 = Training dummy (got training = 0, no training = 1),

X_9 = Selling place dummy (farm level = 0, market level = 1),

$\beta_1, \beta_2 \dots \beta_9$ = coefficients of the independent variables, and

μ_i = Error term.

3.1.3 Constraints faced at various stages of the tomato value chain

Respondents were asked to rank constraints faced by role-players at various stages of the tomato value chain in the rank of severity. Kendall's Concordance of Coefficient (W) was employed to summarise the concordance between various ranked lists. According to Tiwari *et al.* (2021), Pearson correlation coefficient assesses monotonic functions while Spearman's rank correlation coefficient assesses linear relationships between two variables. As a result, Kendall's Coefficient of Concordance (W) was considered the best technique for this investigation.

Hypothesis

Ho: There is no consensus among respondents' ranks.

Ha: There is consensus among respondents' ranks.

The Kendall's Coefficient of Concordance is specified as follows:

$$W = \frac{12[\sum T^2 - (\sum T^2)/n]/n}{nm^2(n^2 - 1)}$$

Where m is the number of sets rated by farmers, wholesalers, and retailers, and n denotes the number of restrictions ranked.

The chi-square test was used to further evaluate the hypothesis and the relevance of the rankings.

3.1.4 The decision rules

If the estimated F-ratio is larger than the F-value from the F-table, the null hypothesis (Ho) is rejected.

If the estimated F-ratio is smaller than the F-value from the F-table, the null hypothesis (Ho) is not rejected.

3.2 Method of data collection

This section focuses on the many data sources utilized in this study, the survey sampling process, study population, and geographical region.

3.2.1 Data collection

This study entirely on primary data. A letter was sent to the Department requesting permission to begin data collection after all ethical clearance related processes were approved by the North West University. Structured questionnaires were used to collect primary data. To verify that the farmers understood the survey questions, each item was pre-tested with two farmers, distributors, and merchants in the research region. Following the preliminary tests, the questions were fine-tuned using data from earlier surveys. The questionnaires were administered to respondents as indicated in the appendix.

3.2.2 Sample size and technique

A three-stage sample selection procedure was utilized to choose the sample size for this investigation. During the initial stage, ten farmers from each of the six villages selected for the study, from Irewole Local Government area, Ikire constituency. The final stage involved a random selection of twenty tomato farmers from each of these rural areas. Data obtained from eighty farmers was considered for further analysis in the study.

To determine the sample size of the study, Raosoft sample size calculator was used to determine the sample size from the list of tomato farmers in the study area. The sample size, using Raosoft software calculator was used in the study as follows:

Where,

SS = Sample size.

Z^2 = Z-value (1.96 for a 95% confidence interval).

P = Percentages of occurrence of a state of a condition; and

C^2 = Confidence interval at 0.05 (5%).

3.2.3 Research design

According to Bloomfield and Fisher (2019), a research design is a plan that a researcher uses to determine the relationships between variables. The goal of the research design is to allow generalisation from a sample to a population to draw conclusions about some characteristics, behaviour, or attitudes of a sampled population. A research design outlines the basic approach

that researchers will take to answer their research questions. It is critical for the researcher to select the appropriate design to accomplish the study's objectives (Green, 2014).

The structured questionnaire was designed to elicit data for economic analysis, socio-economic characteristics, analysis of access to markets and evaluation. The questionnaire comprised both closed and open-ended questions. The study employed a questionnaire because it saves time and is straightforward to code and analyze (Olsen, 2012).

3.3. Geographical area of the study

This research was carried out in Irewole and Ikire in the local government areas of Osun State, Nigeria. Osun State was established on August 27, 1991 and has an area of roughly 8602 km². The state is surrounded in the east by Ondo, Oyo, and Ekiti States, in the north by Kwara State, and in the south by Ogun State. The state has an agricultural economy, with farming employing the majority of the population (Lawal, 2021). According to Oforka *et al.* (2020), there are two distinct geographical seasons in Osun State. These are the rainy season, that starts in late March and end in October and the dry season, from November to early March. The mean annual temperature varies between 21.1°C and 31.1°C. Annual rainfall ranges between 800mm in the derived savannah agro ecological zone to 1500mm in the rain forest zone (11). Under the Osun State Agricultural Development Programme, the State is divided into three agro-ecological zones: Iwo; Osogbo; and Ife/Ijesa (OSSADEP). The area of this study is under Irewole region, Ikire.



Figure 3.1: Map of the three ecological zones of Osun State

Source: State Government of Osun(2001).

3.3.1 Drainage and vegetation

Ikire is in the Nigeria’s rainforest belt. Fresh water plants grow in this region, which is part of the fresh water. The region is endowed with a pleasant climate (Oyewale *et al.*, 2019). The presence of a favourable environment has greatly increased the production of arable and cash crops, which has contributed to the area's economic growth (Alao *et al.*, 2020). Furthermore, the plant cover of the Local Government Area is mainly evergreen rainforest, which is often lush during the rainy season. The existence of the evergreen lush forest has benefited cattle and other domestic animal raising in the Irewole Local Government Area (Jimoh & Bada, 2001).

