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POST-HARVEST LOSSES OF TOMATOES (*LYCOPERSICON ESCULENTUM*) AND HANDLING PRACTICES IN WOTUTU, SOUTH WEST REGION CAMEROON

A Research project submitted to the Department of Development Studies of the Pan African Institute for Development – West Africa (PAID-WA) Buea, in Partial Fulfilment of the Requirements for the Award of a Bachelor of Science (B.Sc.) Degree in Sustainable Development with specialization in Environment and Agriculture

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DECLARATION

I, **Elive Limunga Linda** declare that this research project is my original work and has not been presented for a degree in other Universities and that, all the sources of materials used for the thesis have been duly acknowledged.

9-02-2018

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CERTIFICATION

The research project entitled: "**Post-harvest losses of tomatoes (*lycopersiconesculentum*) and handling practices in Wotutu, South West Region Cameroon**" is submitted to the Department of Development Studies of the Pan African Institute for Development – West Africa (PAID-WA) Buea, by **Elive Limunga Linda**. Registration No. **PAIDWA 00087** for the award of a Bachelor of Science (BSc) degree in Sustainable Development with specialization in Environment and Agricultural Development.

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DEDICATION

To the Elive's family who has been a strong source of support and inspiration during this period.

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ABSTRACT

Huge quantity of food is lost each year in the process of getting to the final consumers. This study accurately assessed the extent of post-harvest losses and evaluated the postharvest handling practices and challenges of tomatoes *(Lycopersicon esculentum)* farmers in Wotutu village, South West Region of Cameroon. Data for the study was primarily collected using a questionnaire survey, key informant interviews and desktop review of related literature. The data were analyzed using descriptive and inferential statistics with the aid of the Statistical Package for Social Science 20. Firstly, the study found out that most of the farmers used on-farm shade for storing fruit after picking, bamboo woven baskets for packaging and motorbikes for transportation to non-farm gate markets. Secondly, the study indicated that significant ($p<0.005$) postharvest losses accounts for about 1,458 baskets of tomatoes, representing a total loss on the production of 11.9% per season. These loss represented a total income loss of 3,240,000 FCFA and 8,640,000 FCFA during tomatoes production glut periods and off-seasons respectively. Thirdly, the study found out that the primary causes of postharvest losses in tomatoes were pest and diseases, poor handling of fruits during harvesting, reduced packaging, poor storage and limited transportation facilities and adverse climatic conditions. Finally, the study found out that the significant challenges to postharvest loss mitigations and reduction were lack of postharvest processing technologies and services, inadequate and unreliable transport facilities and networks, limited access to finance and lack of storage facilities. The study concluded that postharvest loss of tomatoes significantly affected tomatoes production ($p<0.005$) with severe consequences on farm-dependent household's incomes and livelihoods in Wotutu village. It is recommended that farmer's field schools should be established while research and other training initiatives on post-harvest handling and losses prevention of tomatoes should be carried out.

Keywords: *Postharvest loss, loss margins, postharvest handling, tomatoes*

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ABBREVIATIONS AND ACRONYMS

CEPB	Centre of Excellence for Post-harvest Biotechnology
CLPs	Critical Loss Points
FAO	Food and Agricultural Organization
FAO STAT	Food and Agricultural Organization Statistics
ft	Feet
MINADER	Minsitere de l'Agricultureet du DeveloppementRurale
INPHO	Information Network on Post-Harvest Operations
OPV	Open Pollinated Varieties
PHL	Post-Harvest
RL	Regular Leaf
TSS	Total Soluble
USDA	United States Department of Agriculture

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Tomato (*Lycopersicon esculentum*) considered as a primary vegetable crop has achieved remarkable popularity over the last century and is one of the most popular and extensively consumed vegetable crops in the world (Grandillo et al, 1999). It can be eaten raw in salads or as an ingredient in many dishes, and in drinks (Alam et al, 2007). Tomatoes and its by-products provide a wide range of nutrients and many health-related benefits to the body. In areas where it is being cultivated and consumed, it constitutes an essential part of people's diet.

Tomatoes production accounts for about 5.2 million hectares of harvested land area globally with an estimated output of 173 million tons (FAOSTAT, 2016). China leads world tomato production with approximately 50.6 million tones followed by India with 18.5 million tons (FAOSTAT, 2016). It is grown basically in every country of the world. According to FAO (2012), the State of Food Insecurity in the World 2012,870 million people were chronically undernourished during the years 2010/2012, and a majority is living in developing countries. The total proportion of people who do not have enough food in the world has declined since 1990 from 18.6 percent to 12.5 percent. In Western Asia, North Africa and Sub-Saharan Africa, however, an increase in undernourishment has taken place during the last years. 234 million persons, or 26.8 percent do not have enough food available In Sub-Saharan Africa, 2010-2012 (FAO, 2012). The origin of tomato is from South American Andes. (Naika et al, 2005). According to FAO postharvest losses in developing countries can vary from 15 percent up to 50 percent. A considerable amount of agricultural produce in the sub-Saharan Africa is lost due to improper postharvest processes; as a result, there is a significant hole between the gross production and net availability. Today, the main globalchallenges are how to ensure food security for a world growing population while guaranteeing long-term sustainable development. Rendering to FAO, food production will need to increase by 70% to feed world population which will reach 9 billion by 2050.

Tomato is now a valuable cash and industrial crop in most parts of the world (Ayandiji et al, 2011) not only for its economic importance but also its nutritional value to the human diet and subsequent significance in human health (Willcox et al, 2003). Tomatoes also preserve your heart healthy and avoid cancer. Tomato is also rich in vitamins, minerals, sugars, essential amino acids, iron, dietary fibers and phosphorus (Ayandiji et al, 2011). Tomato juice is known to be used for intestinal and liver disorders (Wamache, 2005). It, therefore, serves as a source of these nutrients when consumed.

Tomatoes and tomato-based foods offer a wide range of nutrients and many health related benefits to the body as shown in Table 1.1.

Table 1.1 Major nutrients in tomatoes

Table 2.1: 15 major nutrients can be gotten from tomatoes

Nutrient	**Amount**
Calcium	1.2mg
Carbohydrate	4.7g
Copper	0.073mg
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 NationalNutrient Date base (2010)

Like in other parts of Cameroon, tomatoes constitute an essential ingredient in the meals of most urban and rural communities in South West Region. In Cameroon, South West region is an outstanding producer of tomatoes, ranked only after the Western, Center and North West Region. In 2015, it was estimated that tomatoes production in the South West stood at 2043 tons, a drop from 2290 tons in 2014 (MINADER, 2015).

However, tomatoes making and consumption in Africa is controlled by a myriad of climatic, agronomic (pre-harvest, harvest, and postharvest practices), geographic, logistical, and infrastructural factors (Aidoo et al, 2014). A particularly worrying challenge in the tomatoes production and consumption value chain in invariably all tomatoes producing countries in the continent is the high occurrence of post-harvest losses (Arah et al, 2015).

Post-harvest loss reduction has involved the attention of government and international development organizations (Market Insider, 2015). These efforts have made substantial strides over the years. However, these post-harvest loss reduction efforts are limited by verified and verifiable data on post-harvest loss. The study is an attempt to bridge this gap.

1.2 Statement of Problem

A particularly worrying challenge in the tomatoes production and consumption value chain in invariably all tomatoes producing countries in African continent is the high incidence of post-harvest losses (Arah et al., 2015). The Voice Newsletter (2006) and FAO (2008) posited that post-harvest losses in tomatoes could be as high as 50% in SSA, representing a huge loss of valuable nutrients, income, and employment to millions along the chain (Aidoo et al., 2014). With a continually growing population, there is a frequently increasing demand for tomatoes in Cameroon. But unfortunately, the quantities of tomatoes produced locally cannot reach into the local market. To meet up with domestic needs, Cameroonians have resorted to the importation of tinned tomatoes. It does not only represent a huge loss of foreign earnings to these countries but equally, present a health risk dimension since cases of expired tomatoes importation have been stated in recent years.

These unacceptable extraordinary rates of postharvest losses have involved the attention of the relevant stakeholders, and a panoply of loss reduction policies have been crafted on on-farm and off-farm interventions implemented (Tandi et al., 2014; Sallah, 2015). Substantial strides have

been made on the heels of these loss reduction policies frameworks and initiatives. However, efforts geared towards postharvest loss reduction have been constrained by lack of documents on the subject. Like in all other developing countries, attempts at explaining the postharvest loss in tomatoes production and consumption have primarily remained in the realm

of speculations and conjectures (Aidoo et al., 2014). Limited data exist on postharvest tomatoes losses (Genova et al., 2006; Weinberger et al., 2008; Kitinoja, 2010). Due to the difficulties of postharvest tomatoes losses, policies are needed to be made, reliable documents on the current magnitude and sources of the losses along the supply chain must be determined (Newman et al., 2008; Weinberger et al., 2008).In Cameroon, very limited studies have provided documents on the level and causes of postharvest and on the post-harvest handling practices and limitations faced by farmers. This study seeks to fill this gap.

1.3 Objectives of study

The primary objective of study was to evaluate the post-harvest loses of tomatoes and the handling practices of farmers in Wotutu, South West Region of Cameroon.

The specific objectives of the study are;

1. To identify the level of post-harvest losses in tomatoes and its effect on farmers income in Wotutu village.
2. To assess the causes of post-harvest losses in tomatoes in Wotutu village
3. To determine the harvest and post-harvest handling practices of tomatoes farmers in Wotutu village.
4. To evaluate the post-harvest handling constraints faced by tomatoes farmers in Wotutu village.

1.4 Research Questions

1. What is the level of post-harvest losses in tomatoes and its effect on farmer’s income?
2. What are the causes of post-harvest losses in tomatoes in Wotutu village?

3. What are the harvest and post-harvest handling practices of tomatoes farmers in Wotutu village?
4. What are the post-harvest handling limitations faced by tomatoes farmers in Wotutu village?

1.5 Significance of the study

Theoretically, the study will add to the form of existing knowledge on post-harvest in Wotutu. It will enhance research for scholars serving as a reference material and will bring to light the challenges faced by tomatoes farmers after harvest.

The outcome of the study will help in understanding the causes of post-harvest injuries of tomatoes and the effect of such losses on livelihoods. It will also provide proposals for improving post-harvest technology in tomatoes.

Practically, findings from this study will serve as an essential document for policy formulation and agricultural development strategies on how best to discourse the problems that are associated with losses in vegetables and tomatoes in particular.

It will also contribute to informing and tailoring extension services to the felt needs of tomatoes farmers.

1.6 Scope of the study

Although this work carried out in the south west region, it focused only on one village around mount Fako, where tomato production was identified the principal agricultural activity .The study mainly covered post-harvest activities with regard to tomato production in the area. The period of the study included the peak season which from (October-December) off season from (January –April) season.

1.7 Organization of the Study

The work is separated into five chapters. Chapter one consist of a background, statement of problem, objectives, significance, etc. Section two is separated into three parts, namely literature review, conceptual framework and gaps identified in the literature. Chapter three consists of the materials and methods used for carrying out the study. The chapter constitute of

the presentation of the findings and discussions while section five is made up of the summary of findings, conclusions, and recommendations.

1.7.1 Population and Ethnic composition

About the 2005 census, it has a population of 780 inhabitants (National Institute of Statistics, 2005). The cultural group or tribe that is settled there is the Bakweri; the tribe which inhabits almost the whole of Fako Division which is nestled on the Atlantic Coast of Cameroon. While the native population is made up of the Bakweri tribe as already mentioned, the settler population from other Regions of Cameroon has taken up a reasonable portion of the village as settlers and has reached the status of quasi-natives. Over time, paid to the rapid economic activities such as agriculture in Wotutu has grown to the level of a semi-urban settlement. Transportation is easy since it is linked up between Buea and Limbe two of the fastest growing urban spaces in the Southwest Region of Cameroon. Wotutu is originated on the border between these two municipalities and many are those villagers who don't know if Wotutu is found in Limbe or in Buea. One fact remains unchanged; the fact that this village will play a very vital part in the future of Fako Division.

1.7.2 Description of the biophysical environment

The environment of Wotutu Village is biophysical, which is covered with an evergreen tropical ecosystem, and a variety of biodiversity are found in Wotutu which include birds and animals species. Portions of the mountain slopes have very few species of plants and animal located

Nowhere else in the world such as the unique medicinal Prunus Africana and animal species living only under particular conditions, which can be recognized here. From thick vegetation forest, secondary forest, shrubs to savanna to the peak of the mountain.

The biophysical environment of Wotutu has significantly been tampered with and exploited for:

- Habitation and settlement.

- Agriculture (plantations, smallholders, local farmers) paid to its fertile volcanic soils.

Estates include CTE tea Farms, CDC banana as well as smallholders' palms and tea farms.

- Housing and furniture materials through Cutting down on trees.

- Volcanic activity has significantly altered and influenced the biophysical environment. The exploitation of the primary forests have turned them into secondary forests and in certain cases farms or habitation in almost all available and nearby land in the villages and urban spaces.

These intensive activities have caused and continue to create environmental hazards to soils, water sources, climate, and biodiversity.

1.8 Description of study area

1.8.1 Location

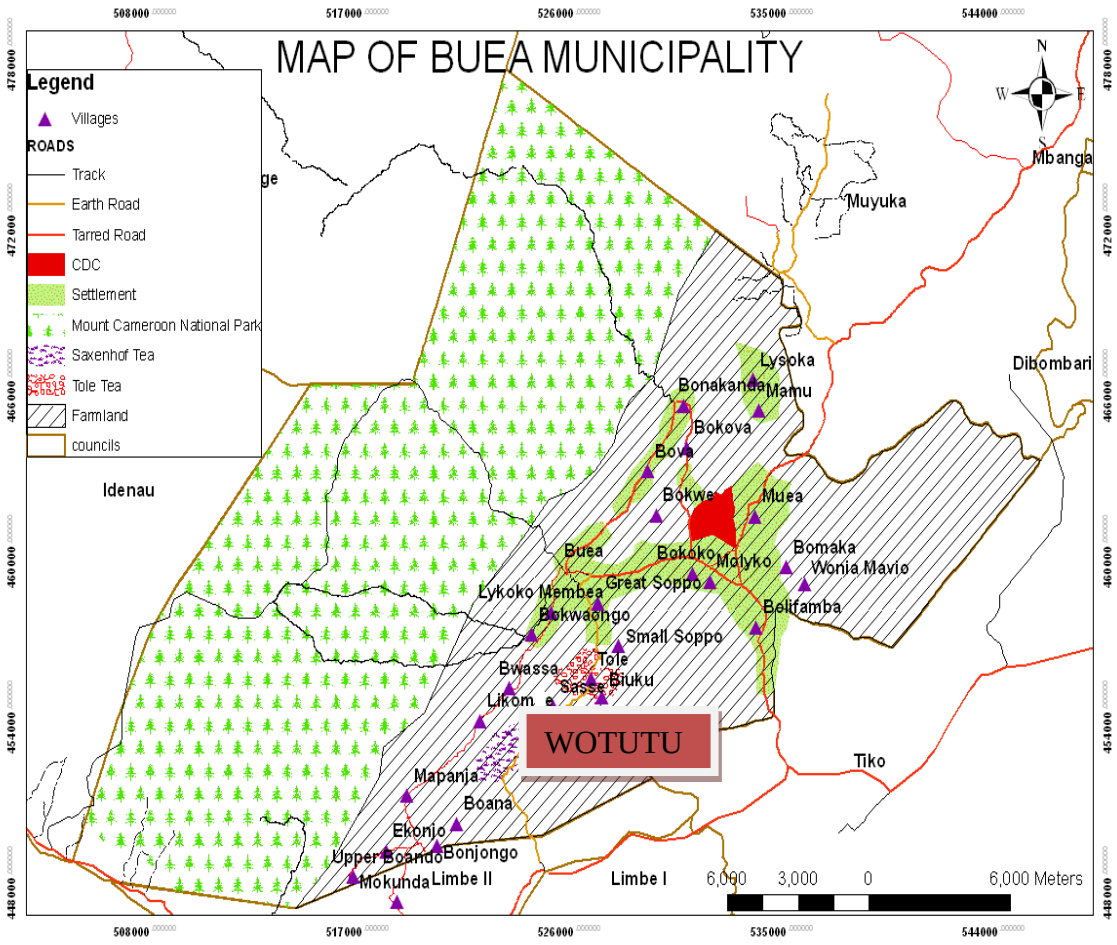

Figure 1.1 Map of Buea Municipality showing Wotutu Village

1.8.1.1 Climate

Wotutu village has an equatorial climate there two significant seasons. Rainy season is in between Marchand October and Dry season IS from November to May). Temperature ranges between 20 C to 28 oC while annual rainfall ranges between 3000mm to 5000mm.

