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STRATEGIES TO REDUCE POST-HARVEST LOSSES ALONG TOMATO VALUE
CHAIN IN NEBBI MUNICIPALITY-UGANDA



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Strategies to reduce post-harvest losses along tomato value chain in Nebbi Municipality-Uganda.

A research project submitted in partial fulfilment of the requirements for the degree of Masters in Agricultural Production Chain Management, specialisation Horticulture Chains.

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DEDICATION

I dedicate this document to the Almighty God, to my beloved children and my siblings. A special feeling of gratitude to my loving parents, Peter and Grace whose words of encouragement and push for persistence ring in my ears. I also dedicate this document to my many friends and church family who have supported me throughout the process.

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List of Acronyms

APCM	Agricultural Production Chain Management
FAO	Food and Agriculture Organization
PHL	Postharvest losses
MATIP	Market and Agricultural Trade Improvement Programme
KII	Key informant Interview
FGD	Focus Group Discussion
NMC	Nebbi Municipal Council
UBO	Uganda Bureau of Standards
UMFSNP	Uganda Multi-sectoral Food Security and Nutrition Project
SWOT	Strength, Weakness, Opportunities and Threats
ANOVA	Analysis of variance

ABSTRACT

Tomatoes is one of the high value crops grown by small scale farmers in Nebbi Municipality to boosts their household income and food security. It is extensively grown in the world with an estimated yearly production of 182 million tons from around 4.8 million hectares of land and is the sixth-most eaten crop in the world because its nutritional importance. The study was conducted to assess the extent and causes of the losses and identify strategies that can effectively reduce post-harvest losses in the tomato value chain in Nebbi Municipality which is divided into three divisions: Thatha, Abindu and Central, each of which has three wards and a total of forty-six (46) cells. Primary data were collected from producers (smallholder farmers) and traders via household survey, focus group discussions and key informant interviews. Secondary data and information were collected from published and unpublished sources. The data was analyzed to determine whether it was normally distributed and comparing percentage means food loss among the various groups of value chain actors was done using one way ANOVA. The results were presented in pie-charts, bar graphs, and tables. The tomato value chain experiences a significant post-harvest losses with an average of 28% among producers and 19% among the traders. The major post-harvest losses occur during harvesting, post-harvest handling, primary processing (sorting), storage, distribution, packaging and at consumption. Postharvest loss is still a big challenge in the tomato value chain caused by pest and disease, mechanical damages resulting from poor postharvest handling, poor transportation, lack of appropriate storage facilities and limited knowledge of actors on postharvest losses. It is, therefore, important to use appropriate post-harvest handling, packaging, transportation, and storage practices to reduce the level of post-harvest loss. Keeping post-harvest losses of tomatoes to a minimum will help to combat poverty, provide food security, and preserve the quality of the produce.

Key word: Post-harvest losses, value chain, tomatoes

1.0 INTRODUCTION

1.1 Background

Over the past century, tomato (*Solanum esculentum*. L) has experienced tremendous growth in popularity. In addition to being delicious, tomatoes encourage a healthy nutritional balance because they are a strong source of vitamins A and C. It is one of the most significant high-value crops that boosts household income and food security for smallholder farmers in Uganda. (Tusiime, 2020; Atuhaire et al., 2016). Tomatoes is extensively grown in the world with an estimated yearly production of 182 million tons from around 4.8 million hectares of land (Adenuga, 2013). Tomato is the sixth-most eaten crop in the world. (Dhamulira et al., 2021). Due to their nutritional importance, nearly 3 million households in Uganda include tomatoes in majority of their meals. Fresh tomatoes are used as a sauce in salads and sandwiches, whereas dried processed tomatoes are used in pasta, preserves, sauces, soups, juices, and drinks (Paresh, 2018).

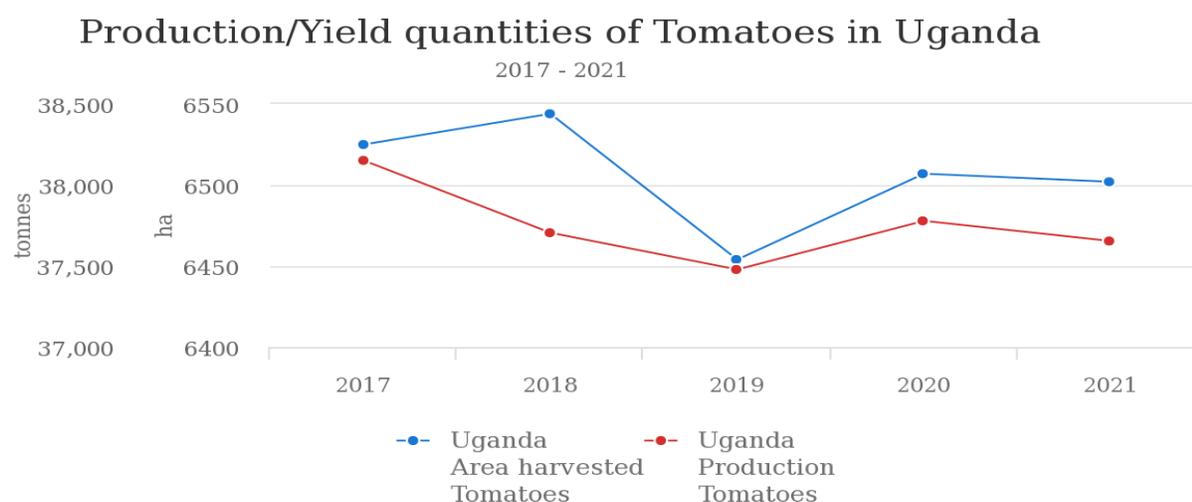
In Uganda, 40,124 tons of tomatoes are produced from 6,671 hectares. It is regarded as an economic crop for both rural and peri-urban farmers; the production statistics are indicated in table 1.

Table 1: Tomato production statistics in Uganda

Period (Year)	Value (tons)
2017	38,152.11
2018	37,705.68
2019	37,478.56
2020	37,778.78
2021	37,654.34

Source: FAOSTAT, 2023

Figure 1: Tomato yield data in Uganda



Source: FAOSTAT, 2023

Source: FAOSTAT (May 24, 2023)

Dhamulira (2021) expressed that smallholder farmers are the principal producers of tomatoes who grow between 0.1 and 3.5 acres with an average land holding of 0.68 acres designated for tomato cultivation, with an average output of 4.7 tons per acre. The tomato production is mainly done by farmers on an individual basis from cultivation to marketing without coming together in farmer groups. The farmers make use of wooden boxes, plastic basins, woven baskets in collecting and transporting tomato to the markets but usually wooden boxes are the most packaging materials used for transporting tomatoes from the field to the market due to their suitability and protection against damage they offer to tomatoes during transportation. On the other hand, plastic basins and woven baskets are frequently utilized during field harvesting (Dhamulira et al., 2021). Besides growing tomatoes, farmers grow other vegetables such as cabbages, eggplants, onions and grow other food crops such as cassava, maize and beans for their livelihood. Agriculture remains the municipality's main economic activity. More than two thirds (69%) of families rely on subsistence farming as their main source of income (Census, 2014).