3.3.2 Climate

Ikire is in the tropical rainforest climatic area, with hot and humid weather throughout the rainy seasons (Oyewale *et al.*, 2019). The arrival of the rainy season in the area is marked by heavy winds. Rain falls nearly seven months of the year (April - October), whereas, two months (November and December) are dry and dusty (Harmattan), and the remaining three months (January – March) are hot and dry (Aga, 2009). These seasons are caused by the area's two dominating winds: the Southwestern trade winds from the Atlantic Ocean; and the North-eastern trade winds from across the Sahara Desert. The mean annual precipitation is from 2500mm to 1000mm. The region sees double maximum rainfall in July and September, as well as high moisture content of roughly 80% all year.

3.3.3 Demographic characteristics of respondents

The study was conducted in Ikire region, Southwest of Nigeria and has (UTM) coordinates of 630450–630770 in the East and 815470–815750 in the North (Figure 3.1). The city has a population of 143,599 and a 271 km² area (National Population Commission 2006). The city has a tropical climate, just like the rest of the nation, with two distinct seasons: the dry season (November to March); and the rainy season (April to October) (Adebayo *et al.*, 2021). The city is surrounded by different villages, which provide food to the main town and surrounding towns. Farming, commerce, and timber work are the town's most common vocations; however, some people work in white collar employment. The city is well-known for the creation of native plantain chips, known as "Dodo Ikire" (Ajao *et al.*, 2021; Jonathan & Olowolafe, 2019). The region's population is growing at a rate of 1.2 percent each year. Furthermore, the census figures show that males predominate females in the region.

3.3.4 Economic activities

Agriculture is the primary economic activity of inhabitants in the Ikire Planning Area, but the informal sector, which mostly consists of tiny traders, craftsmen, and others, is quite important and employs a considerable number of working-age population. Ikire is also known for a distinct kind of peppered fried plantain snack known as 'Dodo Ikire', which is sold in markets as far away as Oyo and Lagos States, among many others. While the enterprise is essentially female-dominated, males also participate in its distribution and marketing (Dabara, 2019).

Though government workers from both the state and federal governments live and work in Ikire, it is believed that the formal sector accounts for around 5% of employment within the LGAs. Majority of formal workers are employed by the Local Government Service and State Ministries, Departments, and Agencies with a presence in the Planning Area, such as the Ministry of Agriculture and Natural Resources, and Federal Government parastatals, such as the Nigerian Police, Fire Service and other security agencies.(Ajao *et al.*, 2021).

3.3.5 Agriculture

Though civil servants work in both states, and as is characteristic of State of Osun, where farming activities related to the production of cash crops and the processing of agricultural products have been the main economic activity for decades, agriculture is the primary economic activity in Ikire, and small-holder peasant farmers have continued to produce the majority of agricultural produce in the local government (Alao *et al.*, 2020). According to LEEDS (2004), around 10,000 households produce crops, such as maize, cassava, legumes (cowpea and soya beans), marsh rice, yam, and veggies, along with commercial crops, such as cocoa, palm oil, kola nuts, oranges, timber, and wood. It is projected that approximately 70 percent of the population is involved in farming activities, either explicitly or implicitly.

3.4 Scope and limitations of the study

The aim of the study was to examine losses along the tomato value chain. The study's aims were to: quantify the proportion of post-harvest losses at various levels of the perishable value chain of tomato farming; identify variables that drive losses; and identify limitations faced by various actors in the tomato value chain. To achieve specified aims, descriptive statistics, Kendall's Coefficient of Concordance and Cobb-Douglas type multiple linear regression were used. It was difficult to assess qualitative loss since measuring the components that generate such loss was extremely challenging. Since qualitative loss is difficult to quantify, only the estimation of quantitative loss was examined.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the empirical findings of the study conducted on the assessment of post-harvest losses in the tomato value chain in Ikire, Osun State, Nigeria. It begins with descriptive statistics (percentage, frequency, pie charts, graphs, and chi-square) to describe the socio-demographic characteristics of tomato farmers, post-harvest handling practices and associated post-harvest loss of tomatoes. Secondly, A functional method was utilized to determine post-harvest wastages in tomatoes at farm level, as well as Cobb Douglas p type of multiple linear regression function. Lastly, to score constraints faced by farmers at various stages of tomato chain in order of severity, Kendall's Coefficient of Concordance (W) was employed.

4.2 Socio-demographic characteristics of farmers, post-harvest handling practices and associated post-harvest loss experienced by tomato farmers

4.2.1 Sex of respondents

Table 4.1 shows the sex of farmers who participated in the study. Eighty small-scale tomato farmers participated in the study. Based on the data collected, it was revealed that 78.8% of respondents were males, while 21.3% were females. Farmers in the locality are likely to be mostly male. This might be caused by the fact that women fulfil additional household and economic duties in society, such as maintenance and agricultural produce selling, and may not have the same amount of spare time for farming as their men equivalents.

This conclusion supports those of recent investigations, such as Cloud (2021) and earlier studies, such as Muhammed *et al.* (2021), w which shows that tomato cultivation is dominated by men in Nigeria. It is also possible to conclude that all tomato merchants in the region are females, considering the fact males are engaged in farming activities, while females prefer to be involved in trading (Jawondo & Oshewolo, 2020). This finding further indicates that the representation of men in the study is higher compared to women, regarding tomato farming. In addition, men are more flexible and energetic while women historically, are linked with house duties, such as taking care of the family and overseeing the welfare of the husband.