The climatic conditions here are the tropical rainforest with rainfall almost throughout the entire year. However, the normal monthly High/Low Temperature for these urban spaces ranges from 23oC low to 32oC high. The more you move downward from Buea station to Muea temperature increases. Some factors are behind this. Firstly, the principle of "higher one goes the colder it becomes" it is practical as the town is along the slopes of the mountain. Secondly, the population of some areas is higher intensity, activity, and growth than others. Molyko, for example, has more infrastructures which reduce circulation and exchange of air.

1.8.1.2 Topography and soil

The area is made of high and low lands with many rocks and gravels due to volcanic eruptions. The earth found in Wotutu is the basalts and is as the outcome of the first volcanic activity in the Fako Mountain area, which occurred in the Cretaceous system. These soils have remained weathered and partly covered by more recent deposits, thus the grounds are black and in these areas are well drained due to the hilly nature of the terrain and the fact that they are free-draining. The soil is actual rich in nutrients and allows the cultivation of various crops such as tomatoes, cabbage, okra, pepper, corn, cocoyam, yams, cassava, plantains, beans, vegetables and even certain cash crops such as palm trees, cocoa, and bananas. The climate gets cooler as one ascends the hills of the mountain thus Citrus trees are less prosperous. The soil and climate is very helpful for vegetation and agriculture though in some areas digging is difficult due to the stony nature of the rocks.

The vegetation is usually green almost throughout the year with fewer trees in areas of high concentration of houses. It is rare to move 200m without spotting green grass, shrubs, and fruit trees.

1.9 Definition of Terms

1.9.1 Post-harvest

Post-harvest has been defined to include all the steps in the production process after harvesting of farm produces (Parfitt et al., 2010).

1.9.2 Postharvest losses (PHL)

Post-harvest loss (PHL) refers to the decrease in edible food mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption (FAO, 2013). The food losses take place at production, post-harvest and processing stages in the food supply chain (Parfitt et al., 2010). Food losses are primarily due to poor infrastructure and logistics, lack of technology, insufficient skills, knowledge, and organisation capacity of supply chain actors, and lack of markets.

1.9.3 Value chain

A value chain is arrangement of organisations, people, activities, information, and resources involved in moving product or service from supplier to customer.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICALFRAMEWORK

2.1 Literature Review

2.1.1 Conceptual Review

2.1.1.1 Tomatoes: History, biology and global production

2.1.1.1.1History

According to Tan et al. (2010) the present-day tomato has a short life cycle history of human consumption. It was believed to have its origin in the South American Andes (Naika et al. 2005) which is in present-day Peru where it was increasing in the wild at the foot of hills. It was then taken to other parts of the world by the early explorers where it was planted as ornamental curiosities but not eaten. In Europe, for instance, it was cultivated in gardens as decorative plants and was considered poisonous. Although tomato was accepted later as an edible crop in Europe in about 1840 (Paran and van der Knaap, 2007), there was still strict opposition to its consumption in other parts of the world. Global tomato production has improved during the 1920s as a result of breakthroughs in technologies that made mechanized processing possible (Tan et al. 2010). With growing knowledge in profit derived from a genetic modification of tomatoes, more desirable parameters have been selected for varietal improvement to enhance the crop for human consumption. Today, Number varieties of vegetables are consumed all over the world in different recipes.

2.1.1.1.2 Biology of tomatoes

Tomatoes are grouped under the family Solanaceae and genus Solanum. Its scientific name is *Solanum lycopersicum*. Tomato plants are vines, originally decumbent, typically growing 180 cm (6 ft) or more above the ground if supported, although erect bush varieties have been bred, generally 100 cm (3 ft) tall or shorter.

Tomato plants are dicots and are growing as a chain of branching stems, with a terminal bud at the tip that does the actual growing. Once suggestion eventually stops growing, whether because

of pruning or flowering, lateral buds take over and develop into other, fully functional, vine. Tomato is covered with short hair; vines are typically pubescent. These hairs ease the vining process, turning into roots wherever the plant is in contact with the ground and moisture, especially if the vine's connection to its source has been damaged or severed.

Most tomato plants have complex leaves and are called regular blade (RL) plants, but some cultivars have simple leaves known as potato leaf (PL) style because of their resemblance to that particular relative. There are variations, such as rugose leaves, of RL plants which are intensely grooved, and variegated, angora leaves, which have additional colors where a genetic mutation causes chlorophyll to be excluded from some portions of the sheets. Their leaves are 10–25 cm (4–10 in) long, odd pinnate, with five to 9 leaflets on petioles, each leaflet up to 8 cm (3 in) long, with a serrated margin; both the stem and leaves are densely glandular-hairy.

Flowers, emerging on the apical meristem, have the anthers fused along the edges, forming a column close to the pistil's style. Flowers in domestic cultivars tend to be self-fertilizing. The flowers are 1–2 cm (0.4–0.8 in) across, yellow, with five pointed lobes on the corolla; they are borne in a cyme of three to 12 together.

Tomato fruit is classified as a berry. As a real fruit, it develops from the ovary of the plant after fertilization, its flesh comprising the pericarp walls. The fruit contains hollow spaces full of seeds and moisture, called locular cavities. These vary, between cultivated species, according to type. Some smaller varieties have two holes, globe-shaped varieties naturally have three to five, beefsteak tomatoes have a significant number of lower cavities, while paste tomatoes have very few, tiny pits. For propagation, seeds need to come from a mature fruit and be dried or fermented before germination.

2.1.1.1.3 Recipes of tomatoes

Tomatoes be able to be processed for a variety of recipes. It can be consumed fresh in salads, cooked in other dishes or transformed into other food products (Grandillo et al. 1999; Ahmed et al. 2012). A few simple recipes for tomatoes include a tomato-egg sandwich, tomato-watermelon sorbet, fried green tomato with bread and butter pickle, grilled chicken-tomato salad, tomato stew, tomato-chili soup and tomato-egg sandwich.

2.1.1.1.4 Nutritional values in tomatoes

Tomato has become a significant cash and industrial crop in many parts of the world (Ayandiji et al. 2011) not only because of its economic weight but also its nutritional value to the human diet and subsequent significance in human health (Willcox et al. 2003). Tomato is wealthy in vitamins, minerals, sugars, essential amino acids, iron, dietary fibers and phosphorus (Ayandiji et al. 011). It, therefore, serves as a source of these nutrients when consumed. Table 2.1 below gives 15 major nutrients and their quantities that can be derived from consuming a 123-gram of ripened tomatoes.

Table 2.2 Major nutrients derived from tomatoes

Table 2.1: 15 major nutrients derived from tomatoes

Nutrient	Amount
Calcium	1.2mg
Carbohydrate	4.7g
Copper	0.073mg
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 Nutrients Date base (2010)

2.1.1.1.5 Health benefits of tomatoes

Tomato contains advanced amounts of lycopene, a type of carotenoid with anti-oxidant properties (Arab and Steck 2000) which is significant in reducing the incidence of some chronic diseases (Basu and Imrhan 2007) like cancer and many other cardiovascular disorders (Freeman and Reimers 2010). This anti-oxidant property and its health advantage have raised the interest in tomato research and its consumption as a crop with medicinal properties (Di Mascio et al. 1989). Lycopene is believed to be the primary contributing compound in tomatoes responsible for lower risk of prostate cancer (Pohar et al. 2003). Other studies have also shown that consumption of vegetables and tomatobased foods can be associated to reduced incidence of a variety of cancers in general, including pancreatic, lung, stomach, colorectal, oral, bladder, breast and cervical cancers (Giovannucci 1999). Lycopene in tomatoes enhances fertility by improving the quality and swimming speed of sperm while reducing the number of abnormal sperm in men (Innes, 2014). Consumption of vegetables can prevent old-age related diseases like dementia, osteoporosis, Parkinson's and Alzheimer's (Freeman and Reimers, 2010). Tomatoes contain high sources of vitamin C and vitamin A which are vital in warding off muscular degeneration and improve eyesight. It is also understood to be a powerful blood purifier and clear up urinary tract infections. Tomatoes are high in fiber which aids easy digestion and can assist in weight loss. These abundant health benefits of vegetables and tomato-based foods may be linked to its high production globally.

2.1.1.1.6 World Production

Tomatoes are estimated to be grown on more than 5 million hectares with a production of nearly 129 million tones. China tops the chart of tomato growers worldwide. Other high growers include the USA, Turkey, and India. In Africa, Egypt Nigeria, Tunisia and Morocco are the leading producers (Table 2.1).

Table 2.3: The top 15 Tomato Producing Countries in Africa.

Rank	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 (former)	529 200
9	Kenya	397 000
10	Ghana	321 000
11	Tanzania	255 000
12	Mozambique	250 000
13	Benin	244 742
14	Libya	225 000
15	Niger	188 767

Source :(FAOSTAT 2014)

2.1.2 Harvesting, postharvest handling, processing and storage of tomatoes

2.1.1.1. Harvesting

Postharvest actions include harvesting handling, storage, processing, packaging, transportation and marketing (Mrema and Rolle, 2002). The principles that dictate at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists differentiate three steps in the lifespan of fruits and vegetables: maturation, ripening, and senescence. Maturation is pinpointing of the fruit being ready for harvest (FAO, 2008).

Harvesting marks the last part of the growth cycle of tomatoes and the beginning of a series of stages of significant activities that ensure that the consumer gets the vegetable in the preferred state and at the best of desired quality. Harvesting fresh-market tomatoes are labor intensive and

require multiple pickings (Orzolek et al., 2006). According to Orzolek et al., (2006), vegetables for the wholesale market should usually be chosen at the mature green stage to breaker stage to stop the fruit from becoming overripe during long transportation/shipping and treatment. They suggest leaving tomatoes on the vine to ripen if they can be brought to market quickly and in excellent condition and that, it is when the market is available that vegetables should be vine-ripe before harvesting.

Usually, fresh market tomatoes are harvested by hand with harvesting operation varying among growers. For the harvesting operation, Kitinoja (2008) recommends the use of plastic buckets for harvesting fruits that are easily crushed, such as tomatoes. These should be smooth without any sharp edges that could harm the produce.

In harvesting, Hurst (2010) advises that a proper harvesting management especially in picking high-quality tomatoes, since the riper the plant, the more susceptible it is to bruise. He also proposes harvest crews to carefully place fruits into picking containers instead of dropping them since research has demonstrated that a drop of more than 6 inches onto a hard surface can cause internal bruising that is not apparent until after the tomato is cut open. Also, Hurst (2010) advises against overloading of bins. He explains that extreme tomato weight will provide a force of compression to cause bruise damage to the tomatoes. He also suggests shading of harvested vegetables to reduce heating-up while waiting to be delivered to the packing house based on the research conclusions that, bulk bin tomatoes held in the hot sun for just one hour can be as high as 25 degrees warmer than fruit kept in the shade.

2.1.2.2 Postharvest handling of fresh tomatoes

According to Kitinoja and Gorny (2009), postharvest handling of fresh vegetables has a direct link with its shelf life. They reported that processing starts right from harvesting and put estimates of losses in developing countries in the range of 20% to 50% tracing causes of injuries to the field, during transport and marketing. Tomatoes are highly perishable and very susceptible to mechanical damage with poor handling and transportation (Bani et al., 2006). Also, at the usually high temperatures fruits and vegetables transpire and respire at high rates, therefore, the need shade from the sun's heat (Robbins and Moore, 1992). It is also recommended that product be harvested in the morning to guarantee that they are at the coldest possible temperature during the delay between harvest and initial cooling. Most often also,

losses of fresh vegetables occur along the long chain of supply from the producer to the consumer. Injuries happen at the stages of sorting, packaging, storage, transport and marketing stages of the life the fresh horticultural produce.

As a remedy, Kitinoja and Gorny (2009) recommend that when handling fresh produce at its market destination, it is essential to avoid rough handling, minimize the number of processing steps and strictly follow a temperature and relative humidity management. Stacking of non-uniform containers should also be done with care to prevent the collapse of weaker packages, and more substantial cartons should always be placed at the bottom of a stack (Kitinoja and Gorny, 2009).

2.1.2.3 Processing of Tomatoes

Right after harvesting, if the tomato is to be transported, little handling is required before they are carried to the processing plant in the shortest possible time. Once at the station, they should be treated immediately or at least stored in the shade (Gould, 1992). The flowchart in Figure 2.1 summarizes the various tomato-processing methods for processing tomatoes into juice, paste, whole, sliced, or diced tomatoes.