Farmers use rural marketplaces and intermediaries to sell tomatoes they grow themselves. Although prices at urban markets are higher than those offered on-farm, most farmers still sell their tomatoes for a profit on-farm to save on transportation expenses and the excessive market dues paid in urban markets. Another motivating aspect is the desire of intermediaries to travel and do commerce with farmers' rights on farms. Tomatoes are rarely sold at the side of the road. Even though there is a large market and considerable demand for tomatoes, there is significant price variation (Dhamulira et al., 2021).

Post-harvest loss which refers to the measurable quantities and quality of product lost at a given moment along the post-harvest chain (Gudila et al., 2013) is a big challenge in the tomato value chain. In less developed countries, the post-harvest losses of fresh fruits and vegetables have been projected at 20 to 50% depending upon the crops (Khatun et al., 2014). Between harvest and consumption, horticulture commodities have both qualitative and quantitative losses; consequently, it is more sustainable to decrease post-harvest losses of already produced food than to increase yield (Khatun et al. 2014). The rotting of products and damage sustained during storage, packing, and shipping are examples of post-harvest losses that result in customer rejection. The final half of the food chain experiences most losses and wastage due to excessive processing, packing, and marketing.

In the retail sector, losses are brought on by mechanical harm, insufficient storage, improper handling, a broken transportation system, and delayed transit. The kind of commodities, the state of the produce at the time of collection, the distance traveled, and the characteristics of the road network all affect how much is lost.

The tomato producers depend on rainfed agriculture that is divided into two growing seasons (March-June and August to November). This leads to high production and harvesting of tomatoes during a certain period of the year and scarcity at certain points. This greatly affects the price of tomatoes due to the glut in the market. Furthermore, vegetables are much less hardy, rapidly perishable except under intensive care during harvesting, handling, and transportation.

1.2 Research Commissioner

Nebbi Municipal Council is commissioner of this research. The Municipality through the Production and Marketing Department wants to promote urban farming with emphasis on tomato production to improve production and productivity aimed at increasing household income and food security in the Municipality.

1.3 Justification

The research topic focuses on identifying strategies to reduce post-harvest losses in the tomato value chain in Nebbi Municipality, Uganda. The justification for this research is based on the importance of tomatoes in the region's economy and food security, the significant losses experienced in the tomato value chain, and the economic, social, and environmental implications of these losses. The research aims to address the knowledge gap in the specific context of Nebbi Municipality and provide valuable insights for farmers, policymakers, and other stakeholders. The findings can contribute to enhancing agricultural productivity, improving livelihoods, ensuring food availability, promoting sustainability, and potentially be applicable to similar regions beyond Nebbi Municipality.

1.4 Problem statement and justification

Post-harvest losses along the tomato value chain in Nebbi Municipality, Uganda, pose significant challenges to farmers, traders, and the local economy. Despite the economic importance of tomatoes and their role in ensuring food security, these losses occur at various stages, including harvesting, postharvest handling, transportation, and storage. The lack of effective strategies to mitigate post-harvest losses leads to significant economic waste, reduced income for farmers, compromised food availability, and negative environmental impacts. Furthermore, the level of losses in Nebbi Municipality warrants a focused investigation, as there is a lack of comprehensive studies and tailored interventions addressing post-harvest losses in the tomato value chain. Thus, a research study is needed to assess the extent and causes of the losses and identify strategies that can effectively reduce post-harvest losses in the tomato value chain in Nebbi Municipality, to improved livelihoods and enhanced food security.

1.5 Objective

To assess the extent and causes of post-harvest losses along the tomato value chain in order to propose mitigation measures that can be adopted to reduce the postharvest losses in Nebbi Municipality.

1.6 Research questions

1. What are the main causes of postharvest losses in the tomato value chain?
 - i. What proportion (quantitative) of tomatoes is lost during post-harvest?
 - ii. What proportions are lost at which stage of the cycle?
 - iii. Are there any variations in losses in relation to seasons?
 - iv. Are there any variations in losses in relation to varieties?
 - v. What is the contribution of governance structure on postharvest losses in the tomato value chain?

2. What are the strategies for reducing postharvest losses in the tomato value chain?
 - i. What practices are currently in use to reduce postharvest losses in the tomato value chain?
 - ii. What is the perception of the actors on tomato postharvest losses in the value chain?
 - iii. What appropriate strategies can be used to reduce postharvest losses in the tomatoes value chain?

2.0 LITERATURE REVIEW

2.1 Post-harvest losses

A measurable quantitative and qualitative loss of a particular product after harvest can happen at any point in the post-harvest chain (Khatun et al., 2014). Production setbacks estimations are difficult to evaluate in developing countries. According to the types of crops grown, post-harvest losses of fresh fruits and vegetables in majority of these nations are predicted to vary from 20 to 50%. Khatun (2014) expressed that both qualitative and quantitative losses occur in horticultural commodities between harvest and consumption, and therefore, reducing post-harvest losses of food that has already been produced is more sustainable than expanding output.

2.1.1 Causes of postharvest losses in tomatoes

Arah (2015) mentioned that causes of post-harvest losses in tomato production can be categorized into two, the on-farm and off-farm causes.

2.1.1.1 On-farm causes of post-harvest losses

Inappropriate harvesting

Quality is significantly impacted by the fruit's physiological maturity at the time of harvest (Famuyini et al., 2020). Therefore, to have the finest quality, care must be given in deciding when to harvest the fruit. Before being harvested, fruits and vegetables go through three stages of development: maturity, ripening, and senescence. There are three maturity levels at which tomatoes may be picked, and the maturation is a sign that the fruit is ready for picking. It can be picked in a fully ripened, slightly ripened, or matured green condition. Since tomatoes are climacteric fruits, they can be picked in their fully developed green condition, enabling ripening and senescence to take place throughout the fruit's postharvest period. Research has shown that physiological factors such as maturity stage, physical damage, and improper handling techniques significantly influence postharvest losses (Obenland et al., 2015; Valero et al., 2019).

In contrast, farmers in most African nations pick tomatoes when they are half or fully ripe. Fully ripened tomatoes have a lower shelf life because they are more likely to sustain damage during harvest. This might be the cause of the high levels of losses in tomatoes harvested in Africa at the peak of ripeness (Arah et al., 2015). Fruit and vegetable losses are also a result of other conditions and cultural practices including drought, excessive rainfall, illnesses, physiological disorders, plant nutrition, plant protection, irrigation, fertilization, and trimming during the pre-harvest period (Aysel et al., 2019).