Table 4.1: Sex of the respondents

Sex	Frequency	Percentages
Male	63	78.8
Female	17	21.3
Total	80	100

Source: Survey results (2021)

4.2.2 Ages and farming experience of the respondents

Respondents' ages is a crucial feature to consider in agricultural production since it determines the farming experience and potential to carry out agricultural activities (Adnan *et al.*, 2020). The age of farmers was investigated as socio-demographic characteristic. It is well-known that more experienced and professional farmers make better decisions, which may impact the viability of their businesses. According to research conducted by Adnan *et al.* (2020), the age of the farmer may be regarded as an indicator of experience and talent, which can be associated to farm economic viability. The age distribution of small-scale tomato producers in the research region is shown in Table 4.2 below. The youngest farmer questioned was 26 years old, while the oldest was 70 years old. The average age of small-scale tomato farmers was 46 years, an indication that tomato production in Irewole Ikire Local Government Area is largely performed by elders or persons of mean age.

Table 4.2 also shows the distribution of farming experience of respondents. From the data collected, the minimum farming experience of small-scale farmers was 2 years, while the maximum was 40 years. The average farming experience of farmers was approximately 11 years. This could be since tomato is a cash and staple crop, which small-scale farmers produce for home consumption and regard it as a means of income. It can also be concluded that years of farming experience allows farmers to participate in the adoption of new technologies over time. It also helps in the involvement of risk decision-taking because they already have the experience of how things are done compared to those who have no or fewer years of experience.

Table 4.2: Age and farming experience of the respondents

Characteristics	Minimum	Maximum	Mean
Age of respondents	26	70	45.86
Farmer's experience	2	40	10.74

Source: Survey data, (2021)

4.2.3 Size of household of respondents

It is evident from Table 4.3 below that 47.5% of farmers had small household size (1-5 people), 46.3% had household sizes of 6 to 10 people, while 6.3% of them had 11 people or more in their households. The average household size was 6. This relatively large household size of farmers may likely enable them to use family labour in carrying out some tomato farming operations, thereby, reducing the incidence or independence on hired labour and on other means of labour. This finding corresponds to Agwu *et al.* (2017), who found that the largest household size lies between 1-5 household members in Nigeria.

Table 4.3: Household size of the respondents

Size of household	Frequency	Percentage
1-5	38	47.5
6-10	37	46.3
11-15	5	6.3
Total	80	100

Source: Survey data (2021)

4.2.4 Marital status of the respondents

Marriage has a considerable influence on reducing the likelihood of poverty and relates to a better probability of obtaining affluence across life (Aidoo-Mensah, 2017; Wei *et al.*, 2021). Unmarried persons have been observed to save substantially less of their income and build far fewer assets than married couples (Aidoo-Mensah, 2017). Thus, from an economic standpoint, marriage has various qualities that may boost the growth of wealth and comes with a slew of advantages, such as savings.

According to the figures in Table 4.4 below, 72.5% of respondents were married while 27.5% were either single or divorced. Over 70% of respondents were married in each of the eight areas. Most farmers were most likely married in order to have extra hands to help them with their farm operations (Aidoo-Mensah, 2017). While it is true that marriage may help with creation of wealth, the truth of this claim is highly dependent on the contribution each member of the marital union provides to the wealth of the home (Aidoo-Mensah, 2017).

Table 4.4: Marital status of the respondents

Marital status	Frequency	Percentage
Married	58	72.5
Single/divorced	22	27.5
Total	80	100

Source: Survey data, (2021)