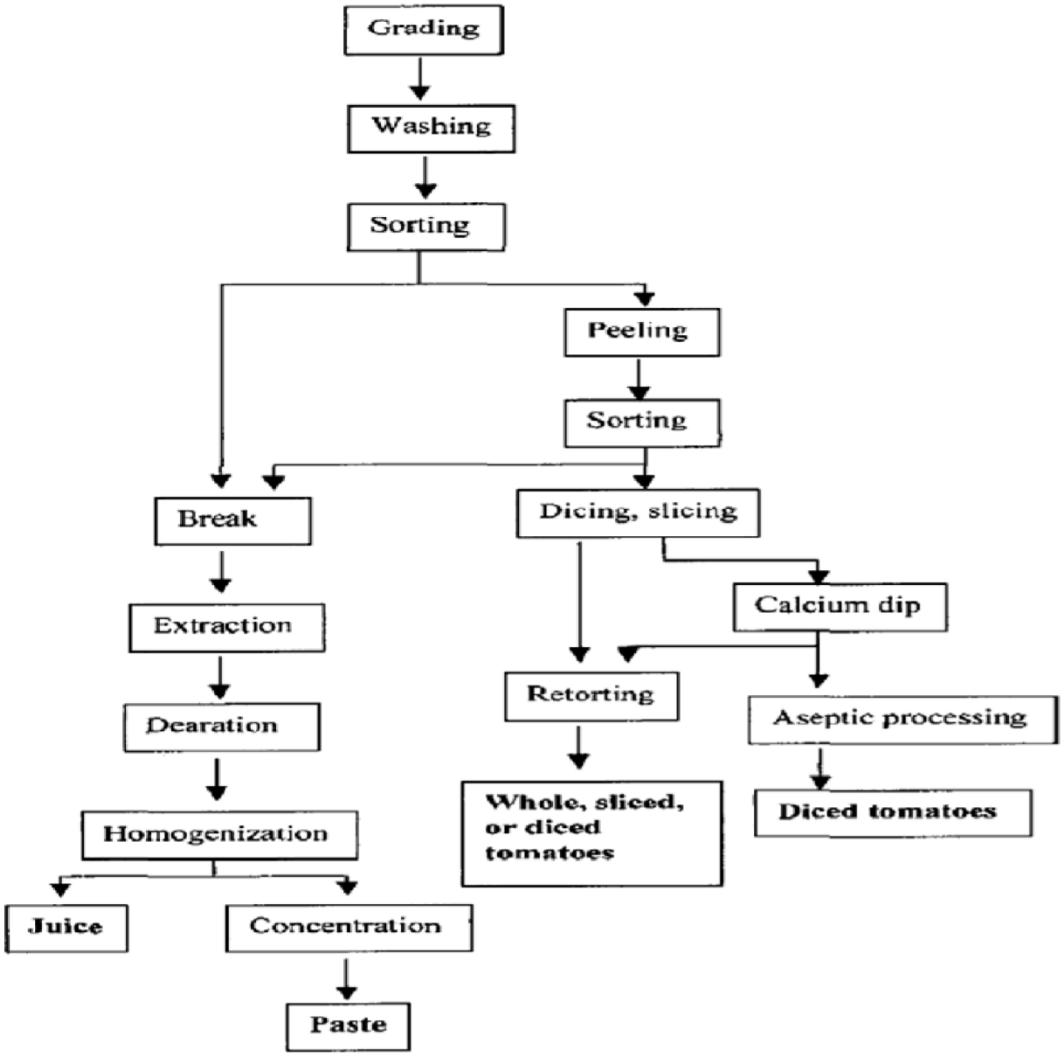

Figure 2.2 Flow Chart of various tomatoes processing methods

Source (Yeboah, 2011)

2.1.2.4 Storage of fresh tomatoes

According to Kitinoja and Gorny (2009), in developing countries, there is absence of storage facilities on-farm or at wholesale or retail markets and lack of ventilation and cooling in the very few existing on-farm facilities. Others comprise over-loading of cold stores (where available) including placing warm produce into the cold room, stacking product too high (beyond container strength) and the practice of mixing the product with others with different temperature and relative humidity requirements. There are few key aspects to consider when storing fresh produce. Because some cultivars have a naturally longer storage potential than

others of the same commodity Kitinoja and Gorny (2009), recommend first determining which varieties would give you the best results. Insect pests can cause a considerable deterioration and spoilage of fresh vegetables by damaging the integrity of the food.

According to Hurst et al. (1993), insects do not destroy tomatoes by consuming huge quantities of it, but once they damage the product, further deterioration results from microbial invasion.

FAO (2008) reported that when stored at 10oC with the optimum humidity of about 80%, green tomatoes can be put for 16 - 24 weeks. In another report, Ashby (2000) recommend 13o to 21oC and a relative humidity of between 90 to 95% as the best transport conditions for green-mature tomatoes.

In Ghana, Ellis et al. (1998) observed that farmers carry out neither on-farm nor off-farm storage of the fresh tomato fruits and that, the primary postharvest sdifficulties of the farmers are the need for permanent purchasing outlets as well as the stabilization of the unit price per box of tomato.

2.1.2.5 Processing and Preservation of Tomatoes

According to Robinson and Kolavalli (2010), in Ghana, many reports only repeat the mantra that processing offers a way of buying up the glut. However, the reality is that “tomato gluts” is an annual feature, which occurs only for a few weeks of the year and usually results from the production of large volumes of rain-fed local varieties that are unsuitable for processing

Ellis *et al.* (1998), reported that although tomato is an extremely perishable crop, the rate and extent of spoilage depends on several factors and that, to overcome this problem calls for the need to develop simple, cost-effective and easily adaptable preservation techniques. They added that doing this requires a better understanding of the farm management system of farmers.

Tomatoes can be processed into many forms to be consumed instantly or preserved for future use. For example, according to Kitinoja, and Gorny (2009), horticultural produce are processed to become part of the following categories: Beverages, condiments, confection and miscellaneous.

Adubofour et al. (2010) also reported about formulating four cocktail juices in different ratios from a combination of carrots, tomatoes (Bolga variety) and two varieties of orange and pineapple. A promotion of this could help increase the consumption of the vegetable whiles helping swab the excess.

On preservation, Kitinoja and Gorny (2009) recommend the use of brine or vinegar to pickle vegetables such as the tomato. Due to the acidic nature of vinegar, there is no need for further processing if it is drafted into sterilized containers before being filled with the tomatoes.

Ashby (2005) described a simple home-drying method for stewing tomatoes. Ripe tomatoes are steamed or dipped into boiling water to loosen skin, chilled in cold water, peeled and cut into sections about ¾ inch wide, or slice. These are blanched for three minutes and dried in the dehydrator for 10 – 18 minutes or twice this time using the conventional oven.

Other preservation methods are described by the Food and Agriculture Organization (FAO) and the Information Network on Post-Harvest Operations (INPHO). FAO and INPHO (1998) describe the pulping method, the drying method, and the peeled tomato preservation method.

2.1.2.6 Marketing of tomatoes

Six basic marketing alternatives are open to the tomato grower: wholesale markets, cooperatives, local retailers, roadside stands, pick-your-own operations, and processing firms (Orzolek*et al.,* 2006).

Marketing cooperatives generally use a daily-pooled cost and price, which spread price fluctuations over all participating producers.

Fresh and processed produce can be marketed on the farm, at the farm gate, locally or regionally via wholesale or retail actions, or through exports to other countries. When deciding how to market your fresh and processed produce, each postharvest handling step taken provides an opportunity to make additional profits (Kitinoja, 2004).

2.1.1.3 Postharvest losses: Definition, types, cost, causes and handling methods

2.1.1.3.1 Definition

Various definitions of applied to postharvest loss for different food products

Table 2.4 Various definitions of postharvest food loss have been stated in the available literature

Definition	Food group	Reference
That weight of wholesale edible products(exclusive of moisture content) tha is normal consumed by humans and that has been separated from the medium and site of its immediate growth or action with the intention of using it for human feeding but which, for any reason , fails to be consumed by humans	Horticultural crops	Bourne,1976
These are qualitative and quantitative losses that take place in horticultural produce between harvest and consumption	Horticultural crops	Kader,1983
That portion of fruit and vegetables which is produced but dose not reach its natural destination: human consumption.	Fruit and vegetables	Fehr and Romao,2001
Physical (weight loss and decay),nutritional, cosmetic(loss of appearance as a result of shrinkage), and economic in nature	Citrus fruits	Ladaniya,2008
Any food substance, raw or cooked, while is discarded, intended or required to be discarded.	Food waste	EUC,2009

Any wholesome food commodity, raw or cooked, that is thrown away or is regarded to be of downgrade quality and does not fetch its potential revenue, qualifies as a postharvest loss (Bourne, 1976; Kader, 1983; Fehr & Romao, 2001; Ladaniya 2008; EUC, 2009). Postharvest losses originate from poor pre-harvest and postharvest management including lousy handling of produce during transit and storage leading to a partial or total loss in produce quality (Prusky, 2011). Food waste which is often referred to in the literature as “food losses and spoilage” is a primary concern with respects to postharvest losses. This type of injury relates to products

intended for human consumption occurring at the end of the food supply chain as a result of retail and consumer behavior (Parfitt et al., 2010).

2.1.1.3.2 Types of postharvest losses

The standard categories of postharvest loss are quantitative and qualitative losses in the post-harvest system (Ladaniya, 2008). The quantitative loss also referred to as physical injury causes a reduction in product weight (Rahman, 2007; Hodges et al., 2011). A downgrade in quality leads to loss of consumer appeal and is usually described by comparison with locally accepted standards for premium quality such as appearance, taste, texture and nutritional value (Ladaniya, 2008; Flores, 2000. There is revenue lost from both quantitative and qualitative losses. The cost of postharvest losses cuts across the entire food supply chain and negates on the potential profits of every actor involved in the vegetable handling and marketing system. The economic losses also influence the marketing prices of each commodity. Accordingly, products with higher postharvest losses often fetch higher prices (Kader, 2002; Sudheer& Indira, 2007).

Although the causes of losses may be readily apparent, the complexity and heterogeneity of vegetable marketing systems make it challenging to quantify postharvest losses. Literature reports on quantitative injuries of vegetables as an entity are limited. Reports on vegetable losses are often combined with those of fruits (Kader, 2005; Parffit et al., 2010; FAO, 2011). However, vegetables are very diverse in their morphology, and this is an essential determinant of quantitative postharvest losses. Leafy greens are more perishable than roots and tubers and also readily susceptible to wilting, mechanical injury and decay (Kitinoja, 2010). To obtain reliable data on postharvest vegetable losses requires investigating losses of specific vegetables as opposed to looking at losses of combined food groups. This strategy provides more insight on postharvest vegetable losses regarding their critical control points. They give the right

information, and policymakers can come up with appropriate loss reduction interventions to control the problem.

Qualitative losses are much more challenging to assess than quantitative losses (Kader &Rolle, 2004; Dorais et al., 2001).). Losses in quality are evidenced by a decrease in the market value of the product (De Lucia &Assennato, 1994; Ward & Jeffries, 2000). Any vegetable which is misshaped or has some blemishes may be as tasty and nutritious as one that is perfect for

appearance. Sadly such produce is only likely to have a market, just if the price is right (Kader, 1983). For most vegetable trades this may entail making price cuts and produce specials for imperfectly shaped produce including products that have passed their "sell by date."

The inherent nutritional quality of vegetables is of great importance particularly for all consumers at large. Nutritional value of plants defines the presence of those essential substances that are important to support life such as vitamins, phytochemicals and proximate composition (Lee & Kader, 2000; Sablani et al., 2006). Changes in fresh produce nutritional quality are not visible but plays an essential role in making correct food choices. Nutritive losses are primarily due to improper postharvest handling and prolonged storage (Rusell, 2009). Vitamins are the most labile of all nutrients; their retention declines rapidly for produce that is controlled to adverse handling and storage conditions (Kader, 2002; Javanmardi & Kubota, 2006; Rusell, 2009). Postharvest nutrient losses impact negatively on the nutritional wellbeing of consumers because it is the quality and not just the quantity of food in a diet that determines the nutritional status of an individual (Vorster, 2010).

There is a shortage of information on the monetary value of postharvest vegetable losses as a food entity. The available data for most countries combine fruit and vegetable losses while others report on ordinary food losses (Kader, 2005; WRAP, 2011; Parfitt et al., 2010; FAO, 2011). A survey conducted in the USA by Kantor et al. (1997) revealed that combined fruit and vegetable losses accounted for nearly 20% of the monetary value of food losses at the consumer and food service levels. These losses were due to product deterioration, discarding of excess perishable products and plate waste (food not consumed by the purchaser).

In 2004, Vietnam produces export revenues declined by US$15 million (R120 million) from the previous year's returns. Inadequate postharvest technologies were identified as the primary cause of this substantial economic loss (the Socialist Republic of Vietnam, 2004). Collective postharvest food losses mainly in the form of waste are reported to cost the USA economy at least US$100 billion (R800 billion) annually (Jones, 2006). Approximately 20% of this loss comprises of fresh fruit and vegetables. In the UK, food waste alone (purchased but not eaten) is valued to be in the region of £10.2 billion (R147 billion) per year (DEFRA, 2007). Raw and minimally processed vegetables are perceived to account at least 9% of the food waste in the UK (Parfitt et al., 2010; FAO, 2011).

2.1.1.3.3 Cost of postharvest losses

Postharvest losses aggravate hunger by causing less food to be available for consumption (FAO, 2009). Also, consumers are deprived of getting a premium product for every qualitative loss. When 30% of a harvest is wasted, 30% of all the factors that contributed to producing the crop is also lost (World Resources, 1998). That, in turn, has severe repercussions on poverty alleviation, income generation, and economic growth. Vegetable production is a resource-intensive industry, and any means of loss translates into resource waste. The world's already limited natural resources are not saved from wastage by the injuries.

Agriculture alone utilizes almost 80% of all fresh water, making a significant impact on the water footprint (FAO, 2009). Agricultural and industrial growth has seen many countries extracting groundwater faster than it can be replenished (Mexico by 20%, China by 25%, India by 56% (Marien, 2011). With an increasing decline of global freshwater resources especially in the arid and semi-arid areas, there is a great need for more efforts aimed towards sustainable water use. It highlights the importance of reducing postharvest losses as part of the drive to increase food availability. Promoting resource conservation can serve as a complementary alternative to increasing resource inputs aimed towards improving agricultural production.

The vegetable production utilizes various forms of mechanical energy. This energy is required for plowing, planting, applying agrochemicals, irrigating, harvesting, refrigeration, transporting, food processing, and packaging of vegetables (Yahia, 2008; FAO, 2009). All these processes consecutively contribute to some adverse environmental impacts, which impact on, among other things, climate change (Maraseni *et al.,* 2010).

2.1.1.3.4 Causes of postharvest losses

The primary purposes of postharvest injuries can be classified into direct primary (technical origin) and indirect secondary (socio-economic origin) factors (Kader, 2002, Sudheer & Indira, 2007). Both the primary and secondary elements contribute to physiological deterioration, mechanical damage, biological and microbiological spoilage of fresh produce. Table 2.3 highlights some of the common causes for postharvest loss in vegetable production and marketing systems.