Lack of appropriate harvesting containers

In Uganda, hand picking of tomatoes is preferred over machine harvesting. During harvesting, care should be made to prevent mechanical damage that might serve as a pathogen entry site. Many African farmers pack their gathered produce mechanically hurt by using woven baskets and wooden containers with harsh, sharp edges (Arah et al., 2015; Eskindir et al., 2022). Fruit crushing in the bottom of the containers because of severe compression can occur when containers are overloaded during collection (Tiwari et al., 2020). To prevent overloads, flat surfaces and shallow containers should be used to reduce mechanical damage and fruit shredding. Tiwari (2020) has thus advised using a plastic basket to collect tomatoes.

Excessive field heats & lack of on-farm storage facilities

The field heat of the harvested crop should be rapidly removed because it is often high, especially in the tropics and this should be done before beginning any post-harvest handling operations (Arah et al., 2015). It is crucial to quickly cool down after harvest to lower metabolism since field temps also cause a fast increase in metabolic activity. Early in the morning or late in the evening are the best times to get the ideal temperature of around 20 o C for tomato picking. If fruit is picked outside of the suggested times, it must be pre-cooled to prevent excessive field heat. Most growers keep their tomatoes in storage until purchasers arrive under tree cover. Tree shadows are unreliable because they may move away from the fruit as the sun's position changes. As a result of being exposed to the intense sun, the fruits develop a buildup of field heat.

Inappropriate packaging materials

The commonly used packing materials in poor nations include large green leaves, clay pots, braided cane baskets, wooden crates, cardboard crates, cardboard boxes, plastic buckets, nylon sacks, jute sacks, and polytene bags. The bulk of these packing materials prevent the tomatoes from breathing well within, which results in a buildup of heat from respiration. In a normal circumstance, the commodity should be protected by a proper packing method from diseases, natural predators, moisture loss, temperature extremes, crushing, deformation, and bruising (Arah et al., 2015).

Poor Field Sanitation

Produce handlers place a high priority on sanitation, both to safeguard their products from post-harvest infections and to safeguard customers from food-borne illnesses. One of the biggest causes of food-borne diseases is fresh vegetables. Most farmers in underdeveloped nations, particularly those in Africa, lack on-farm facilities for disinfecting their crops. Additionally, sorting is not done, resulting in the mixing of good fruits with decaying fruits that may contain germs that cause sickness. This approach causes infections to proliferate quickly within the packed product, greatly accelerating degradation.

2.1.1.2 Off-farm causes of post-harvest losses

Poor road infra-structures

Poor access roads to producing areas are a significant barrier to the viability of the tomato business in many African nations. The majority of producing fields are situated in remote areas, far from developed roadways, making access to competitive markets challenging and expensive. Transporting picked tomatoes to the marketing centers is highly challenging, costly, and time-consuming due to the poor condition of the road infrastructure. Meanwhile any delay between harvest and consumption of the tomatoes can result in losses (Arah et al., 2015). Arah (2015) asserts that farmers might experience losses of up to 20% because of delays in transportation. Most developing nations face a serious problem with poor road infrastructure, which is expected to have long-term effects for tomato farmers and distributors.

Inappropriate mode of transport

The use of appropriate transport means is believed to be another challenge in postharvest handling of tomatoes. One of the main causes of post-harvest losses to most fruits and vegetables, notably tomatoes, is vibration and impact during transportation because of road undulations (Arah et al., 2015). Therefore, these adverse variables during transportation result in significant losses due to the poor quality of the roads in most African nations and the inappropriateness of the available transportation choices.

Microbial and Fungal Diseases

Pathogens, including bacteria, fungi, and viruses, are responsible for substantial postharvest losses in tomatoes. Common diseases such as bacterial soft rot, gray mold, and late blight can lead to significant decay during storage and transportation (Hong et al., 2016; Lahlali et al., 2017). Effective disease management practices, including proper sanitation, fungicide applications, and postharvest treatments, are essential to minimize these losses.

Lack of processing facilities

Another difficulty experienced by growers of tomatoes in poor nations is the lack of processing facilities (Arah et al., 2015). Lack of processing facilities that can be utilized to prepare and store the fruits for later consumption just makes the issue worse.

Unreliable market

Most tomato growers in poor nations, particularly those in Africa, have a significant problem with market accessibility. The pattern of production, which results in gluts, is one of the main causes. More growers still rely on output that is fueled by the rain. According to Arah (2015), the majority of the tomato crop is produced during the production year's rainy season in Nigeria, for instance. This results in high output peaks that are consistently higher than the demand for fresh fruit in the area. African producers lack knowledge on the availability of trustworthy markets. There is a paucity of market knowledge and insufficient producer-consumer dialogue. Therefore, to avoid a complete loss, producers must sell their yield at very cheap prices.

Poor market infra-structure

According to Gudila et al., (2013) the use of temporary roofing materials to temporarily shield fruits from sunshine and/or rain at the market causes significant market losses owing to rotting and physical damage by insects and rat infestation. Sunlight and fruit softening are the primary causes of significant loss-causing spoiling. In addition, fruit exposure to sunshine results in water loss through transpiration, changing the fruit's quality, and fruit rotting from rain, which adds moisture to the fruit.

Perceived causes of postharvest losses

Post-harvest losses are primarily due to rot, bruising, improper handling, and fruit that is deformed. The absence of a viable market and a greater travel distance to the farm are, in the opinion of the farmers, the two most important secondary factors that have a significant impact on postharvest losses in tomato production. Poor handling method, a lack of processing facilities, farmers' choice of variety, and a bad road network are also factors (Wongnaa et al., 2023).

2.1.2 Postharvest loss reduction practices

Harvesting

The quality and storage life of tomatoes are determined by harvesting, which is a crucial unit action that also helps to minimize significant losses. Maximizing crop output, minimizing crop losses and quality deterioration, and maintaining the harvested produce in excellent condition until it is consumed or sold are the objectives of a successful harvest. Important variables that impact post-harvest losses and product quality include maturity criteria, harvesting procedures, harvesting instruments, field packing, and transportation circumstances to the packinghouse (Aysel et al., 2019). In addition, research has shown

that practices such as selective harvesting, and optimal timing can significantly reduce losses (Singh et al., 2017; Zhang et al., 2019).

Abera (2020) expressed that harvesting tomatoes early morning and late evening has high impact of the quality of harvested tomatoes and careful handling of fruits as well during the harvesting processes. Implementing proper harvesting techniques is crucial to minimize postharvest losses.

Cleaning of tomato

Few farmers clean tomatoes with clean water because of a lack of knowledge of proper cleaning and application of different disinfectants like thiabendazole solution to decrease the plant microbial load. Most of the farmers do not clean tomatoes at all after harvesting (Tiwari et al., 2020).

Sorting and Grading

Khatun (2014). expressed that only a small number of farmers categorize their tomatoes according to their size, disease infected status, size and disease infected status, maturity and disease infected status, and size, maturity, and disease infected status. Most farmers sorted their tomatoes based on size and disease infected. On the other hand, most grading is done among the retailers. She further mentioned that many products benefit from being graded on appearance prior to being placed on the market since it enhances the likelihood that they will sell, raises their price, and simplifies marketing.