4.2.5 Educational level of the respondents

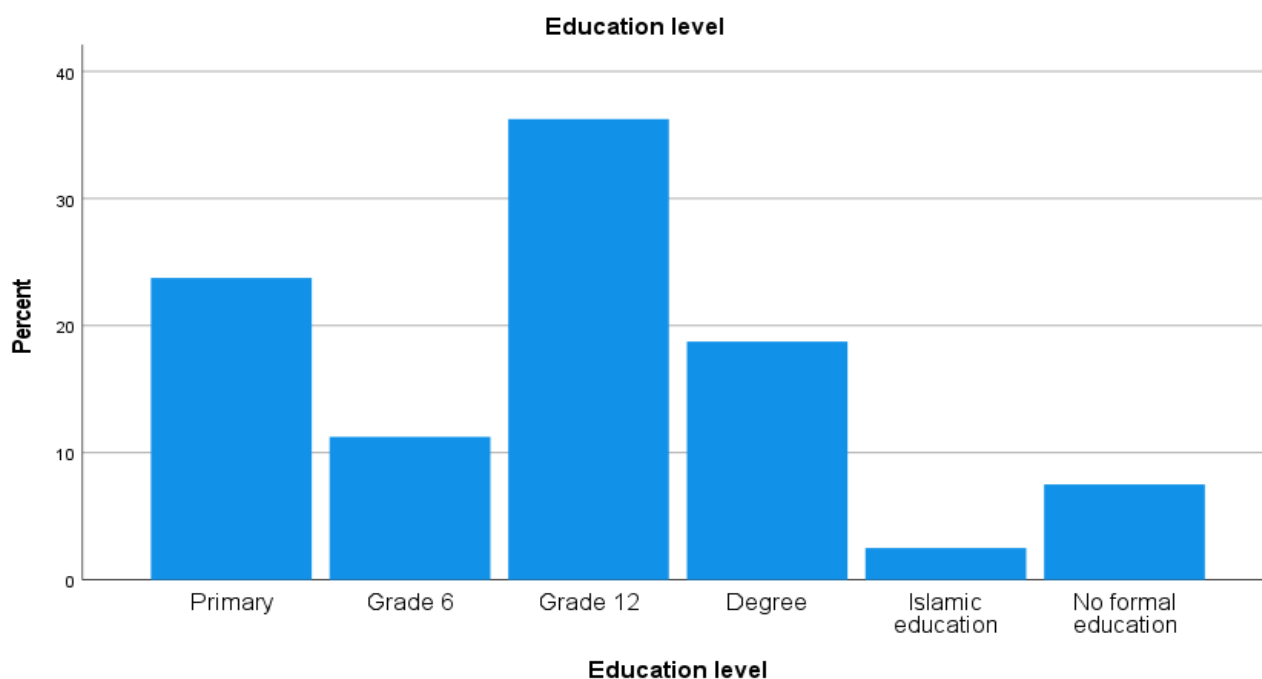


Figure 4.1: Educational level of the respondents

Source: Survey data, (2022)

Level of education of farmers is very important as it plays a vital role in farming and in the adoption of new technologies (Ajibade *et al.*, 2021). It is expected that level of education can improve production and efficiency (Iliyasu & Mohamed, 2016). Figure 4.1 shows the level of education of respondents. The results show that 23.8% of small-scale farmers had primary level of education, while 9% of those who enrolled for primary education, progressed to grade 6. The results also show that 36.3% of farmers attended school up to grade 12. Furthermore, 2.5% of farmers had Islamic education, while 6% had no formal qualification. Only 18.8% of farmers had a university qualification. Liangxin *et al.* (2013) found that low levels of education of elders lead to low production and efficiency compared to younger farmers. This could be attributed to the fact that younger farmers are more informed and educated about the use of modern technological tools in production through knowledge acquired. Based on the data collected, it is evident that level of education of tomato farmers in the area is low.

4.2.6 Main occupation of respondents

Source of income of a farmer is very important. Studies have shown that farmers with other sources of income are stable in production than those who only depend on farming, as the only source of income (Fahad *et al.*, 2018). Table 4.5 shows that 17.5% of farmers had professional jobs, 16% were traders, while 35% had no other job, except farming. Furthermore, 8.8% of respondents were public transporters, while 13.8% were civil servants. It can be concluded that most respondents engaged in farming in the study area were mainly farmers and depended on farming for income and livelihood. It can also be concluded that only few respondents had government jobs, while 20% of farmers sold their tomatoes in local markets around them.

Table 4.5: Main occupation of the respondents

	Frequency	Percentage
Artisans	14	17.5
Civil servants	16	13.8
Farming	28	35.0
Public transporters	7	8.8
Traders	16	20.0
Other	4	5.0
Total	80	100

Source: Survey (2022)

4.2.6 Access to government support services

In developing countries, such as Nigeria, farmers depend greatly on government support in order to enhance their production efficiency (Chandio *et al.*, 2020). The findings revealed that many farm inputs are very costly and small-scale farmers have no capacity to purchase these items hence, the need for support is crucial (Mgbenka *et al.*, 2016). Table 4.6 shows that 22.5% of small-scale tomato farmers were supported by the government, while 77.5% never received any support from any government association or agents.

Table 4.6: Access to government support services

Government support	Frequency	Percentage
Yes	18	22.5%
No	62	77.5%
Total	80	100

Source: Survey, (2022)

4.2.7. Forms of government support services

Table 4.7 shows that 1.3% farmers had access to financial support from government, while 15% received support from extension officers in terms of guiding them on tomato cultivation and production. The results also show that 1.3% of respondents received free equipment, while 2.5% had access to free supply of agrochemicals. The results show that only a few respondents received support thus, most farmers could not meet up with their production obligation. This is in line with previous findings that lack of government support slows down the efficiency of small-scale production (Okeke & Nwankwo, 2017).

Table 4.7: Forms of government support services

Form of support	Frequency	Percentage
Financial	1	1.3
Extension support	12	15
Free farm equipment	1	1.3
Free supply of agrochemicals	2	2.5
Other	64	80
Total	80	100

Source: Survey data (2022)

4.3 Post-harvest handling practices

4.3.1 Harvesting methods

The harvesting method used is of great importance as it determines the longevity of the product after harvest. The use of modern tools in harvesting prevents mechanical damage and helps in post-harvest processes (Kasso & Bekele, 2018). Table 4.8 shows the different methods used by small-scale tomato farmers in the study area during harvesting. Out of the 80 respondents, only 1.3% adopted mechanical methods in harvesting tomatoes, while 98.8% harvested their tomatoes manually. The Table shows that most of farmers had no access to modern harvesting tools thus, most of the harvested tomatoes were subjected to mechanical damage due to poor handling systems, resulting in losses.

Table 4.8: Harvesting methods

	Frequency	Percent
Manual	79	98.8
Mechanical	1	1.3
Total	80	100

Source: Survey data (2022)

4.3.2 Harvesting challenges

Table 4.9 shows that 20% of small-scale tomato farmers lacked manpower during harvesting, 27% percent had no access to harvesting tools, while 26% had challenges with transporting harvested crops. It can, therefore, be concluded that most farmers had challenges that hindered them from effectively carrying out harvesting operations thus, affecting post-harvest processes. Most farmers faced transportation challenge, which, in turn, could delay marketing of tomatoes, resulting in damages to output.