Table 2.1 Classification of postharvest vegetable losses and their significant causes

Primary Causes	Secondary Causes
Biological	Pre-harvest management
Microbiological	Harvesting methods and handling
Chemical	Storage type
Biochemical	Transport mode, type and availability
Physiological	Refrigeration facilities
Mechanical	Bumper crops creating over supply.
Environmental	Drying equipment
Pathological	Marketing and processing systems
Physical	Legal standards in place
	Tool maintenance
	Type of packaging

(FAO, 1989; Flores 2000; Marsh et al., 2001)

2.1.1.3.5. Handing methods

2.1.1.3.5.1 Harvesting

The physiological development of any fruit at harvest has a sign on postharvest quality of that fruit, therefore; care must be taken as tow when to harvest the fruit to achieve the best quality. The shelf life of fruits and vegetables is characterized by postharvest physiologists in three stages: the maturation, ripening, and senescence stages. The maturation step indicates the fruit is ready for harvest. Tomatoes can be harvested in either matured green, partially ripe, or ripe state. Tomato being a climacteric fruit can be collected at the developed green time letting ripening and senescence to happen during the postharvest phase of the fruit. Producers targeting distant warehouses must harvest their tomatoes in a matured green state. Harvesting tomatoes in a developed green state will not only give producers Sample time to prepare the fruit for the market but also prevent mechanical injuries during harvesting. Unluckily, most producers from developing countries especially those in Africa harvest tomatoes when they are partially or fully ripened. Fully ripened plants are sensitive to mechanical injuries during harvesting resulting in

shorter shelf life. Attention must, therefore, be taken when harvesting tomatoes in a ready state to bypass these injuries which will hasten decay. Also, the use of harvesting and packaging containers with sharp edges must be checked to limit bruising and puncturing of these fruits. Collection of fruits should be taken in either early or late hour of the day to avoid excessive heat generation. Access to ready market is a big challenge when dealing with highly perishable crops like tomatoes in most developing countries. Is challenge can beat tribute to many factors, but the primary factor is the pattern of production resulting in huge gluts(Isaac Arah et al.,2016). In most developing countries, a higher proportion of tomato production is rain-fed because large peaks in output during the raining seasons which is ever more than the local consumption of the product. The problem is further intensified by the shortage of processing facilities or equipment which can be utilized to process the crop into a more long-lasting form for later use. Processing tomatoes into an added strong form will also serve as a means of value addition which will give a better market value for the crop. Producers from developed countries constantly have supply contracts with multinational supermarkets to supply tomatoes. In the case of producers in many developing countries, there is absence of communication between producers and consumers and also lack of market information which could be the principal cause for the mismatch within production and available markets. Producers, therefore, have to sell their product at little cost to prevent total loss. (FAO, 2008)

2.1.1.3.5.2 Precooling after Harvest

Field heat is usually high and unattractive at harvesting stage of many fruits and vegetables and should be removed as quickly as possible before any postharvest handling activity. Excessive field heat gives rise to an unacceptable increase in metabolic activity and immediate cooling after harvest is therefore essential]. Precooling minimizes the result of microbial activity, metabolic activity, respiration rate, and ethylene production, while reducing the ripening rate, water loss, and decay, thereby conserving quality and extending the shelf life of harvested tomatoes. The suitable temperature range from about 13–20°C for tomato handling can be attained either in the early hours of the morning or late in the evening. Harvested fruit must be pre-cooled to remove excessive field heat if collected at times other than the recommended periods. A cheap but effective way of precooling harvested tomatoes for producers of developing countries can be by dipping fruits in cold water (hydro cooling) mixed with disinfectants such as sodium hypochlorite if the availability of clean water is not a challenge. This method is useful in removing field heat while decreasing microbial loads on the harvested

fruits. Tomato producers in developing countries especially those from Africa assemble their harvested produce under tree shade in an attempt to minimize field heat. Tree shade, however, is not a reliable and efficient way of reducing field heat in harvested produce (Arah et al., 2016). Therefore, it is recommended that the adoption of a simple on-farm structure like a small hut made of thatch can be very beneficial in precooling of harvested tomatoes

2.1.1.3.5.3 Cleaning or Disinfecting

Proper hygiene is a significant concern to all produce handlers, because of not only postharvest diseases but also the incidence of food-borne illnesses that can be transferred to consumers. According to a report by the Government of India, Salmonella, Cryptosporidium, Cyclospora, and hepatitis A virus are some examples of disease Causing plants that have been forwarded to consumers within fresh fruits and vegetables. Unluckily, cleaning or disinfecting tomatoes after harvest is not a typical customer for most tomatoes handlers in developing countries particularly those from Africa. This practice may be associated with either the unavailability of potable water at the production sites or the sheer ignorance of the method. However, in areas where water is not a problem, the practice of disinfectants in water either for washing or cooling can reduce both postharvest and food-borne diseases in fruits and vegetables. The purpose of various disinfectants during postharvest treatment of tomatoes is well documented. For instance, sodium hypochlorite solution has been used to sterilize tomato fruits in order to reduce the incidence of fungal infection before any postharvest treatment was applied. Dipping of tomato products in thiabendazole solution reduced the microbial load on the fruit. Fruits and vegetables are treated with chlorinated water after washing to reduce the microbial pressure before packaging. (Workneh et al., 2012) Show that anolyte water dipping disinfection of tomatoes not only reduced the microbial loads on the fruits but also maintained the superior quality of vegetables during storage. Disinfection can be used in conjunction with hydro cooling to achieve the purpose of reducing excessive field heat and reducing microbial infection at the same time.

2.1.1.3.5.4. Sorting and Grading

One of an essential process in packaging and marketing of fruit and vegetables is sorting and grading. Sorting is the removal of rotten, spoiled, or diseased fruits from the fresh and clean ones. The damaged or diseased fruits can yield ethylene in substantial amounts which can

change the adjacent fruits. Grading is also the process of categorizing fruits and vegetables by color, size, stage of maturity, or degree of ripening. The two methods are essential in maintaining postharvest shelf life and quality of harvested tomatoes. Sorting ends the spread of infectious microorganisms from bad fruits to other healthy fruits during postharvest handling of plants. Grading also helps handlers to categories fruits and vegetables in a given standard parameter which enables easy handling. For instance, classification by color or maturity stage will help reduce overripe fruits which will quickly provide ethylene to hasten the ripening method in the whole batch. Commercial tomato farmers frequently use sophisticated systems that require precise sorting and grading standards for their produce. Small-scale producers and retailers in developing countries, in contrast, may not use written downgrading and sorting standards; however, the fruit must still be sorted and sized to some degree before selling or processing it. (Arah et al., 2016)

2.1.1.3.5.5 Packaging

Packaging is also one of the primary aspects to consider in addressing postharvest losses in fruits and vegetables. It is enclosing food produce or product to defend it from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources. Packaging as a postharvest handling method in tomato production is essential in putting the product into sizeable portions for easy handling. However, using improper packaging can cause fruit damage resulting in losses. Some common packaging materials used in most developing countries comprise wooden crates, cardboard boxes, woven palm baskets, plastic crates, nylon sacks, jute sacks, and polythene bags. Most of the abovementioned packaging elements do not give all the protection needed by the commodity. While the majority of these packaging materials like the nylon sacks do not allow proper aeration within the packaged product causing a build-up of heat due to respiration, likewise the woven basket, have rough surfaces and edges which cause mechanical injuries to the produce. The wooden crate and the woven palm basket are some of the standard packaging elements used in many developing countries particularly those in Africa for packaging tomatoes. The main shortcoming of the wooden crate is in its height which creates a lot of compressive forces on fruits located at the base of the container These undesirable compressive troops cause internal injuries which finally result in a reduced postharvest quality of the tomatoes. There have been recommendations of modifying the wooden crate to make it more suitable for packaging tomatoes. Kitinoja (2007), has therefore

recommended that the depth of the container should be decreased significantly to reduce the build-up of compressive strengths which can cause mechanical injuries to fruits at the base of the; crate after packaging. The palm woven baskets used by tomato handlers have sharp edges facing the inside which puncture or bruise the fruit when they are used. It has also been suggested by Idah et al., (2007) that woven palm baskets should be made with the smooth side of the material turned inward.

2.1.1.3.5.6 Storage

Tomato has very high moisture content and therefore is very challenging to store at ambient temperatures for a long time. While storage, in the value chain, is usually required to ensure uninterrupted supply of raw materials for processors. The room increases the length of the processing season and helps give continuity of product supply during the periods. For short-term warehouse (up to a week), tomato products can be stored at ambient conditions if there is enough ventilation to reduce the accumulation of heat from respiration. For longer-term storage, ripe tomatoes can be prevented at temperatures of about 10–15°C and 85–95% relative humidity. At these temperatures, both ripening and chilling injuries are minimized to the least levels. These conditions are also challenging to obtain in most tropical countries, and therefore losses of appreciable quantities of harvested tomatoes have been reported. It is consistent with the claim that the quality of vegetable is jeopardized when exposed to high temperatures and high relative humidity. Very low-temperature storage to is harmful to the shelf life and quality of many tropical fruits like tomatoes. For instance, refrigerating a plant will decrease its flavor, a quality trait of vegetables which is principally determined by the total soluble solids (TSS)

and pH of the fruit. A knowledge of the correct temperature management during storage of tomatoes is essential in increasing the shelf life of the fruit while maintaining fruit qualities. Tomatoes handlers in tropical countries can store vegetables for short, intermediate time by using an evaporative cooling system made from woven jute sacks. (Arah et al, 2016)

2.1.1.3.5.7 Transportation

In most developing countries, the production sites for many tomato producers are far from the marketing centers and also unreachable by road. Carrying harvested tomatoes to the market on such lousy road network and the lack of proper transportation like refrigerated vans become a

big trial for both producers and distributors. This problem, therefore, causes unnecessary delays in getting the produce to the market. Meanwhile, any delay between harvest and consumption of tomatoes can result in losses. Producers incur injuries of up to about 20% due to transportation delays. Producers will, therefore, make use of any available means of transport for their products without considering its appropriateness to avoid delays. Some modes of transportation include human labor, donkeys, public transport, rented trucks, busses, Lorries, fuel tankers, articulator trucks, and pick-up vans. However, the use of proper transportation for tomatoes is a significant factor to consider in postharvest handling of the fruit. During transport, the produce should be immobilized by appropriate packaging and stacking to escape from excessive movement or vibration. Vibration and impact during transportation as a result of undulations on roads is one of the major causes of postharvest losses to most fruits and vegetables especially tomatoes. The critical nature of road networks in most developing countries, therefore, provides these unfavorable factors during transportation resulting in numerous losses. The wobbling nature of most of the vehicles coupled with the lousy kind of roads causes a lot of mechanical damage to the product before it arrives its destination. Handlers from developed countries, on the opposite hand, use refrigerated containers and trailers which travel on reasonably good roads. Transporting tomatoes in refrigerated trucks is not only suitable but also useful in preserving the quality of fruits. However, both the initial investment and the operating costs of these vehicles are costly and behind the affordable reach of most producers in developing countries. Handlers of developing countries, hence, transport their produce using the most affordable mode of transport without considering the effect it will have on the postharvest quality of the fruit. Even though handlers from developing countries may not have the volume to use refrigerated trucks, they should be well educated on the consequences that any other transportation option they use may have on their produce (Arah et al., 2016).

2.1.1.4 Challenges faced by tomatoes farmers

The challenges faced by tomatoes farmers can be classified into on farm and off-farm difficulties

2.1.1.4.1 Off-farm obstacles

2.1.1.4.1.1 Lack of access or risky nature of roads

Lack of access roads to production fields in many African countries is a significant challenge hampering the success of the tomato industry. Majority of the production fields are located in remote areas, which are far from improved roads making access to competitive markets difficult and costly. In cases where roads are linking these farming sites, these roads are in a very disgraceful condition. A study conducted by Yeboah (2011), indicated about 76% of farmers and traders in Brong Ahafo region of Ghana complained of bad roads affecting their business. The bad state of road infrastructure makes it very hard, expensive and time consuming to transport harvested produce to marketing centers. Meanwhile any delay between harvest and consumption of the tomatoes can result in losses (Kader 1986). Losses of up to about 20% are incurred by farmers due to transportation delays (Babatola et al. 2008). This claim may even be an exaggeration of the actual transportation losses as vehicles which ply these deplorable roads sometimes get stuck in the mud and may take hours or even days to get them out which may result in losses higher than the 20% assertion by Babatola et al. (2008). Bad road infrastructure is a major challenge facing most developing countries and this challenge is likely to affect both producers and distributors of tomatoes for a long period. The inaccessible nature of most farming sites has led farmers in Wotutu to adopt the use of Bikes" – a motorized tricycle which can easily access most of the inaccessible sites.

2.1.1.4.1.2. Inappropriate mode of transport

The use of appropriate transportation is another factor to consider in postharvest handling of tomatoes. During transportation, the produce must be immobilized by proper packaging and stacking to avoid excessive movement or vibration. Vibration and impact during transportation as a result of undulations on roads is one of the main causes of postharvest losses to most fruits and vegetable especially tomatoes (Idah et al., 2007). The bad nature of road networks in most developing countries therefore provides these negative factors during transportation resulting in great losses. Farmers in develop countries use refrigerated containers and trailers which travel

on practically good roads. Transporting tomatoes in refrigerated trucks is not only convenient, but also effective in preserving the quality of fruits. However, both the initial investment and the operating costs are very high and beyond the affordable reach of most farmers in developing

countries. Farmers therefore transport their produce using the most affordable mode of transport without seeing the effect it will have the quality of produce. The nature of these transportation options available to the farmers in Africa does not provide the stability the stacked produce needs during transportation. The wobbling nature of the vehicles coupled with the bad roads causes a lot of mechanical damage to the produce before it reaches its destination.

2.1.1.1.4.1.3. Inappropriate retail packaging

Packaging of fresh fruits and vegetables including tomatoes has a great significance in reducing postharvest losses. Proper packaging should provide the produce the protection required from physical damages during handling, storage, transportation and marketing.

Unsuitable packaging can result in postharvest loses to tomato producers (Idah et al., 2007). The majority of producers and retailers in Africa make choices of using a particular package or packaging material based on affordability but not necessarily the suitability. Most of the choices made by tomato producers are not the appropriate package or packaging material for the commodity in question therefore causing postharvest losses as being identified by(Idah et al. 2007). The woven cane basket is a common choice of packaging material used by producers and retailers of tomatoes in Cameroon and other African countries. There have been suggestions of modifying the wooden crate to make it more suitable for tomatoes. The depth of the crate is reduced considerably to reduce the buildup of compressive forces which can cause mechanical injuries to fruits at the base of the crate during packaging.

2.1.14.1.4. Lack of reliable market

Market availability is a big challenge facing most tomato producers in developing countries especially those in Africa. This challenge can be attributed to many factors. One of the factors is the pattern of production resulting in gluts. Although there has been a tremendous improvement of the use of irrigation scheduling in dry season tomato production (Ofori-Sarpong, 2001) a greater proportion of producers still rely on rain fed production. The bulk of tomato production in Nigeria for example is carried out during the wet season of the production year (Adenuga et al., 2013). This causes high peaks in production which is always more than fresh consumption demand of the fruit locally. The problem is further compounded by the lack of processing facilities which can be used to process the fruits into a more durable form for later consumption. Producers from developed countries always have supply contract with multinational

supermarkets to supply tomatoes. An example is the Blush tomatoes in Guyra of New South Wales in Australia. Blush tomatoes provide Coles and Woolworth with vegetables making access to market already predetermined for the producers. In the case of producers in Africa, there is no information on reliable market availability. There is lack of communication between producers and consumers, and also lack of market information (Kader, 2005). There has been the main reason for the mismatch between production and available markets. Marketing cooperatives are needed by producers in African countries in significant tomatoes producing areas to create a market for producers.