Packaging

Tiwari et al., (2020) mentioned that tomato farmers package their products in plastic crates and some use Bamboo baskets before transporting to the local or wholesale market although vegetables are often packed in containers because they are convenient to handle, offer decent protection from mechanical harm, and have enough air.

Storage

According to Tiwari et al (2020), some farmers cover their food with plastic to keep it. which are only kept for a day before being sold on the market. Farmers have no facilities of storage for highly perishable vegetables. There are huge losses of fresh tomatoes every year due to this.

2.2 Chain governance along tomato value chain

The framework and mechanisms that control the relationships, interactions, and decision-making processes among the numerous parties involved in the tomato industry, are referred to as the governance structure in a value chain. It defines how authority, responsibility, and power are allocated among the parties involved, and it is essential for ensuring efficient coordination and collaboration along the value chain.

Siam (2018) noted that a high number of actors, lack of tight relationships, and lack of information exchange define the tomato value chain. The traders and intermediaries are the actors at the centre of the interactions, and they most influence the value chain. The following are the relationships for governance coordination.

Farmers and input suppliers: In the input marketplaces, a huge number of farmers make up the demand side while there are few retailers and wholesalers on the supply side. Because there is little competition among input suppliers, smallholder farmers have few options when it comes to the quality and cost of the

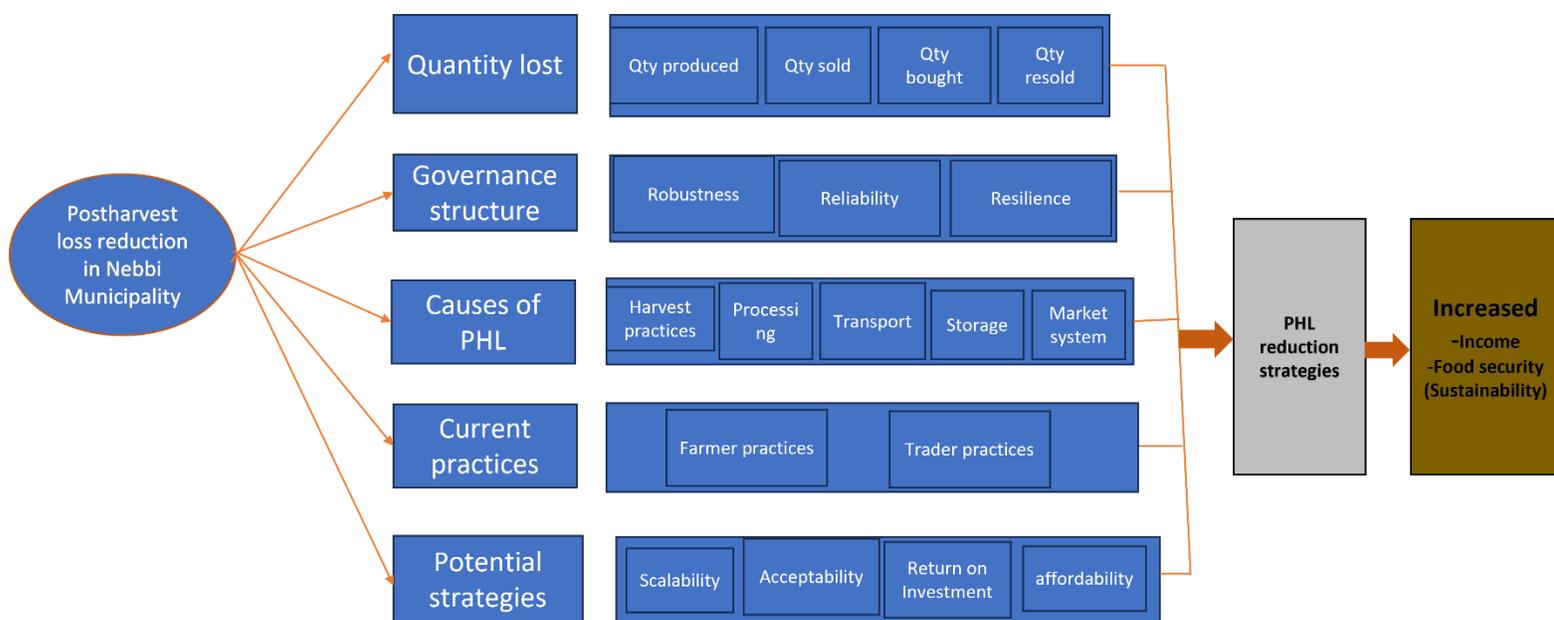
supplies they may buy. The fact that smallholders' purchases of inputs are too little to allow them to negotiate with retailers for lower rates or to buy directly from input wholesalers also weakens their position in the input market. The input sellers do have the chance to direct the connection between the parties unless tomato farmers are federated and represented by an association (Siam et al., 2018).

Farmers and traders: The conventional value chain for fresh tomatoes is rather straightforward, and the standards for market quality are likewise modest. Therefore, there is no motivation for traders and wholesalers to develop special connections with smallholders. As a result, smallholders find themselves at the mercy of wholesalers, who alone decide whether or not they will purchase, how much they will buy, when they will buy it, and at what price, particularly if the output of smallholders is based on credit. If a tiny holding rejects an offer, it runs the danger of having nothing to sell if no other dealer shows up. With this oligopolistic cooperation among retailers, it may be inferred that traders coordinate and manage the management of the connection between farmers and traders (Siam et al., 2018).

2.3 Conceptual framework

The assumption is that a product's shelf-life peaks during harvest and declines as it moves further down the supply chain. This framework conceptualizes the five areas of focus for postharvest losses in tomatoes value chain that include, the harvested quantity lost, the chain governance structure, causes of the postharvest losses, current practices of postharvest loss reduction and potential strategies for postharvest loss reduction in the tomato value chain in Nebbi Municipality. It further looks at the separate factors—harvest quality, postharvest processing, transport and storage and market systems that contribute to shelf-life of tomatoes. All the activities undertaken at the various points contribute to the product shelf life. Depending on the severity, a decrease in shelf-life results in either qualitative or quantitative losses. The Postharvest losses are the total of both losses, and they arise as the product moves further down the supply chain.