Table 4.9: Harvesting challenges encountered by respondents

	Frequency	Percentage
Lack of manpower	16	20
No harvesting tools	22	27.5
Transportation	26	32.5
Other	16	20
Total	80	100

Source: Survey data (2022)

4.3.3 Sorting and grading after harvesting

Sorting and grading after harvest help prevent the spread of diseases and enhance the shelf life of the harvested crop. Sorting helps to separate damaged and infested crops from good ones. It also helps to separate ripe from unripe tomatoes (Mehra *et al.*, 2016). Table 4.10 shows that 91.3% of small-scale farmers sorted and graded their harvested crops, while 8.8% did not grade or sort their harvested products. This is an indication that most farmers who graded their products knew about grading, which helped in preventing further damage, such as the spread of microbial diseases, resulting in rot and spoilage. Some farmers either take their tomatoes

directly to the market where they are sold directly or consume the harvested crops in their households.

Table 4.10: Sorting and grading after harvesting

	Frequency	Percentage
Yes	73	91.3
No	7	8.8
Total	80	100

Source: Survey (2022)

4.3.4 Storage facilities of tomatoes after harvesting

Storage after harvesting preserves the shelf life of crops, helps the farmer to meet market demands and maximize profit (Nassarawa & Sulaiman, 2019). Table 4.11 shows the storing capacity of farmers in the study area. Table 4.11 shows that 15% of tomato farmers in the study area stored their crops after harvest, while 85% did not do so. This is an indication that most farmers do not have storage facilities, resulting in spoilage of harvested tomatoes in the study area.

Table 4.11: Storage facilities of tomatoes after harvesting

	Frequency	Percentage
Yes	12	15
No	68	85
Total	80	100

Source: Survey(2022)

4.4. The results from Cobb Douglas Regression Model on determinants of post-harvest losses

The goodness-of-fit of the estimated model was measured using the F-statistic and the results show an F-statistic p-value of 0.000, an indication of a very good measure of fit. The cost associated measures were converted to their natural log form and the dummy variables computed as independent variables.

The results of Cobb Douglas model presented in Table 4.11 show determinants of post-harvest losses. The model has R-square of 0.67, an indication that 67% of the variation in post-harvest loss was explained by the variables included in the model. Out of nine variables considered in the model, four were statistically significant in explaining post -harvest losses.

4.4.1 Determinants of post-harvest losses of tomatoes at the level of the farm

The results of Cobb Douglas model presented in Table 4.12 show determinants of post-harvest losses. The model has R-square of 0.67, an indication that 67% of the variation in post-harvest loss was explained by the variables included in the model. Out of nine variables considered in the model, four were statistically significant in explaining post-harvest losses.

With regard to education, the results in Table 4.12 indicates a negative relationship between post-harvest losses and education which is significant at (Coeff: -0.308*:P<1%). This is an indication that lack of formal education among respondents resulted in higher post-harvest losses. This result is consistent with Busari Ahmed *et al.* (2015), who found that lack of formal education will result in higher post-harvest losses.

The selling price, as shown in Table 12 below, shows a negative and was statistically significant at (Coeff: -1.766** :P<0.05). This is an indication that a drop in the selling price of tomatoes leads to higher post-harvest losses among respondents. It also shows that losses made should reflect in the price of goods produced in order to reduce the extreme effects felt by respondents, that could help prevent default among producers. This finding is similar to that of Cattaneo *et al.* (2021), who found that the lower the selling price of a product, the higher the post-harvest loss incurred.

Table 4.12 also shows the size of household of respondents. It shows the existence of a statistically significant relationship (Coeff: -0.255: P<0.05) between size of household and post-harvest losses. This is an indication that the smaller the size of the household, the higher the post-harvest losses. This can be attributed to lack of family labour. This result is in line with the findings of Bello *et al.* (2022), who found that the smaller the household number of the family, the higher the level of post-harvest losses.

Interestingly, among variables that were not significant, is lack of training, as it has a positive relationship with post-harvest loss. This implies that absence of training among respondents contributes to post-harvest losses. Thus, training of numerous actors on a regular basis throughout the tomato value chain plays critical roles in abating post-harvest losses. This finding is in line with that of (Sanyé-Mengual *et al.*, 2016), who found out that although packaging was not statistically significant, it has a negative relationship with post-harvest losses. This implies that the more farmers fail to package their produce, the higher risk of post-harvest losses. This can be attributed to the fact that agricultural produce is time-sensitive, particularly among small-scale producers, as they lack storage facilities to keep their produce

for a longer period in their own places. Absence of storage facilities results in higher rates of produce spoilage thus increasing post-harvest losses. There is need for government to take this factor into consideration when initiating programmes aimed at assisting farmers to reduce post-harvest losses. Such action can help in containing and/or reducing inflation. This finding correlates with that of Özdemir and SEMİZER (2021), who found that lack of packaging during post-harvest contributes to post-harvest losses.