2.1.1.5: Suggested practices to reduces post-harvest losses of vegetables

The following measures can be used to cut post-harvest losses

2.1.1.5.1Modified atmosphere packaging

Changed atmosphere packaging slows decay, but is relatively costly. Researchers at the Centre of Excellence for Post-harvest Biotechnology (CEPB) at the University of Nottingham Malaysia have come up with a reasonable alternative: edible sheets made of gum Arabic. CEPB's research found that applying a solution with a 10% gum Arabic edible coating delayed tomato ripening and meant the fruits could be stored for up to 20 days without deteriorating. Gum Arabic is obtained from acacia trees native to the Sahel. That makes it a potentially sustainable tool for farmers in that region to use in postharvest handling, though widespread use depends on the development of production and distribution channels, and raising awareness among smallholder farmers.

2.1.1.5.2 Improvement in research and technological innovations.

The Lack of appropriate technologies and innovations related to reducing postharvest losses imply that there is a need to promote and finance greater research and technological innovation at the public and private level, to reduce postharvest losses of horticultural produce.

2.1.1.5.3 Development of the Information or communication system.

The lack of scientific and consistent information on postharvest losses needs to be discussed in general. There is a need to conduct national surveys and studies to provide a better

understanding of the problem along the different value chains to be able to value the economic costs and to identify potential solutions.

2.1.1.5.4 Development of storage facilities.

The consistent lack of access to cold storage facilities across the region by producers is a major contributor to postharvest loss of fruits and vegetables. Establishment of an effective "cold chain" to preserve fruits and vegetables, especially those destined to export markets would contribute significantly to reducing associated losses.

2.1.15.5 Improvement in the drying and storage facilities.

The means of drying and storage of essential grains is essential to ensuring quality and reducing losses due to high humidity, plant pests, and general deterioration. Most small and medium producers, the principal producers do not have ready access to low-cost, drying or storage facilities. This lack of local drying and storage facilities contribute significantly to postharvest losses. Many potential solutions are being tried including small metal storage facilities, plastic-based storage products, among others. Many of these are being made available by the private sector. Also, many low- technology lowcost processes have been formed by farmers themselves which are being identified and shared among producers.

2.1.1.5.6 Need for infrastructural development.

Appropriate infrastructure for ready access to markets also contributes to post-harvest losses. Also, low-quality roads, high costs of transporting products to markets, and lack of access to ports and information increases losses when sending a product to export markets. Thus, the development or provision of an efficient transport system will go a long way to reduce post-harvest losses of horticultural produce.

2.1.1.5.7 Provision of agricultural extension services and credit facilities.

There is a need for more significant technical assistance, information, appropriate technologies and credit for the needed investments to take place to enable postharvest loss reduction in that the lack of access to credit, infrastructure, and relevant technologies contribute to postharvest losses. Often producers do not have ready access to the money needed to reach markets or to invest in needed improvements or new technologies that would reduce their postharvest losses. It is also not evident due to lack of studies and supportive information that investments will provide the needed returns associated with reduction in losses. Lack of access to adequate technical assistance and dissemination of good agricultural practices for farmers in the areas of

harvesting, packaging, transport, and storage of products is another area which is essential for achieving reductions in postharvest losses.

2.1.2 Empirical Review

2.1.2.1 Estimates of post-harvest losses in tomatoes and economic damage to farmers

The World Resource Institute (1998), post-harvest losses for horticultural produce are difficult to measure. The authors affirm that in some cases everything harvested may end up being sold to consumers whiles in others, injuries or waste may be considerable. Use of average loss figures is thus often misleading. Also, there could be losses in quality, as measured both by the price obtained and the nutritional value, as well as in quantity (World Resource Institute, 1998). However, Kedar et al. (1985) argue that post-harvest losses of fresh fruits and vegetables including tomatoes are estimated to be 5 to 25% in developed and 20 to 50% in developing countries.

2.1.2.1 Estimates of post-harvest losses of tomatoes in Asia.

Rehman et al. (2007), conducted a study to estimate the post-harvest losses in tomato crop produced in Peshawar valley in Pakistan. Working data collected randomly from sixty-eight tomato growers in the area, and the study found out that postharvest losses in tomatoes in the Peshawar valley were 20% of the total production.

In a survey in the Lahore, Punjab Province of Pakistan, Saheedand Khan (2010) evaluated that the deterioration of the produce due to packing material was 25%, transportation system was 10%, means of distribution was 5 %, exceeding post-harvest losses up to 30% and sometimes the whole lot is lost. Genova et al. (2006) argue that in Cambodia, 246 kg for every MT of tomato produced or 24.5% of total production was lost due to spoilage between the farms and the retailer.

Institute for the Prevention of Postharvest Loss (2015) have estimated post-harvest losses in tomatoes for Cambodia at 26% and 23% of the total harvested quantity. In Nepal, quantitative losses were 26% and 19% and in Bangladesh, quantitative postharvest loss of tomato and were around 26% and 20% of the total harvested quantity respectively. Gauraha (1999), reported the overall post-harvest loss towards the consumption end of the distribution system was around 17.26% of the amount collected in India. The maximum post-harvest damage was observed in

tomato is 32.64%. On the other hand, Pal (2002) stated that total losses of tomato during different post-harvest operations were found in the range of 30.3-39.6%. The maximum quantity of injuries occurred during transportation from rural markets to urban markets.

2.1.2.2 Estimates of post-harvest losses of tomatoes in Latin America

According to Institute for the Prevention of Postharvest Loss (2015), postharvest losses of tomatoes measured at the end of the postharvest handling system in Trinidad and Tobago were 27%. Three critical Critical Loss Points (CLPs) for vegetables were at harvest, at pack house, and during retail marketing. In Trinidad and Tobago, the observed losses were 7%, 8% and 12% at yield, at pack house and during retail marketing respectively. In the case of Trinidad, the total economic loss was measured at US$1.9 million. In the fact of Guyana, the postharvest losses of tomatoes were 34%. At harvest, at pack house and during retail marketing, losses were 11%, 10.5%, and 12.5% respectively. Hence the total economic damage was estimated at US$7.9 million. Postharvest losses of tomatoes in St. Lucia were 20%. At harvest, at pack house and during retail marketing, postharvest losses averaged 7.0%, 8.0%, and 5.0% respectively. The total economic loss for tomatoes in St. Lucia was therefore calculated at US$166,579.

Ferreira (2006) reported that the tomato post-harvest losses are very high in Brazil, the effect of handling and the transport of tomato from the harvesting, weighing, and transportation to the packinghouse was identified as critical points. The administration was the cause of an increase of 6.6% in external damage and 1.93% of weight loss after storage. The main reason for post-harvest losses was due to mechanical injury caused by transportation mainly due to compressive force among fruits and against the plastic boxes.

2.1.2.3 Estimates of post-harvest losses of tomatoes in Africa

Postharvest loss estimate figure for fruits and vegetables are difficult to substantiate especially at the country and continental level. However, local level studies offer a possibility to provide estimates for specific localities within the continent.

Olayemi et al. (2016) in an assessment of postharvest challenges of small-scale farm holders of tomatoes, bell and hot pepper in some local government areas of Kano State, Nigeria reported that most of the vegetables, ball, and hot pepper farmers experience losses of 10-30%. Bani et al. (2006) in research conducted in Ghana to evaluate injuries of tomatoes from Bolgatanga to

Accra revealed that losses along the route alone amounted to 20%. In an assessment of post-harvest losses in 46 districts in the Forest, Guinea Savannah and Transition Agro-ecological zones in Ghana involving the Greater Accra, Ashanti, and Upper East regions, indicated that quantitatively, losses during harvest across the areas ranged between 4.6 % and 10.85 %, with the highest in Upper East region. During grading and parking, between 3.6 % and 13.75 % of fruits were lost; 2.3 % to 7.4 %; and 2.6 % to 3.3 % during transporting and marketing respectively.

In a study in the Offinso North district of Ghana, Aidoo et al (2014) reported that farmers produced 1,159.21 kg of tomatoes in the major seasons and the 962.75kg in the minor season on an average farm size of 5 hectares, out of which 40 and 14% were lost, respectively.

Owino et al. (2006) cited in Institute for the Prevention of Postharvest Loss (2015) assessed postharvest loss for tomato and amaranths value chains in some

Regions in Kenya, including Kitengela, Mwea, East and West, Subukia, Juja, Lugari, and Bondo. The postharvest losses of amaranth totaled 34% at harvest mainly due to leaf shredding, insect and pest damage, and harvesting of over mature leaves. In the market, the losses of the leaves were about 43% mainly due to poor handling. For tomatoes, the causes of injuries for vegetable were dependent on the region. At the farms in Kitengela, the primary reason for losses was physiological damage (blossom end rot) and other diseases which accounted for 31% of fruit losses. In total, about 57% of the harvested fruit from Kitengela farms was damaged. In tomatoes from Mwea, the leading causes of the injuries were insect and pest damage, accounting for 20% damage at harvest. Transportation and poor handling contributed to about 24% of the fruit losses in the market.

2.2 Conceptual Framework

2.2.1 Tomatoes supply value chain

As shown in Figure 2.2, the tomatoes supply value chain input equipment, production, bulking/transportation, processing/packaging, and wholesale/retail.

2.2.1.1 Input Supply

For high-quality tomato production the use of commercial seed, enhanced nutrition and pesticides must be considered. These inputs can be sourced from local agro-dealers, bought from specialist shops and are also distributed by development organizations.

Open Pollinated Varieties (OPV) are less expensive than hybrid varieties and are thus more popular with smallholders. Many smallholders do not buy any seed but instead recycle local varieties.

2.2.1.2 Production

The majority of tomato production is by smallholders with a few commercial producers nationwide. Ex Agric Africa is an example of a business producer.

Tomato production is reported to be a favorite crop choice in the two areas under study. It is grown as a cash crop but can also support diets when necessary. On average about 0.4ha is used to cultivate tomatoes. Farmers stated that if they could afford more inputs, then the production area could be increased; land availability is not a constraint.

Tomatoes are grown in two growing seasons. . Each growing season lasts for around 812 weeks. Reported yields were 6mT per growing season from 1 acre of land.

2.2.1.3 Trading

There tends to be at least three levels of trading between production and the end-market in the tomato value chain. The levels of trading are determined by the geography of production and market, but also by cultural factors and access to resources.

The primary level of trading is between the rural farmer and the nearest trading centres (at times the end market). These traders are often residents of the village and are producers of the crop. Transport is of small, intermittent volumes, often carried by head or by bicycle.

The secondary level of trading is from the trading center to the city. This is done by individuals from outside the area and with access to capital. These traders have the ability to transport produce via truck and thus deal in larger volumes of produce. By being able to travel to alternative buying areas they have a greater bargaining power than the primary trader and tend to

dictate the buying price. Secondary traders deliver produce to a certain market in the designated city. These informal areas are particular to a type of produce and have been formed, and their status reinforced, over many years.

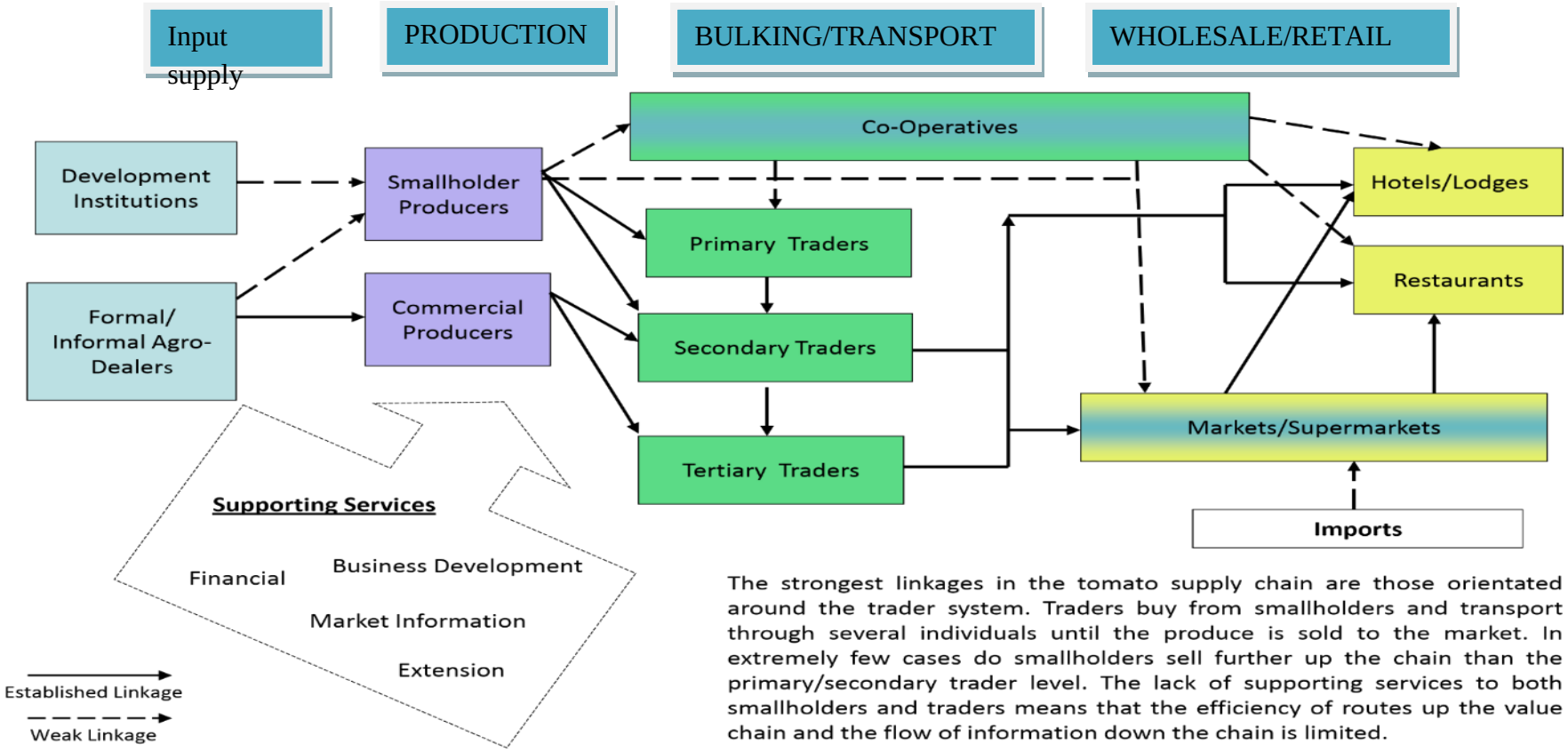

Figure 2.3 Typical tomatoes supply chain (Source: Business Innovation Facility, 2011)

This three-tier system of trading is widespread in all areas of the country and across a range of products. There are three determinants for the trading system: Geography – the fragmentation of producers across vast rural areas means that the most efficient way for producers to be bulked is via a network of small traders Resources – many traders do not have the capital or infrastructure available to them to complete longer journeys with produce

Culture – there are active informal systems in place that dictate the pattern of buying and selling. For example, a trader bringing food to a market is prevented by custom to sell directly to buyers.