Figure 2: Conceptual framework for estimation of tomato post-harvest losses



Source: Author

3.0 RESEARCH MATERIAL AND METHODOLOGIES

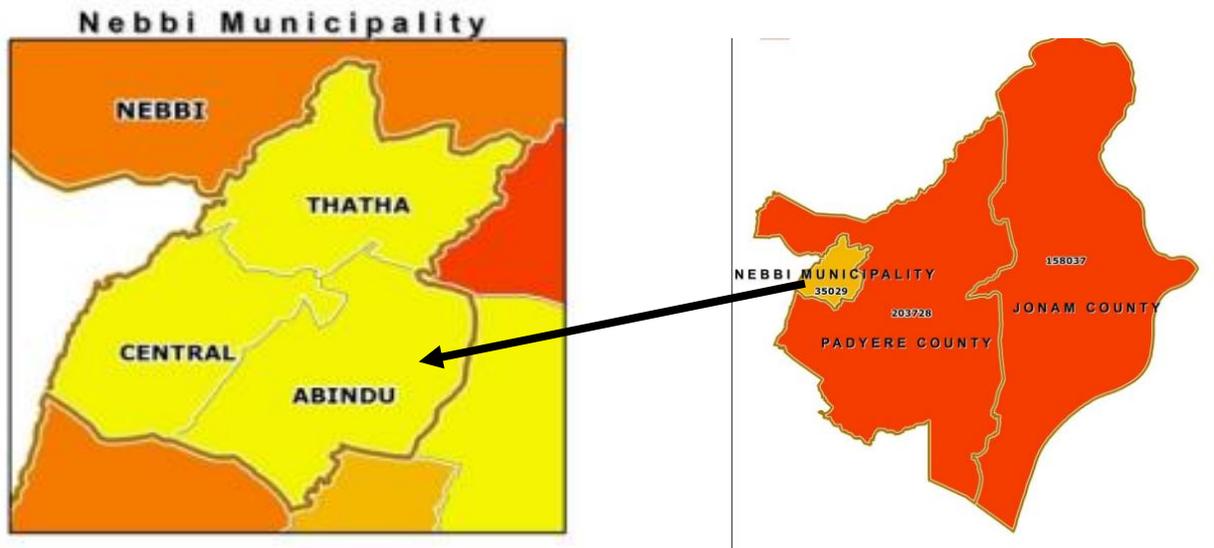
3.1 Research design

This research employed a combination of quantitative and qualitative research methods. Primary data was collected through surveys, interviews, and focus group discussions with key stakeholders involved in the tomato value chain, including farmers, traders, and key informants to ensure that the data collected is reliable. Secondary data, including reports, studies, and publications, were reviewed to gather additional insights. The data collected was analyzed using SPSS software and Value chain map and SWOT.

3.2 Description of study area

The study was conducted in Nebbi Municipality which is divided into three divisions: Thatha, Abindu and Central, each of which has three wards and a total of forty-six (46) cells. It became Municipality in 2016 when it was elevated from a Town Council in Nebbi district. The Municipality is in the North-Western part of Uganda lying within the coordinates of 2°28'45.0"N, 31°05'24.0"E (Latitude: 2.479167; Longitude: 31.0900). It sits at an average elevation of 1,002 metres (3,287 ft), above mean sea level and has a total land area of 76 Km². According to census data of 2014, the population of Nebbi Municipality was 35,029 people with 16,714 males and 18,315 females, (Census 2014). According to the UBO (2020) projection, it homes up to 41,400 people. The Municipality's primary economic sector is still agriculture. The primary source of income for more than two thirds (69 percent) of families is subsistence farming (Census 2014).

Figure 3: Map of Nebbi Municipality



Source: Census 2014

3.2 Sampling procedures and sample size

Farmers from the three Divisions of the Municipality — Central, Thatha, and Abindu—were chosen at random. The farmers who produce tomatoes were the ones who were targeted. To communicate with the various farms, the snowball technique was adopted. 30 farmers from the research region were chosen at random to participate in the survey, along with 15 traders (who comprised wholesalers and retailers) and interviews with 4 key informants. For retailers who deal in tomatoes, a straightforward random sampling procedure was used. In agreement with the chairwoman of the vendors organization, traders were chosen

at random from among the market stalls and given questionnaires. There were two focus groups with a total of 12 participants.

3.3 Data collection

Data collection for the research was gathered through desk study, survey, focus group discussions and semi-structured interviews for key informants in Nebbi Municipality.

3.3.1 Secondary data

Desk study

Prior to the commencement of the field, desk study research was done to obtain literature and secondary data on postharvest losses in tomato value chain. This information was gathered from the VHL library, online textbooks, journals, and published publications. Additionally, extra details about postharvest losses in the tomato value chain were produced using web resources including Google Scholar, Greeni, and CABI.

3.3.2 Primary data

Survey

The survey was done using questionnaires which was pretested prior the commencement of the data collection process. The questionnaire had both closed-ended questions and open-ended questions. The questionnaires were administered by the researcher to the respondents. Thirty (30) farmers and fifteen (15) dealers along the tomato value chain in Nebbi Municipality received the surveys.

Figure 4: Survey exercise



Focus group discussions

Two focus groups discussions were held at Nebbi Municipal Council facility for the two categories of the value chain actors: the farmers and tomato traders. Each category consisted of six members and this activity was guided by semi structured questions in the checklist.

The focus group discussion was utilized to get opinions from all of the attendees. The focus group discussion included topics such as the governance structure in the tomato value chain, causes of

postharvest losses, variables leading to postharvest losses, current procedures utilized to reduce postharvest losses, and potential solutions to do so.

Figure 5: Focus group discussion with farmers and traders



Key informant interviews

Four people—the assistant agricultural officer, the community facilitator for Uganda Multi-sectoral Food and Nutrition Security (UMFSNP), the chair of the association for market vendors, and the manager of the tomato wholesalers' stall in the market—were the subjects of the key informant interviews. The stakeholder interviews were facilitated by a checklist. This included information on the chain's stakeholders and their roles, the governance structure, the flow of market information, the sources of losses, and solutions for reducing losses.

Observations

As part of the data collection process, observations were made to better understand some social behaviors of the actors and their customers related to postharvest losses and the facilities, practices, and procedures used to reduce postharvest losses. This was done in order to validate the information gathered from the respondents and the other stakeholders involved in the tomato value chain.

3.4 Data processing and analysis

The KS normality test was used to further analyze the quantitative data to determine whether it was normally distributed and comparing percentage means food loss among the various groups of value chain actors was done using one way ANOVA. Bar graphs and statistical tables were used to display the results.

3.5 Limitation of the study

During data collecting the study ran into limitations. The survey was unable to reach the transporters and traveling traders since they travel at night and deliver the tomatoes to the market, and when they were called by phone for the information, they refused to provide it. Nevertheless, the data collected from the Municipality's stakeholders was sufficient for the thesis report.

4.0 RESULTS AND FINDINGS

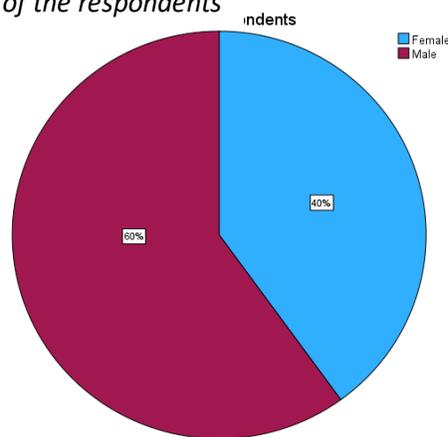
The research study's findings, as well as those from focus groups, interviews with key informants, and surveys, are presented in this chapter. The outcomes include general data, an analysis of the tomato value chain's current setting in Nebbi Municipality, as well as information on stakeholders, supporters, and their respective roles. It goes on to detail the projected % losses of tomatoes along the tomato value chain as well as the causes, contributing variables, current methods of loss reduction, governance frameworks, and loss reduction strategies.