Table 4.12: The results of Cobb Douglas regression model on determinants of post-harvest losses

Regression variables	Regression coefficient	t-statistic	p-value	Standard error
Intercept (α)		7.145	0.000	15.378
Total harvested amount (X_1)	1.844*	7.516	0.000	2.825
Education (X_2)	-0.308	-2.355	0.021	0.131
Household number (X_3)	-0.255	-2.244	0.028	0.245
Farming experience (X_4)	-0.085	-1.096	0.277	0.107
Selling price (X_5)	-1.766*	-7.272	0.041	2.741
Vehicle type dummy (X_6)	-0.062	-0.849	0.399	0.145
Packaging dummy (X_7)	-0.054	-0.54	0.505	0.150
Lack of training dummy (X_8)	0.041	0.569	0.571	0.212
Selling place dummy (X_9)	0.061	0.813	0.419	0.224
Number of observations		80		
R ²		0.667		
F (80, 9)		15.349		

***, **, * significance at 1%, 5% and 10% respectively

Source: Survey data analysis (2022)

4.5 Constraints faced by farmers at various stages of tomato value chain in Ikire.

The third objective of the study was to identify major constraints faced by farmers along the tomato throughout the tomato value chain. To rank the constraints encountered by farmers on every point along the value chain, Kendall's coefficient of concord (W) was employed. Table 4.13 shows the constraints face by farmers at each level respectively.

Table 4.13 demonstrates that between the seven constraints in the region, pests and diseases consistently rated as their most pressing constraint. Due to lack of pesticides during planting, most of the tomatoes were damaged by pests, while some were unable to survive. This finding is in line with Abimbola (2014), who reported that pests and diseases is one of the major causes of post-harvest losses in the tomato sector in Nigeria. Major post-harvest constraints reported by farmers in the study area (Table 4.13) were lack of storage facilities, lack of financial report, lack of ready market and poor transport system, while the least reported constraint was lack of technical support. This is consistent with the findings of (Abimbola, 2014).

Table 4.13 shows that most farmers lacked storage facilities, resulting losses after harvesting, as unsold tomato needed to be stored. Farmers require funds to purchase better tomato seed types, agrochemicals and inputs, and labor. Due to a lack of economic backing, farmers are forced to farm smaller areas of land in order to meet their current financial capacities. The absence of technical help was considered as that of the least restrictive factor. Farmers had the necessary skills in tomato farming, thus, did not give much attention to technical support.

Kendall's coefficient of concordance (W) equaled 0.148, with 1% being asymptotically significant. This indicates that there was 14.8% consensus among tomato producers' evaluations of restrictions. As a result, the null hypothesis, in which there is no agreement among the constraints' ranking, is discarded.

Table 4.13: Constraints faced by farmers at each stage of the tomato value chain

Constraints	Mean score	Rank
Pests and diseases	2.49	1 st
Lack of storage facilities	3.46	2 nd
Lack of financial support	4.28	3 rd
Lack of ready market	4.36	4 th
Unreliable transport system	4.41	5 th
High production cost	4.45	6 th
Lack of technical support	4.55	7 th

Statistics

N	80
Kendall's W ^a	0.148
Chi-square	71.175
Def.	6
Asymp. Sig.	.000

Source: Generated from field data analysis (2022)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the main findings, the conclusion, and recommendations.

5.2 Summary

The study's overarching goal was to evaluate post-harvest losses in the tomato value chain in Ikire, Osun State, Nigeria. The goals were to: investigate the sociodemographic characteristics, post-harvest handling practices and post-harvest losses experienced by tomato farmers; examine determinants of post-harvest losses of tomatoes at the level of the farm; and investigate constraints faced by farmers at various stages of the tomato value chain. SPSS (version 21) and Microsoft Excel 360 were used to re-code, arrange and analyse the raw data from the survey questionnaire. Mathematical computations and assumptions were performed. Descriptive statistical analysis (means standard deviation, percentage and Chi-square) was performed to describe socio-demographic characteristics of respondents, post-harvest handling practices and post-harvest losses experienced by tomato farmers. Cobb Douglass production function was used to examine determinants of post-harvest losses in tomato farming. Kendall's Coefficient of Concordance (W) was used to determine constraints faced by farmers at each stage of the tomato value chain. Analytical techniques, such as descriptive statistics and multiple regression models were used in the study, and significant and non-significant variables recognised.

5.3 Major findings of the study

The study revealed that 78.8% of respondents were male. This is an indication that males were more involved in tomato production and sales compared to females. It was also revealed that older people dominated the sector in the study area. The average age of respondents in the area was 46 years. Lack of full participation of young people in agriculture is due to the perception that agriculture is irrelevant, retarding and a difficult task. The study further revealed that 72.5% of respondents were married. This is an indication that married small-scale farmers are more stable, financially stable and have support from their spouses. The study then revealed that 27.5% of respondents were single and divorced. This is an indication that unmarried or divorced respondents lacked stability and received no support from either their spouses or households.

The study further revealed that 6% of respondents did not have formal education, while 36% dropped out of school in Grade 12. As indicated, majority of respondents had either lower level or no formal education. The study also revealed that 77.5% of farmers were not supported by government. This could be due to lack of effective governance. Majority (98%) of respondents in the study area did not have modern tools thus harvested their tomatoes manually, 27% of farmers had no access to harvesting tools, while 26% had challenges with transporting harvested tomatoes. Furthermore, 85% of farmers did not store their tomatoes due to lack of storage facilities. Thus, most of the harvested fruits were wasted, either through mechanical damage or deterioration during post-harvest processes, resulting in high post-harvest losses.