2.2.1.34 Wholesale/ Retail

The main tomato markets are supermarkets, hotels/lodges, restaurants, and personal consumers.

2.2.2 Conceptual framework for postharvest loss and mitigation

Figure 2.3, provides a conceptual framework that considers the whole postharvest system.

The term "system" denotes logically interconnected functions within the post-production chain. In analyzing the whole system, losses occur: (i) at harvest; (ii) as preliminary processing; (iii) at handling; (iv) during transportation ; (v) at storage due to pests, and contaminations; (vi) during processing due to inefficient technologies; and (vii) commercialization. The framework thus associates PHL to activities and practices from farm-to-fork, and recognizes quantity and quality losses. The losses attract innovations whose overall usefulness in preventing or reducing them is governed by the type, of innovations, their technical efficacy, cost-effectiveness, adoption, and impacts. If users do not acknowledge the innovations as being helpful within the contexts of their social, cultural, and economic settings, the innovations become abandoned, and loss mitigation is not achieved

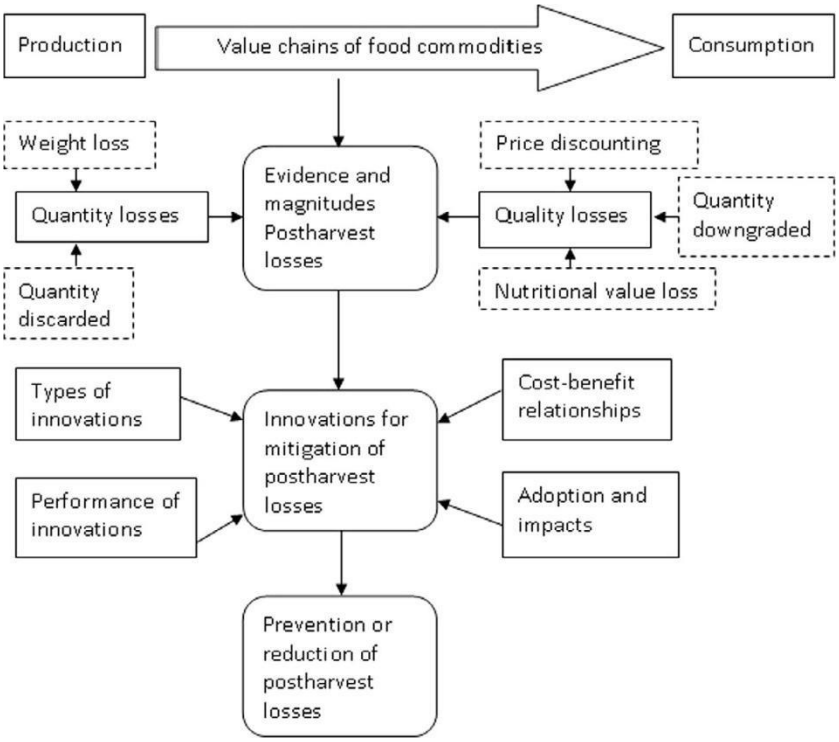

Figure 2.4 Conceptual framework for post-harvest loss and mitigation(Source: Affognon et al (2015).

2.3 Gaps Identified In the Literature and How the Work Shall Attempt To Fill Tehm

There is extensive literature on postharvest losses in Cameroon, particularly for cereals and tuber crops. However, postharvest loses in vegetables have received little academic attention over the last years in this country. It is particularly true for tomatoes. Also, there are very few and available evidence on estimates and causes of post-harvest loss, and post handling practices and constraints of smallholder farmers in Wotutu Village, a significant tomatoes production hub in the Buea Municipality. This research will fill this gap by providing this mission information in existing literature for the two countries of concern.

CHAPTER THREE

METHODOLOGY OF THE STUDY

3.1 Model specification

To assess post-harvest loss and loss margins, the study employed the following mathematical models

$$PHL = \Sigma H - \Sigma S$$

Where PHL = Post-harvest loss

H = Quantity of tomatoes harvested

S = Quantity of tomatoes remaining after sorting

3.2 Description of variables in the model

3.2.1 Dependent variable

The dependent variable is postharvest losses. It was measured concerning number of baskets of tomatoes

3.2.2 Independent variables

The independent variables were total quantity of tomatoes harvested and a total quantity of tomatoes remaining after sorting. They were all measured regarding some baskets.

3.1 Study Design

The study adopted both the cross-sectional and case study design. The study was cross sectional in that it involved the collection, description, and narration of post-harvest losses of tomatoes within a defined period as opposed to a time series.

The research was a case study because narrowed its focus to a particular geographic area (Wotutu Village in the Buea Municipality of the South West Region) and individual farmers

(producers of tomatoes). Also, the study explored and investigated postharvest losses within a specific period thereby making it a cross-sectional study

3.2 Population and Target Population

The population of the study consisted of farmers and more specifically of tomatoes farmers in Wotutu Village in the Buea Municipality, South West Region of Cameroon. This locality was chosen because it constitutes an essential agricultural pole and it is a tomatoes production hub within the Buea municipality. According to the South West Regional Delegation of Agriculture and Rural Development, tomatoes farmers in Wotutu Village are estimated at 250 farmers.

3.3 Sampling Technique and Sample Size

In the absence of up to date list on tomatoes farmers in the locality, the study employed the convenient sampling technique to select the individual tomato farmers for the study. The farmers were chosen based on their availability and willingness to participate in the study.

To arrive at the sample size, the Taro Yamani's formulae was employed, which is explicitly stated as

$$n=N/(1+N〖(e)〗^2)$$

Where n = sample size

N = population of the study

e = margin of error (0.05)

The theoretical sample of the study was 153. But due to the financial constraints in administering questionnaires to this large population, it was narrowed down to 120.

3.4 Data Collection Techniques / Instruments

3.4.1 Primary data collection techniques

Primary data were collected using questionnaire survey, key informant interviews and field observations

3.4.1.1 Questionnaire survey

Structured questionnaires containing closed-ended questions were used to elicit information from the farmers (Appendix 1). Each questionnaire was divided into five sections. Section A contained questions on the socio-demographic characteristics of the respondents. Section B indirectly assessed postharvest loss and estimates loss margins. The postharvest loss was estimated using the indirect method via survey interviews of farmers who experience the Losses (Kwami and Kamarulzaman, 2014). Though this method may suffer from the possibility of overestimation or underestimation (Kwami and Kamarulzaman, 2014), it enabled the researcher to cover a broader population in the study area.

Section C consisted of questions related to farm and non-farm causes of post-harvest losses of tomatoes. Section D contained to questions farmers' postharvest loss handling practices while Section E included to the questions on challenges to postharvest loss reductions.

A total of 120 questionnaires were administered by the researcher in the study locality. At the end of this exercise, 26 questionnaires were discarded for incomplete information given a questionnaire retention rate of 78.3%.

3.4.1.2 Key Informant Interviews (KIIs)

A total of 3 KIIs were conducted with relevant stakeholders in the field. These included government extension worker, a very influential tomatoes farmer and chief the questionnaire was used as an interview guide.

3.4.1.3 Field Observation

In the course of questionnaire administration, the researcher observed, took notes and photographs of the farmers harvesting and post-harvest handling practices.

3.4.1 .4 Secondary data collection techniques

Secondary data was collected through desktop review of related literature form textbooks, journal articles, newspaper articles, magazine articles, website publication, government reports and a written thesis.

3.4.1.5 Data Analysis and Presentation

The study employed both descriptive and inferential statistics to analyze the data collected from the questionnaires. The descriptive statistics applied included frequencies, percentages, mean, maximum and minimum values, standard deviations and sums. The inferential statistics used included chi-square test and correlation. These statistics were used to assess relationships. Data analysis was carried out using the Statistical Package for Social Science (SPSS) 20. Microsoft Excel 2013 was used to develop charts and tables used to enhance the narratives.

3.4.1.6 Validity and Reliability of Instruments

The study used a triangulation approach or cross-checking data from multiple sources and search for regularities in the research data. To ensure the validity and reliability of the instruments, the questionnaires were pre-tested and submitted for expert review and validation.

3.4.1.7 Ethical Consideration

The researcher obtained the consent of the farmers before the questionnaires were administered. Also, the information provided by the farmers was strictly confidential.

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CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

4.1 Socio-demographic characteristics of respondents

4.1.1 Gender of farmers

Table 4.1 shows gender distribution of the farmers. Out of the 94 farmers, most (n=56, 59.6%) were male while the rest (n=38, 40.4%) were female

Table 4.2 Gender of respondents

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	56	59.6	60.9	60.9
Female	38	40.4	40.4	100.0
Total	**94**	**100.0**	**100.0**	

This indicated that tomatoes production in Wotutu is a male-dominated business. The reasons for this male dominance might be that tomatoes production is a labor and capital intensive, and women lack the preceding to engage substantially in tomatoes production.

4.1.2 Age group of farmers

Table 4.2 shows the age group distribution of the farmers under study. Four (4.3%) were below 20 years, 44 (46.8%) were between the ages of 20 and 35 years, 30 (31.9%) were between the ages of 35 and 50 years and 16 (17.1%) were between the ages of 51 and 75 years.

This indicates that tomatoes production in Wotutu Village is mainly undertaken by the youthful and productive age group.

Table 4.3 Age group of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
< 20 years	4	4.3	4.3	4.3
20-35	44	46.8	46.8	51.0
35-50	30	31.9	31.9	82.9
51-75	16	17.1	17.1	100.0
Total	**94**	**100.0**	**100.0**	

4.1.3 Marital Status of farmers

Table 4.3 shows the marital status of tomatoes farmers in Wotutu Village. Thirty-two (34%) of them were single, 56 (59.5%) were married, 2 (2.1%) were widowed and 4 (4.3%) were divorced.

Table 4.4 Marital status of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Single	32	34.0	34.8	34.8
Married	56	59.5	59.5	93.5
Widowed	2	2.1	2.1	95.7
Divorced	4	4.3	4.3	100.0
Total	**94**	**100**	**100.0**	

This indicates that the majority of those involved in tomatoes production in Wotutu Village are married.

4.1.4 Level of education

With regards to the educational attainment of the farmers, 34 (36.2%) had primary level education, 16 (17%) had secondary school level education, 22 (23.4%) had high school level education, 20 (21.3%) had university level education while the rest (n=2, 2.1%) had other form of education (Table 4.4).

Table 4.5 Level of education of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Primary	34	36.2	36.2	36.2
Secondary	16	17.0	17.8	51.1
Highschool level	22	23.4	23.4	75.6
University level	20	21.3	21.3	97.8
Others	2	2.1	2.1	100.0
Total	**94**	**100.0**	**100.0**	

This is indicative that the majority of the tomatoes producers are literate since most of them have some form of formal education.

4.1.5 Religion

Out of the 88 farmers who reported their religion, 40 (90.9%) were Christians, 4 (4.5%) were Muslims while the rest (n=4, 4.5%) were practicing some other form of religion (Table

Table 4.6 Religion of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Christian	80	85.1	90.9	90.9
Muslim	4	4.3	4.5	95.5
Others	4	4.3	4.5	100.0
Total	88	93.6	100.0	
System	6	6.4		
Total	**47**	**100.0**		

This means that the majority of the tomatoes farmers in the study village are Christians.

4.1.6 Farming experience

Table.4.6. Presents Descriptive Statistics of the farming experience of the 47 farmers. The farmers declared an average of 3.54 (±1.629) years in the cultivation of tomatoes in Wotutu village.

Table 4.7 Descriptive statistics for farming experience

Mean	3.54
Std. Deviation	1.629
Minimum	1
Maximum	6

This indicates that tomatoes farmers in Wotutu Village have some relatively substantial experience in tomatoes production.

4.1.7 Farm size

Table 4.7 shows the farm size distribution. Twenty four (25.5%) of the respondents had farms with volumes equal to or less than 500m2, 20 (21.3%) had farms with sizes between

500m2 and 1 hectare, and 50 (53.2%) had farms with sizes above 1 hectare.

Table 4.8 Farm size distribution

	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
< = 500m^2 ha	24	25.5	25.5	25.5
500m^2-1 ha	20	21.3	21.3	47.8
>1ha	50	53.2	53.2	100.0
Total	**94**	**100.0**	**100.0**	

4.2. Post-harvest losses and impact on farmer's income

4.2.1 Extent of post-harvest losses of tomatoes

The 94 farmers reported a total production of 12,170 baskets of tomatoes with an average of 129.4 (±252.165) baskets per farmer. After sorting, the farmers reported a total of 10,712 baskets of tomatoes with an average of 113.9 (±247.717) baskets per farmer (Table 4.8)

Table 4.9 Statistics on quantity of tomatoes harvested and quantity left after sorting

Statistics	Quantity harvested	Quantity left after sorting
Mean	129.4	113.9
Std. Deviation	252.165	247.717
Minimum	1	1
Maximum	1000	994
Sum	12170	10712

A paired sample t-test showed that there were statistically significant differences (p=0.045) in the quantity of tomatoes harvested and the quantity left after sorting (Table 4.9).

Table 4.10 Mean differences on quantity of tomatoes harvested and quantity left after sorting

Paired Differences							
			95% Confidence Interval of the Difference		t	df	P
Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
14.333	49.504	20.210	-37.618	66.285	.709	5	.045

This implies that farmers observe a significant reduction in the quantity of tomatoes they harvested after performing sorting.

Table 4.9 presents the estimated losses calculated by measuring the difference between the quantity of tomatoes harvested and the quantity left after sorting quantity of tomatoes.

Table 4.11 Post-harvest loss estimates for tomatoes in Wotutu

	Total Quantity Produced	**Total quantity after sorting**	**Loss**	**% of loss**
Mean	129.4	113.9	15.5	11.9
Total	**12170**	**10712**	**1458**	**11.9**

The result shows that farmers incurred a mean loss of 15.5 baskets and a total loss of 1,458 baskets of tomatoes, with a loss margin of 11.9% on production.

4.2.2. The effect of postharvest loss on farmer's income

Table 4.10 presents an economic analysis of the quantity of tomatoes produces by farmers in Wotutu village, calculated using relevant seasonal market prices, during the on and off seasons.

Table 4.12 Economic analyses of postharvest losses of tomatoes in Wotutu Village.

Seasons	Unit price	Harvest Value	Post-harvest Value	Total loss value	Loss %
On season	4500	27382500	24142500	3240000	11.83
Off-season	12000	73020000	64380000	8640000	11.83

The result from the economic analysis indicates that with a market value of 4500FCFA per basket during the glut or tomatoes seasons and 12000FCAF per basket during off-seasons, farmers incur losses, estimated at FCFA 3,280,500 during on seasons and 8748000FCFA during off seasons representing a loss margin of 11.83%.