4.1 Demographic information

4.1.1 Gender of respondents

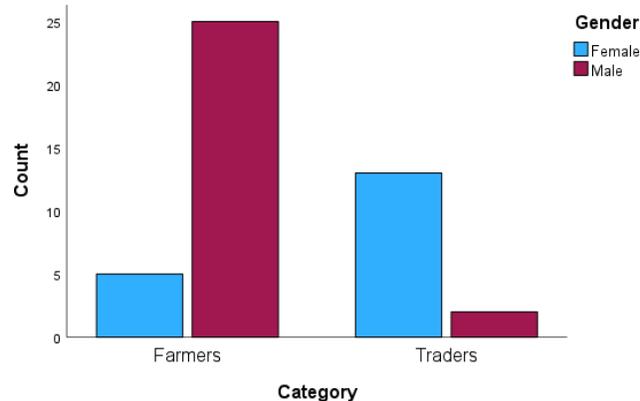
The number of responses was 45, which included both tomato growers and traders. The gender was divided into two groups, as shown in figure 6 below, which shows that men (60%) predominate in the value chain for tomatoes as presented in Figure 6 below.

Figure 6: Gender of the respondents



A deeper analysis was done to find out which gender was involved at what levels of the value chain and the result is presented in Figure 7 below.

Figure 7: Distribution of gender along the value chain

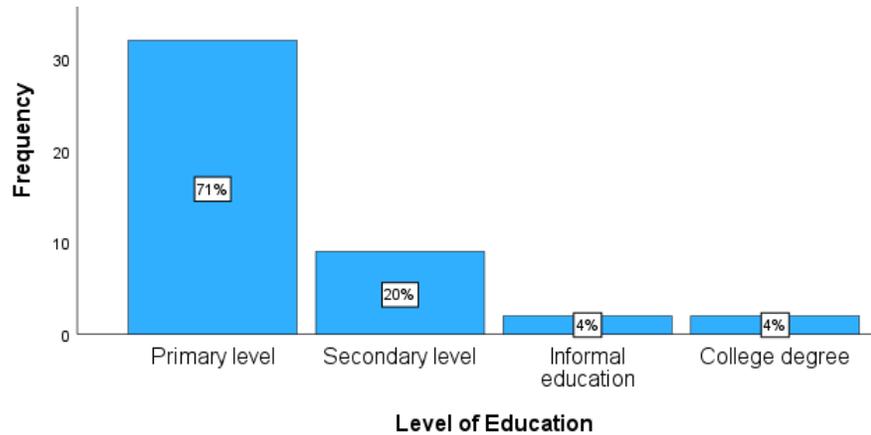


The result shows that females are more involved in the marketing side (upstream of the chain) while males are more involved in the production side (downstream of the chain) of the value chain. This has implications during the design of future interventions.

4.1.2 Level of education of respondents

The level of education of the 45 respondents was clustered into five categories: (1) Those who did not get formal education, (2) those who did not go beyond Primary education, (3) Secondary level and (4) College. The data is presented in Figure 8 below.

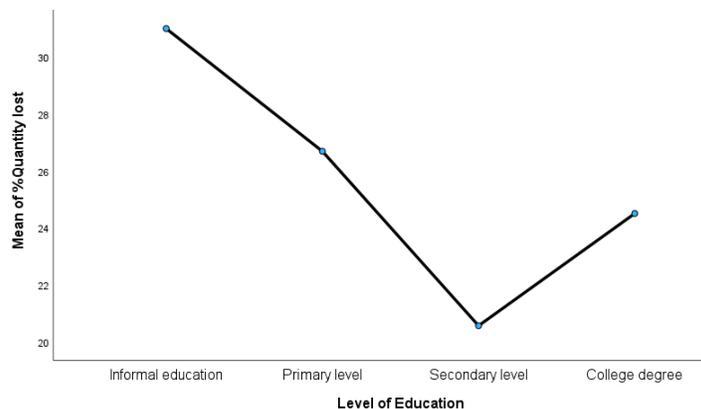
Figure 8: Education level of respondents



Universal Primary Education- Free Education offered in Government aided schools where the level of performance is not a major concern by the stakeholders and teacher pupil ratio is not proportionate.

According to the findings, majority (71%) of those participating in the tomato value chain in Nebbi Municipality stopped their education in primary school, just a tiny minority continued to secondary school (20%), and the fewest got a college degree (4%) while (4%) had informal education. We are therefore basically dealing with semi-illiterate people, and this has implications for intervention designs. To note also is low standards especially at Primary Education level in the country in the wake of Universal Primary Education (UPE) where many children who have completed primary education cannot read sentences in English or write legibly. This has implications for intervention design. To substantiate, the above assertion, an analysis was performed to find out if there was a relation between level of education and the percentage of post-harvest losses. The result is presented below,

Figure 9: Correlation between level of education and percentage post-harvest losses

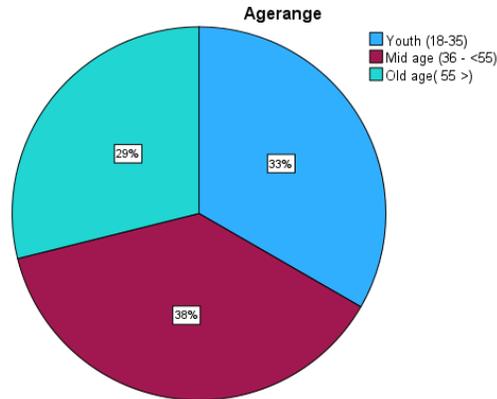


The college graduates mostly farm as a hobby and do not devote enough time tomato cultivation and they are pre-occupied with other employment duties.

4.1.3 Age ranges of respondents

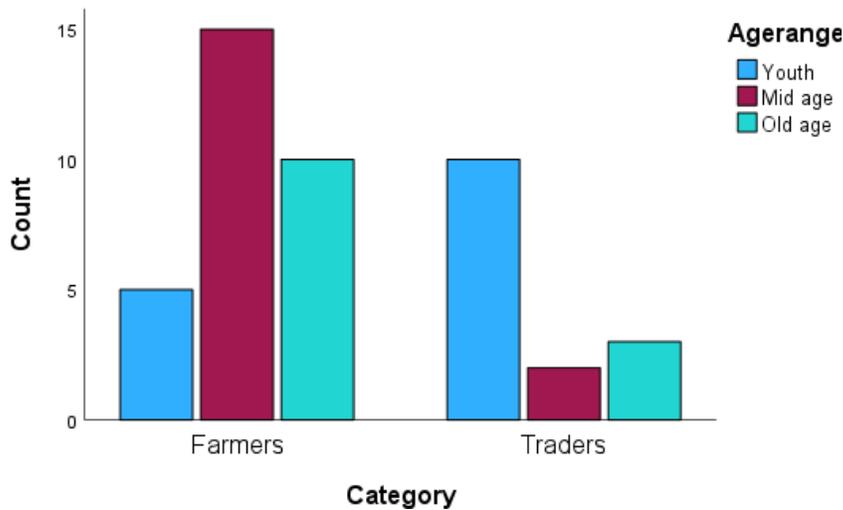
Age was grouped into 3 categories, the youth (age group from 18-35years), middle age (36-54) and old age (55 years and above). In Nebbi Municipality, the people involved in the tomato value chain is virtually evenly distributed throughout the three age categories of youth (33%), middle-ages (38%), and old ages groups (29%), However, the mid-age group is slightly more, as shown in figure 10.