Table 4.11 shows the results of Cobb Douglass production function used to analyse factors causing post-harvest losses of tomatoes in Ikire, Osun State, Nigeria. The regression showed that total loss of tomatoes produced regressed with nine explanatory variables in the regression model. The results from Cobb Douglass production function indicated that four of the variables were statistically significant. The findings showed that six variables were negative towards total quantity of tomato loss in Ikire, Osun State, Nigeria as follows: level of education of respondents; size of households; farming experience; selling price; vehicle type; and packaging. However, some of the variables were negative, such as: total amount of harvest; lack of training; and selling place of tomatoes.

Outcomes from Cobb Douglass production function revealed that education was significant at 99% confidence interval ($P=0.021$), an increase in education of respondents is more likely to reduce post-harvest losses of tomatoes. This is because the coefficient of education was found to be -0.308 , which signify that an increase in 1% will lead to a decrease in post-harvest losses of tomatoes by 0.308. Education plays an important role in reducing post-harvest loss of tomatoes in the value chain. The P value of size of household (0.028) was found to be significant at 5%, with the coefficient of -0.255 , an indication that an increase in 1% will lead to a decrease in post-harvest losses by 0.25. Selling price had a negative value on post-harvest losses and was found to be significant at 5% confidence interval ($P=0.041$), an increase in the selling price of tomatoes is more likely to reduce post-harvest losses. However, total amount of harvest had a positive influence on post-harvest losses. Quantity harvested was significant at 1% level of probability, reflecting a 99% level of confidence since the value of p obtained was 0.000. Total quantity harvested plays an important role in the rate of post-harvest losses. This is because the coefficient of total quantity harvested is 1.844. This is an indication that an increase

in 1% in the quantity of tomatoes harvested will lead to an increase in post-harvest losses by 1.888.

Given the results, the hypothesis that there is no statistical relationship between socio-demographic characteristics of small-scale tomato farmers and post-harvest losses of tomatoes in Ikire, Osun State, Nigeria is rejected. The hypothesis that shows a statistically significant relation amongst socio-demographic features of small-scale farmers and post-harvest losses of tomatoes in Ikire, Osun State, Nigeria, is accepted.

5.4 Conclusion

Results revealed important factors which had significant effect on post-harvest losses in the tomato value chain in Ikire, Osun State, Nigeria were total quantity of harvest; education; size of household; and selling price. This implies that an increase in each of the variables can significantly reduce the rate of post-harvest losses in the tomato value chain. The results revealed a reduction in post-harvest losses, which has a great impact on post-harvest losses in the tomato value chain. For instance, education was found to be statistically significant in the reduction of post-harvest losses.

5.5 Recommendations

The recommendations discussed below are made based on the findings of this study.

- There is need for Government to provide regular support to farmers in the region, such as formal means of education. There is also the need to provide primary and secondary education to rural areas where inhabitants lack basic amenities to enhance education. Agricultural organisations should assist in educating farmers living in the area on the importance of basic education.
- There is need for farmers to maintain a stable relationship between spouse and members of the family in order to increase support rendered to them on the farm. This will help them to build better homes on trust and support farmers in terms of family labour and funds.
- There is need for farmers to seek technical and financial information from various institutions on credit facilities and technical support. If farmers have access to technical and financial assistance, they will have some knowledge on technical know-how and be able to buy farm inputs.

- There is the need for a system that determines the pricing of tomatoes. It is expected that this system will help in constructing a price mechanism that considers the total cost and losses involved during harvesting and post-harvest processes. Such system will help farmers recover losses incurred during and after production.

5.7 Summary of the chapter

The Chapter has provided a summary of the study, major findings, conclusion, and recommendations. Hypothesis testing was performed in this Chapter and the null hypothesis was rejected.

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QUESTIONNAIRE

Questionnaire on “**Assessment of post-harvest losses in the tomatoes value chain in Ikire, Osun State, Nigeria.**”

Dear Sir/Madam

This study is an assessment of post-harvest losses in the tomato value chain in Ikire Local Government Area, Osun State, Nigeria, in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Economics.

All information gathered will be treated with much confidentiality and would solely be for academic purposes. Your support and contribution would be very much appreciated. For further inquiries, please contact me on 40018059@student.g.nwu.ac.za or +27781757400

DEMOGRAPHY CHARACTERISTICS OF RESPONDENTS

Date of interview:

1. Name of interviewer..... Tel No
2. District.....
3. Town/Community.....

4. Name of respondent.....
5. Age of respondent
6. Sex: Male [] Female []
7. What is your level of educational? Tick as appropriate: Primary [] Middle/JSS []
Secondary /SSS [] Tertiary [] Islamic education [] None []
Other.....
8. What type(s) of work (major) do you do in addition to farming?
9. How long have you been involved in tomato business/farming?yrs.
10. What is your family size? a)1-5 b)5-10 c)10-15
11. What is the size of your tomato farm land(plots)? a)1-3 b) 3-6 c) 6-9, others specify...
12. What other vegetable crops do you cultivate? Lettuce [] Cabbage [] Beans [] Pepper []
Green Pepper [] Eggplant [] Others [] (Please specify).....
13. Do you have any reason for your choice? Yes [] / No []
14. What are your reasons for your choice above?.....
.....
.....
15. What type of tomato do you prefer? a) local [] b)exotic []
16. Is post-harvest loss a challenge you face? a) Yes [] b) No []
17. Where do you obtain your vegetable produce from? (Tick as many as applicable) On
farm [] Purchase from farmer [] Purchase from wholesaler[] Others[] (Please
specify)
18. Please name the variety/varieties of tomatoes you cultivate. a) Ibadan local b) Roma VF
(c) NHLe 158-13, others specify,.....
19. Source of planting tomato seed: a) Family [] b) Friends [] c) Market [] d) Others[]
(Please specify.....
20. What informs your choice of market preference for tomato seedlings [] ease of
cultivation[] very portable [] less post-harvest damage [] Others[] (Please
specify).....
21. Do you get any form of support to help improve on production? Yes [] / No []
22. Do you have any post-harvest loss management knowledge? Yes [] / No []
23. If “yes”, did you acquire this knowledge through a special training in post-harvest loss
management? Yes [] / No []