4.2.3 Causes of post-harvest losses of tomatoes

Table 4.11 present an extraction table (code-code description-grounding-quotation table) assessing farmers' perception of the major causes of tomatoes post-harvest loss in Wotutu

Table 4.13 Farmers perception of the major causes of tomatoes loss in Wotutu Village

Code	Code description	Grounding	Testimonies from interviews
Handling	Poor handling during harvest, packaging and transportation	50/94	*During harvest, packaging and transportation, the fruits are poorly handled leading to physical damages* ..... [Farmer, Male, 35-40 years, Wotutu Village]
Insects and disease	Insects and disease attacks	86/94	*Insects infestation and disease attacks are the primary cause of tomatoes loss in this village* [Farmer, Female, 35-40 years, Wotutu Village]
Climatic	Adverse climatic conditions	44/94	*.....over sun and too much rain experienced*

conditions			*sometimes in this locality speed up the deterioration of fruits*….[Farmer, Male, 32-37 years, Wotutu Village]
Theft	Stealing of tomatoes fruits	30/94	*Instances of theft of tomatoes fruits have been recorded so many times in this locality* [Farmer, Female 30-35 years, Wotutu Village]

According to them, the major causes of loss were poor handling of fruits during harvesting, packaging, storing and transportation (n=50, 53.19%), pest and disease infections (n=86, 91.5%), adverse climatic conditions (n=48, 51.07%), and theft (n=30, 31.9%).

Farmers' perceptions of the major causes of post-harvest tomatoes loss in Wotutu Village are shown in Figure 4.1.

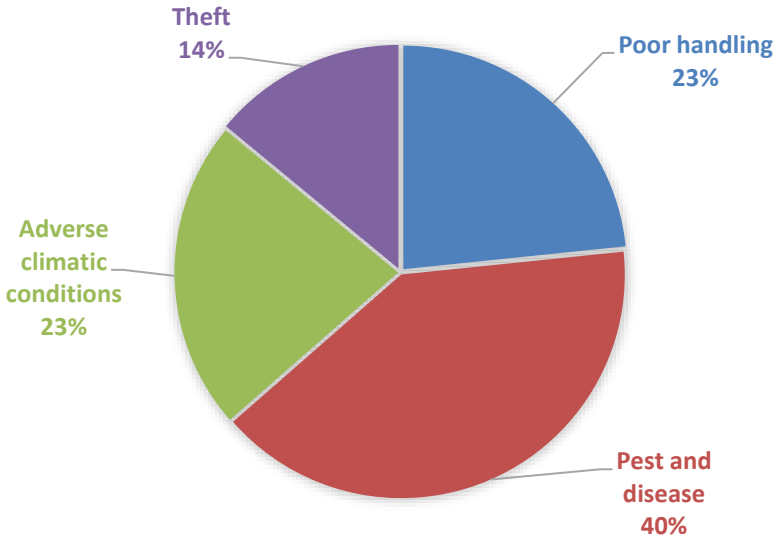

Figure 4.1 Farmers perceptions of the major causes of postharvest

Loss of tomatoes in Wotutu Village.

The major diseases and pest affecting tomatoes and causing post-harvest losses in Wotutu Village were identified as shown in **Figure 4.4.**

According to the respondents, the major diseases affecting tomatoes and leading to postharvest losses were early and late blight (n=48 or 51.1%), blossom end rot (n=4 or 4.3%), fungi and bacteria (n=6 or 6.4%) and others (n=16 or 17%).

Also, the major pest affecting tomatoes in the locality were identified as butterflies (n=18 or 19.1%), aphids and white flies (n=42 or 44.7%) and other insects (n=18 or 19.1%).

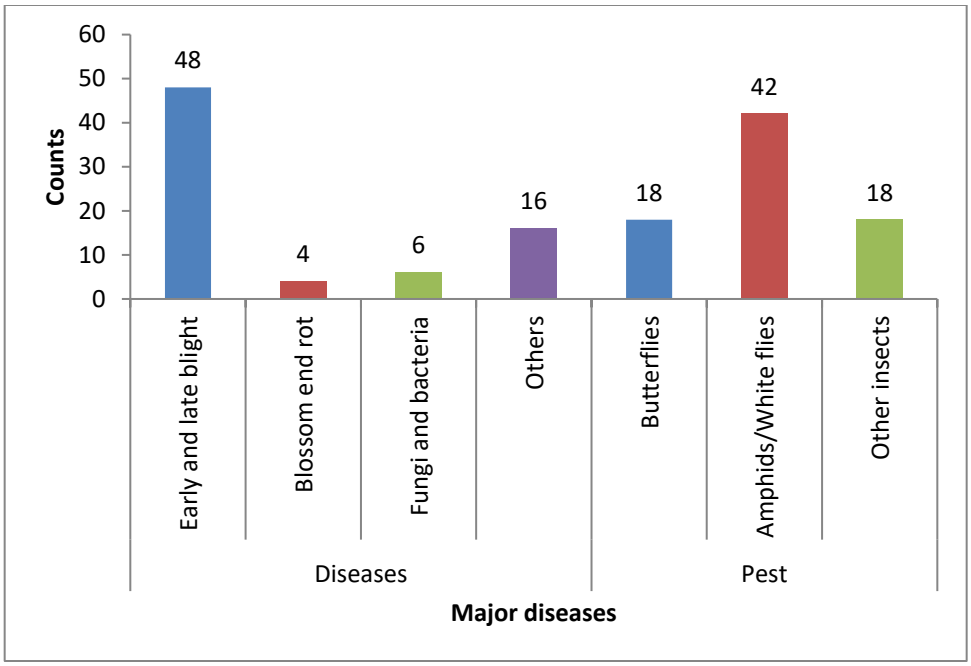

Figure 4.2 Major pest and diseases affecting tomatoes in Wotutu Village

4.2.3 .1Harvesting and post-harvest handling practices of tomatoes farmers

Figure 4.1 present the tomatoes harvesting practices prevalent among farmers in the Wotutu Village area.

With regards to the method of harvesting, most (n=92 or 97.8%) of the farmer harvest tomatoes fruits by hand picking while the rest (n=2, 2.1%) harvest using a knife. No statistically significant association ($p>0.05$) were observed between methods of the tomatoes harvesting and the farmer's socio-demographic markers of gender, age group, marital status, level of education, and religion. This indicates that hand picking is invariably practiced by all farmers despite their socio-demographic characteristics.

Most (n=66, 70.2%) of the farmers harvest their tomatoes fruits when it is red, while the rest of them harvest when it still green (n=6, 6.9%), when it is yellow (n=18, 19.14%) and based on other physical properties of the fruits (n=4, 4.2%). No statistically significant association was observed between stage at harvest and gender, age group, marital status, level of education, and religion.

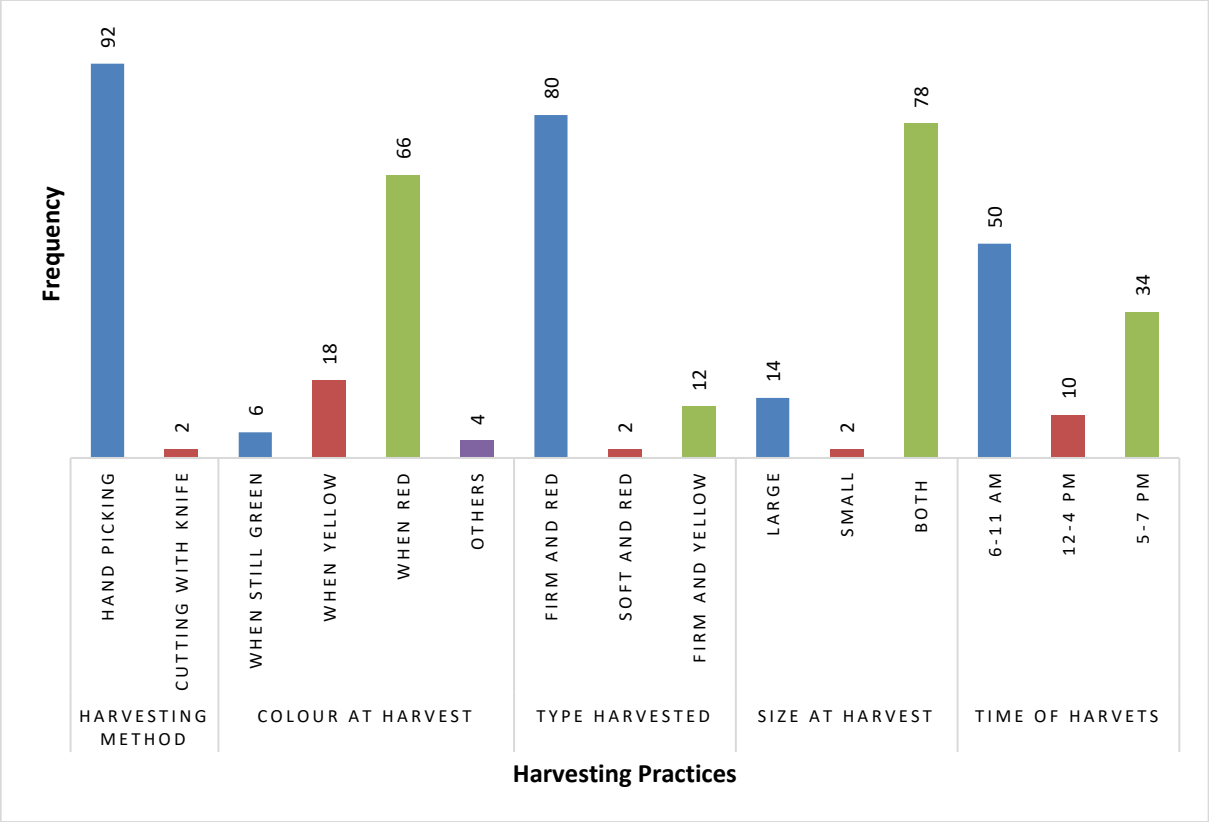

Figure 4.3 Tomatoes harvesting practices of farmers in the Wotutu Village area.

Most (n=80, 85.1%) of the farmers harvest their tomatoes fruits when firm and red, 2 (2.1%) harvest when soft and red while the rest (n=12, 12.7%) harvest when firm and yellow. No statistically significant ($p>0.05$) association were observed between the quality of tomatoes harvested and gender, age group, marital status, level of education, and religion. This indicates that stage at harvest does not vary within and between socio-demographic characteristics of farmers.

In terms of fruit size, the majority of the farmers (n=78, 82.9%) harvest both small and large fruits, 14 (14.8%) harvest large fruits only while 2 (2.1%) harvest small fruits. No statistically significant association ($p>0.05$) were observed between size of tomatoes harvested and gender, age group, marital status, level of education, and religion.

Finally, most (n=50, 53.2%) of the farmers harvest their fruits between 6-11 am, 10 (10.6%) harvest between 12 to 4 pm while the rest (34 or 36.2%) harvest between 5 and 7 pm. No statistically significant association were observed between the time of tomatoes harvested and gender, age group, marital status, level of education, religion, farming experience and farm size.

4.2.3.1.2Tomatoes postharvest handling practices

The results indicate that the farmers in Wotutu village use different postharvest handling practices including packaging, shading, transporting, storing and chemical treatment.

Show pictures of harvesting and post-harvest handling practices here!! Discuss them here and relate the findings to what other researchers found around Cameroon or in other African countries**Figure 4.4** shows the percentages of the different post-harvest handling practices used by tomatoes farmers in Wotutu Village. The results show that 2 (2.2%) of the farmers use crates for packaging their fruits, 84 (89.4%) use bamboo woven baskets, 6 (6.3%) use buckets while the rest (n=2 or 2.1%) use some other packaging type. No statistically significant association (p>0.05) were observed between packaging practices and the farmers' gender, age group, marital status, level of education, religion, farm size and farming experience.

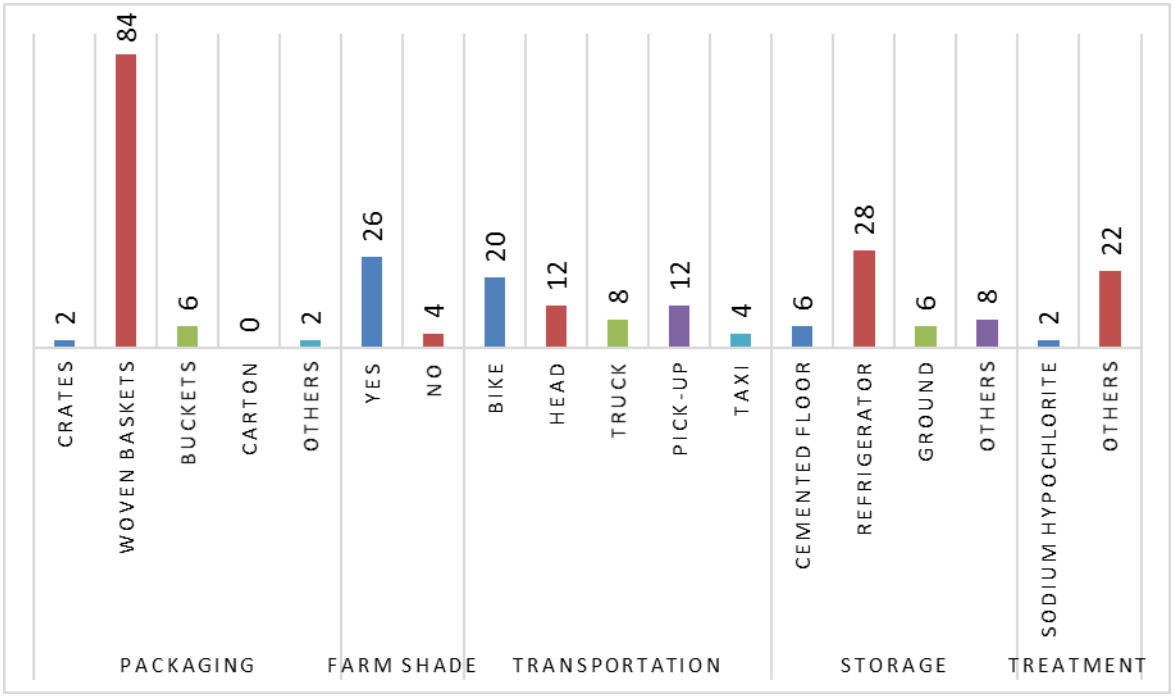

Figure 4.4 Postharvest handling practices of tomatoes farmers in Wotutu

Among the 30 (31.9%) of the farmers who have shades in their farms, 26 (86.6%) of them use it for on-farm storage while the rest (n=4, 13.4%) do not use it. No statistically significant association (p>0.05) were observed between use of shade for on-farm storage and the farmers' gender, age group, marital status, level of education, religion, farm size and farming experience.