Figure 10: Age of respondents



When further analysis was done it was found out that participation of youth was inclined to marketing side than production which was attributed to the time consumption and labour demand in maintaining the crop though tomato is a highly paying enterprise during FGD. Secondly, tomatoes require high capital investment which is another challenge.

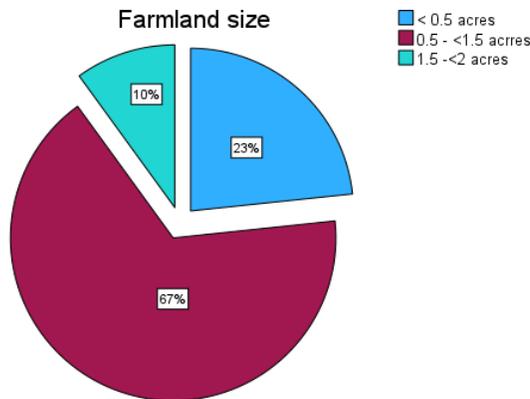
Figure 11: Distribution of the various age groups along the tomato value chain



4.2.1 Tomato farmland sizes

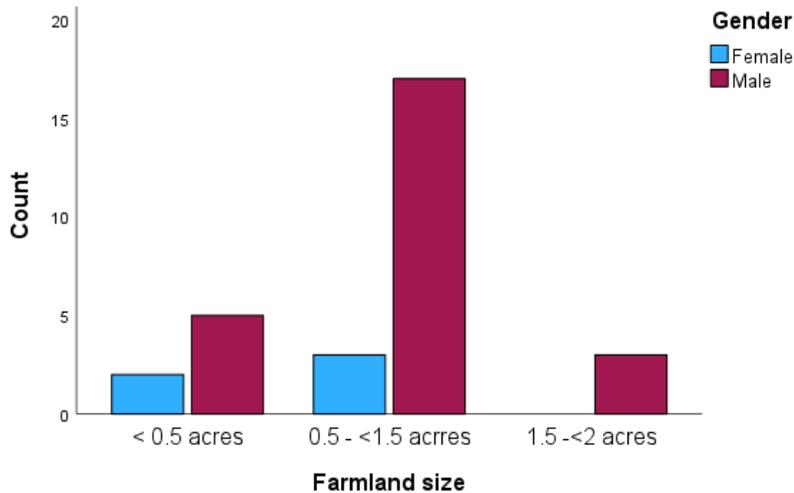
The tomato farmland sizes of the different farmers vary from less than 0.5 acres to about less than 2 acres per farmer with majority (67%) of farmers having farmland sizes of between 0.5 to 1.5 acres, 23% make use of between 1.5-2acres and 10% use less than 0.5 acres for cultivation of tomatoes (Figure 12). These are large areas of land devoted to tomatoes given that the average size of land holding in the study area is 2.5 acres. It underscores the significance farmers give to the crop. It was mentioned during FGD that majority of the farmers produce tomatoes on hired pieces of land which are located near water sources.

Figure 12: Tomato farmland sizes



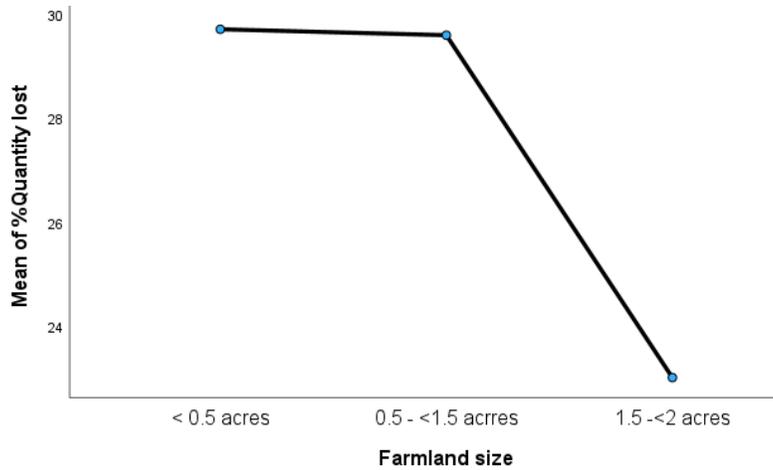
When the tomato farmland size was investigated further in terms of gender, it was discovered that no female produced tomatoes on more than 1.5 acres as presented in figure 13.

Figure 13: Tomato farmland verse gender



Further analysis was made to find the correlation between tomato farmland sizes and percentage losses in the value chain and the results show that there is less losses among farmers that grow tomatoes on large scale than those that grow on less than 1.5 acres this is presented in figure 14.

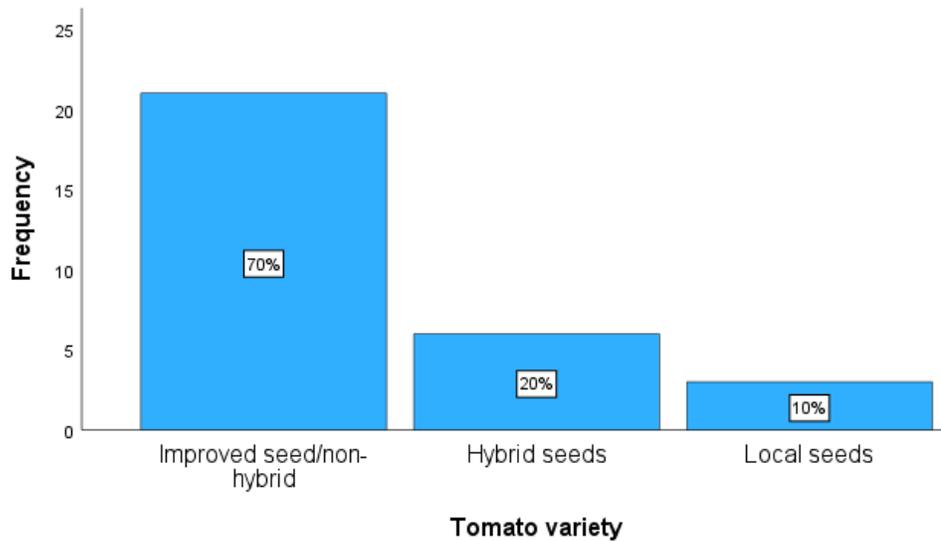
Figure 14: The correlation between farmland size and percentage losses in tomato value chain