24. If "yes", what form of support do you usually receive? Financial [] Subsidy of farm equipment [] Technical [] Free farm equipment [] Free Agrochemical supply [] Subsidy on agrochemicals [] Other [] (Please specify)
25. What quantity of tomatoes did you buy/harvest in 2021(Baskets)? a) 1-20 b) 20-50 c) 50-100, Others: specify? ...
26. Out of the quantity of tomatoes bought or cultivated, how much was sold? a) 1-20 b) 20-50 c) 50-100, Others: specify, ...
27. Do you incur any commodity losses from the point of cultivation to the point of sale? Yes [] No []
28. Please provide the name of the important communities where you get your produce.
a) b) c)
29. What mode of transportation do you use to transport your tomatoes? Human labour [] Rented trucks [] By own vehicle [] Others [] (Please specify).....
30. What packaging material do you use for your produce? Wooden crates [] Cardboard boxes [] Woven palm baskets [] Plastic crates [] Others [] (please specify).....
31. How do you determine the price of tomatoes? a) Market force b) Associations c) Yourself

HARVESTING, HARVESTING CHALLENGES AND HARVESTING OPERATIONS

32. How do you harvest your produce?
Manual [] Mechanical []
33. If manual, please specify. By knife cutting [] by hand twisting [] cutlass []
34. What is the average maturity period of produce?
2-3 months [] 3-4months [] 4-5month [] If different, please specify.....
35. What time of the day do you harvest your tomatoes? Early in the morning [] After sunset (evening) [] Any time of the day[]
36. At what stage of maturity of the fruit do you harvest?

When fully ripe [] when partially ripe [] when green and unripe []

37. How do you check for the maturity of your produce before harvesting?

By hand feeling [] By visual observation [] Using an instrument to measure []

38. Do you grade your produce immediately after harvesting? Yes [] No []

39. What quality indicators do you use for grading your produce? (Tick as many as applicable)

a) color []

b) size []

c) Weight []

d) shape []

e) Physical blemishes []

40. What quantity of produce do/did you now harvest from your plot?

.....(baskets) a)1-20 b) 20-50 c) 50-100, Other specify...

41. What are the challenges faced during harvesting seasons? a) Lack of manpower b) Lack of available harvesting tools c) Transportation

LOSSES AT STORAGE AND STORAGE PRACTICES

42. Do you store some of the produce after harvesting? Yes [] No []

43. If yes, where do you store them before marketing? On farm [] At home []

44. How long can you store your tomatoes.....(days)

45. Please describe the losses you incur, during harvesting and post-harvest processing, including the quantity.

Stages of handling	Nature of loss (See code below)	Quantity of produce harvested (weight)	Estimated losses (Quantity)
Harvesting operations			

Gathering and transportation, packing on at the farm			
Grading and sorting operations on the farm			
Temporal processing (Drying, curing, etc)			
Transport to home, store, or market			

1=Weight loss 2=Presence of insects 3=Destruction by rodents/birds 4=rotting of fruits 5=Wilting and shrinking 6= Microbial or disease infections 7=Spillage 8=Boring by insects 9=Others (specify)

46. What do you think should be done to minimise these losses?

a)

b)

47. Describe the types and quantity incurred during storage at home or the farm.

Stages of handling	Nature of loss (See code below)	Quantity of produce harvested (weight)	Estimated losses (Quantity)
Storage on farm			
Storage at home			

1=Weight loss 2=Presence of insects 3=Destruction by rodents/birds 4=rotting of fruits
5=Wilting and shrinking 6= Microbial or disease infections 7=Spillage 8=Boring by
insects 9=Others (specify)

48. How do you package your produce for storage?

Specify.....

49. What are the major storage problems of your produce?

a)

b)

50. Do you encounter some pests (insects, mites, and rodents) at storage?

Yes [] No []

51. If yes, how do you control these pests?

a) Mechanical control; b) Chemical control; c) Biological control

52. What are some of the ways you adopt to improve the storage life of the vegetables?

.....
.....

53. Which of the following accounted for the losses? (Tick as many as applicable)

Lack of ready market []

Lack of transport of produce []

Lack of storage facility []

Poor storage []

Pest attack []

Others [] (Please specify.....)

54. Which of the following constraints do tomato farmers face in your community?

Challenges Rank

Lack of storage facilities []

Lack of financial support	[]
Lack of technical support	[]
Lack of ready markets	[]
Unreliable transport systems	[]
High costs of production	[]