Twenty four (25.5%) of the farmers reported treatment of their fruits after harvest. Among these, 2 (8.3%) use sodium hypochlorite solution while the rest (n=22, 91.7%) use some other form of treatment. No statistically significant association (p>0.05) were observed between fruit treatment and the farmers' gender, age group, marital status, level of education, religion, farm size and farming experience.

Most (n=56, 59.57%) of the farmers sell their produce at the market while 16 (34.1%) of them sell their products at the farm or farm-gate. Among those who sell their products at the market, 20 (35.7%) use motorbike to transport their fruits, 12 (21.4%) carry the baskets on their head to the market, 8 (14.28%) use trucks, 12 (21.4%) use pick-up vehicles and 4 (7.14%) use taxis. Transport mode was significantly associated (p=0.00) with marital status. No statistically significant association (p>0.05) were observed between transport mode and the farmers' gender, age group, level of education, religion, farm size and farming experience.

Among the 48 farmers who reported their postharvest storage practices, 6 (13.6%) of the farmers use cemented floor, 28 (63.6%) use refrigerators, 6 (13.6%) use the ground while the rest (n=8, 18.18%) store using some other storage practices. No statistically significant association (p>0.05) were observed between home storage practices and the farmers' gender, age group, marital status, level of education, religion, farm size and farming experience.

4.2.3.1.3 Challenges to post-harvest losses prevention and mitigation

Figure 4.5 presents the major challenges faced by tomatoes farmers in reducing postharvest in Wotutu village.

According to the farmers, the major challenges to postharvest loss preventions are lack of postharvest processing technologies/facilities (n=62 or 65.9%), poor and unreliable transport facilities and networks (n=42 or 44.6%), limited access to finance (n=52 or 55.3%), lack of

storage facilities (n=49 or 52.12%), high cost of production (e.g. labor, inputs and equipment) (n=34 or 36.1%) and limited skills on post-harvest reduction (n=17or 18.1%)

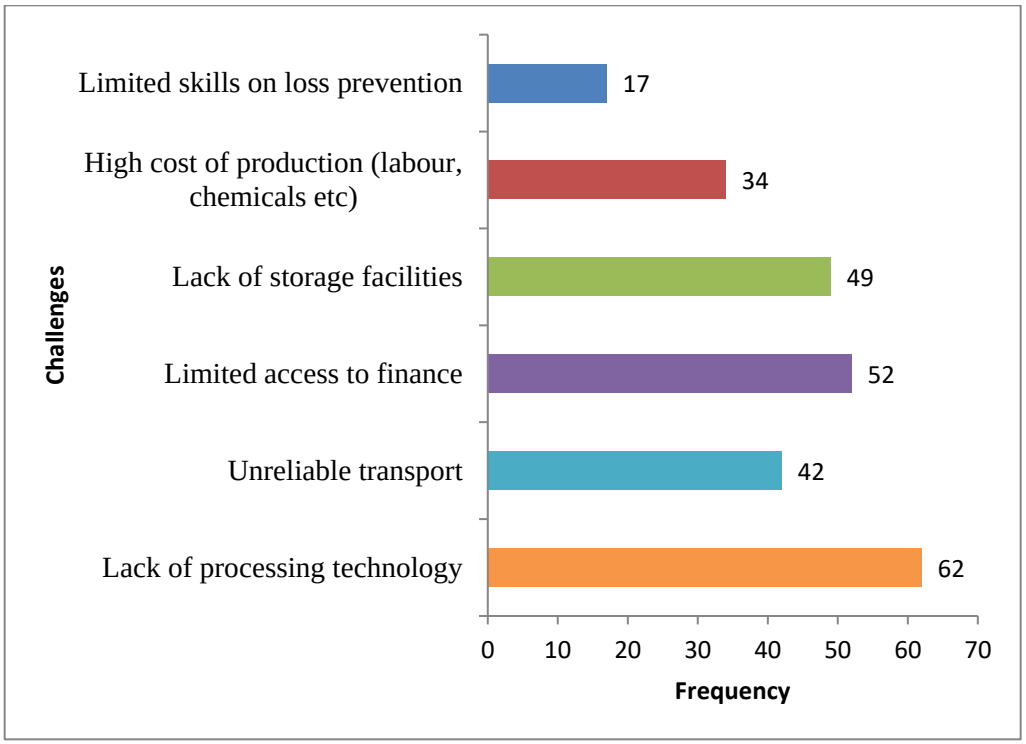

Figure 4.5 Challenges faced in reducing postharvest loss of tomatoes in

4.3 Implication of the results

4.3.1 Socio-demographic characteristics of respondents

Most of the farmers were married males between the ages of 20 and 35 years with less than high school level education and average farming experience of 3.54 years working on farms size of above 1 hectare.

4.3.2 Harvesting and post-harvest handling practices of tomatoes farmers

Concerning tomatoes harvesting practices, most of the farmers reported handpicking both large and small tomatoes when ripe and firm between 6-11 am.

In terms of the postharvest handling practices, most of the farmers used on farm shade for storing fruits immediately after picking. Most used some other traditional treatment method

other than the use of sodium hypochlorite for postharvest treatments of tomatoes. After harvesting, most of the farmers used the woven basket for packaging harvested fruits and bikes for the transportation of fruits to non-farm gate markets. At home, most of the farmers used refrigerators for storing unsold fruits.

4.3.3 Tomatoes post-harvest losses estimates and effects on farmer's income

With a total reported production of 12170 baskets of tomatoes, farmers experienced a loss of 1458 baskets representing a total loss on the production of 11.9%.

In glut seasons, this represents a total income loss of 3,240,000 FCFA while during off-seasons, this represents a total income loss of 8,640,000 FCFA.

4.3.4 Major causes of postharvest loss of tomatoes

According to most of the farmers, the major causes of post-harvest losses of tomatoes in Wotutu Village were pest and diseases (particularly early and late blight and aphids and white flies), poor handling of fruits during harvesting, packaging, storing and transportation and adverse climatic conditions.

4.3.5Challenges to post-harvest losses prevention and mitigation

The major challenges to postharvest loss preventions are lack of postharvest processing technologies and facilities, poor and unreliable transport facilities and networks, limited access to finance and lack of storage facilities.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of findings

The present study aimed explicitly at assessing the harvesting and post-handling practices of tomatoes farmers, postharvest loss estimates and effects on farmer's income, causes of postharvest losses and challenges to post-harvest loss prevention and mitigation in Wotutu Village in the Buea Municipality. The study found out that;

5.1.1 Summary of findings for specific objective one: To identify the level of post-harvest losses in tomatoes and its effect on farmer's income.

Concerning tomatoes harvesting practice, the harvesting of both small and large fully ripe and firm fruits between 6-11am was prevalent among farmers. Concerning postharvest handling practices, most of the farmers used on farm shade for storing fruit after picking, woven baskets were used for packaging and transportation to non-farm gate markets was primarily done with the aid of motorbikes.

5.1.2 Summary of finding for specific objective two: To assess the causes of post-harvest losses in tomatoes

The study found out that the farmers reported a loss of 1458 baskets of tomatoes after sorting, representing a total loss on the production of 11.9%. These losses were found to have a severe impact on the income of the farmers. In glut periods, this represents a total income loss of 3,240,000 FCFA while during off-seasons; this represents a total income loss of 8,640,000 FCFA.

The study also found out that, the major causes of post-harvest losses of tomatoes in Wotutu Village were pest and diseases (unusually early and late blight and aphids and whiteflies), poor handling of fruits during harvesting, packaging, storing and transportation and adverse climatic conditions.

5.1.3 Summary of findings for specific objective three: To determine the harvest and post-harvest handling practices of tomatoes farmers

The study found out that the significant challenges to postharvest loss preventions or mitigation in Wotutu Village were principally the lack of postharvest processing technologies and facilities, inadequate and unreliable transport facilities and networks, limited access to finance and lack of storage facilities.

5.2 Conclusion

On the bases of the preceding findings, the study concluded that farmers in the Wotutu Village in the Buea Municipality engage in a host of tomatoes harvesting and postharvest handling practices to ensure optimal tomatoes production. In spite of these methods, farmers still sustained significant post-harvest losses with non-negligible consequences on their income. While some of these losses can be attributed to exogenous factors which are not within the control of the farmers such as climatic conditions and pest/disease, others such as the poor harvesting and postharvest handling practices still account for significant proportion of the losses. Therefore, it can be concluded that farmers in Wotutu continue to face evitable post-harvest challenges which remain to effects their income and livelihood.

5.3 Recommendations

In a bid to reduce postharvest losses experienced by tomatoes farmers in the locality, the study made the following recommendations to farmers, government or policy-makers, the general public, financial and business community, and researchers.

To farmers

a. Tomato farmers should group themselves into cooperatives for them to assess inputs and subsidies from the government.

b. Farmer's field schools and other training initiatives on post-harvest handling of perishable products such as tomato should be encouraged and follow-ups, feedback and adoption measurement should be conducted periodically for sustainability.

c. Farmers should use sustainable packaging to reduce all types of mechanical damage during storage, handling, and transportation.

To government

a. The government should provide agricultural extension agents who will organize training on post-harvest practices to increase farmers' incomes and minimize tomatoes wastages in the study area. Should provide the farmers with excellent storage facilities to store the products that are harvested before they are being taken to the market. This will help to reduce the losses that occur at the farm level.
b. Roads linking farms to market should be constructed or existing ones created to minimize transit losses.

To the General Public

The public should be encouraged to accept processed agricultural products. This will reduce the percentages of losses that occur between transporting to the market by wholesalers and storage by retailers

To the financial and business communities

Financial institutions should provide affordable financial support to tomato farmers to acquire necessary inputs and improve their acreage while the business community should create processing facilities were tomatoes can be produced during a period of glut.

To Researchers

a. Further research should be carried out on the determinants of postharvest loss reduction innovation adoption among poor tomatoes farmers. This will enable post-harvest informed innovation diffusion and adoption initiatives in the area...
b. More research should be carried out on the determinants of postharvest loss reduction innovation adoption among poor tomatoes farmers. This will enable post-harvest informed innovation diffusion and adoption initiatives in the area
c. Should provide the farmers with excellent storage facilities to store the products that are harvested before they are being taken to the market. This will help to reduce the losses that occur at the farm level.

d. Roads linking farms to market should be constructed or existing ones created to minimize transit losses.

To the General Public

The public should be encouraged to accept processed agricultural products. This will reduce the percentages of losses that occur between transporting to the market by wholesalers and storage by retailers

To the financial and business communities

Financial institutions should provide affordable financial support to tomato farmers to acquire necessary inputs and improve their acreage while the business community should create processing facilities were tomatoes can be produced during period of glut.

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APPENDIX

Appendix 1

Questionnaire survey

Dear respondents:

This questionnaire is conceived to provide useful information to a student in the Department of Development studies with specialization in Environment and Agriculture, at the Pan African Institute for Development-West Africa (PAIDWA), Buea Cameroon, with regards to a research titled:" **postharvest losses and handling practices of tomatoes on livelihoods. The case of Wotutu, South West Region Cameroon"**.presented by **ELIVE LIMUNGA LINDA** Every response is strictly for academic purposes and its confidentiality is primordial. Thanks for your understanding.

Date of collection: _____

Questionnaire number: _____

SECTION A: DEMOGRAPHIC INFORMATION

1. Sex: Male ☐ female ☐
2. To which age group do you belong below?20 years: ☐ 20-35 years ☐

55-75 years ☐ 75 years and above ☐

Marital status**:** A)Single ☐ C)Widow ☐ D)Divorced ☐

3. Level of Education: A)Primary level ☐ B) Secondary level ☐ C) High school level ☐

a.D)University level ☐ E) others please specific

4. **Religion A)** Christian ☐ B)Muslim ☐ C)Atheist ☐ D)Other ☐

SECTION B HARVESTING

1.How do you harvest your tomato fruits?

A)Hand picking C)others, please specify……

2.At what color stage do you harvest the fruit?

A)When it's still green in color ☐ B)when its turns yellow ☐ C)when its red in color ☐

D) Other, please specific……..

3. Which kind of tomato do you pick?

A)firm and red ☐ B) soft and red ☐ C)firm and yellow ☐

4. What size do you pick?

A)Large size ☐ B) small size ☐ C)any size ☐

5. At what time of the day do you harvest?

A)morning period 6-11am ☐ B) afternoon 12-4:00pm ☐ C)evening 5-7pm ☐

SECTION C POST-HARVEST HANDLING

1. How do you store your fruits after harvesting?

A. placed in crate ☐ B. Placed in woven baskets ☐ C. placed in buckets ☐

D. placed in cartons ☐ E. Others, please specify……..

2.Do you have shades in your farm?

A. yes ☐ B. No ☐

3.If yes do you place the harvest under the shades?

A. yes ☐ B. No ☐ C. Other, please specific…….

4.Do you treat your fruit after harvesting ?

A. Yes ☐ B .NO ☐

5.If yes, what do you use to treat the fruit after harvest?

A. using sodium hypochlorite after harvesting B) No treatment after harvesting ☐

C).Others, please specify…….

6. Where do you sell your harvest?

A. on the farm ☐ B. at the market ☐

7. If you sell your harvest at the market, how does it get there?

A. Transport through bike ☐ B. head ☐ C. Truck ☐ D. Pick up vehicles ☐
E.Taxi ☐ thers please specify…….....

8. What is the approximate distance from the farm to the market?

A. < 1km ☐ B. 1km mile ☐ C.> 1mile ☐

9.Howdo you store your tomatoes after harvest?

A)On the floor ☐ B) in a refrigerator ☐ C) on dry plastic bags D) on the ground ☐

E. Others, please specify……

SECTION D: POST-HARVEST LOSSES

1. What quantity of tomato do you harvest from your farm (units in baskets)?

2. Do you practice sorting after harvesting?
A)Yes ☐ B)No ☐

3. If yes, what kind of tomato do yoursort? Please be specific.....……

4. What quantity of tomato is sorted out (unit in basket)?

5. What quantity remains after sorting (units in baskets)?

6. Do you witness any losses after harvest? Yes ☐ No ☐

If yes, please specify…….

7. What is the cause of thislosses?.....……

8. How does this loss affect you? …….

……
……

1. What are the common diseases affecting tomato in Wotutu?
A) Early and last blight ☐ B) Blosson-end –rot ☐ C) fungi and bacteria ☐

Others, please specify…….....

2. What are the common pests of tomato in Wotutu?
A) Butterflies and moths ☐ B) Aphids and whiteflies ☐ C) others, please specify……
……..

3. What is the duration between harvesting and collecting of fruit by the buyer
   A) <2days ☐ B) 2-3days ☐ >3days ☐

4. What are the challenges faced in post-harvest handing of tomato

   A) Lack of technology ☐ B) unreliable transport ☐ C) Limited access to finances ☐

   D)Lack of storage facilities ☐ F)High cost of production ☐

SECTION F: CHALLENGES OF POST-HARVEST LOSSES OF TOMATO

Please list all the challenges you face in preventing post-harvest losses in Wotutu

_____
_____
_____
_____
_____
_____
_____