4.2.2 Type of seeds used by farmers.

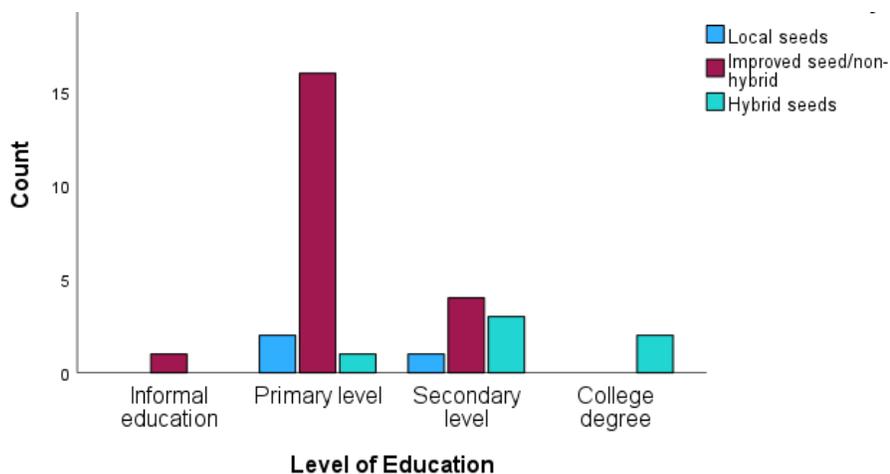
In the study area, three types of seeds were being used by farmers (1) Locally extracted seeds, (2) non-hybrid but improved seeds and (3) hybrid seeds. Most farmers (70%) utilize non-hybrid but improved seeds such as Cal J, Rio Grande, Money Maker, etc., while some farmers (20%) also use hybrid seeds such as Bawito, Ansal, etc that they purchase from the local input suppliers within the Municipality. A small percentage (10%) of farmers use local seeds extracted manually from mechanically damaged fruits (figure 15). This was attributed to the cost of the different varieties during the FGD.

Figure 15: Types of seeds used by producers.



Further analysis was done to find the correlation between types of seeds used and the level of education of farmers. The results show that more educated farmers use hybrid seeds than the less educated farmers.

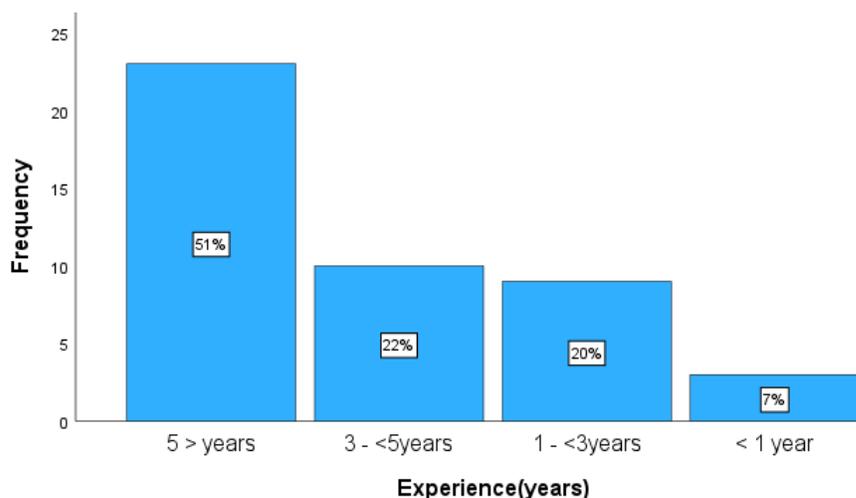
Figure 16: graph showing correlation between type of seeds used and education level.



4.2.3 Experience of actors in tomato value chain

The level of experience in the tomato value chain was divided into four (1) less than 1 year, (2) between 1- < 3years, (3) between 3- <5 years (4) 5> years. The findings show that majority (51%) of the actors have more than five years of experience in the tomato value chain, 22% have between 3-<5years of experience, 20% have 1- <3 years of experience and only 7% have less than one year of experience (figure 17).

Figure 17: Experience of the actor in the tomato value chain



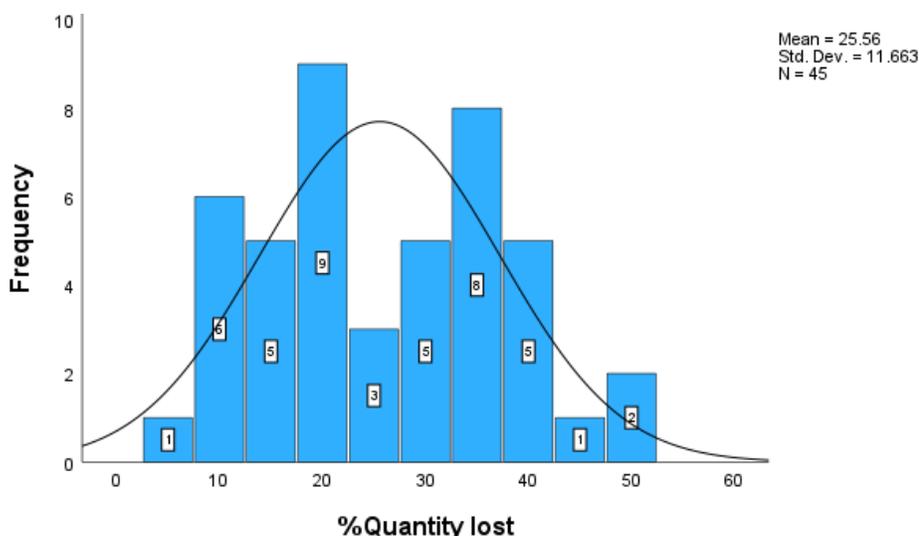
4.3.1 Estimated percentage quantity of tomatoes lost along the value chain in Nebbi Municipality

$$\text{Percentage PHL by farmers} = \frac{\text{Quantity harvested} - \text{Quantity sold}}{\text{Quantity harvested}} \times 100$$

$$\text{Percentage PHL by traders} = \frac{\text{Quantity bought} - \text{Quantity re-sold}}{\text{Quantity bought}} \times 100$$

The estimated percentage of tomatoes lost in the value chain varied between the various players, ranging from 5% to 50%, with most actors reporting losses between 10% and 40%. The losses are not normally distributed among the value chain actors while more losses reported among producers than the traders.

Figure 18: Estimated percentage post-harvest losses of tomatoes in the value chain



During FGD the producers reported that the level of postharvest losses varies from season to season with more losses occurring during the main production season normally referred to as the second season and the losses tend to be less during the minor season.

4.3.2 Monetary losses along the tomato value chain

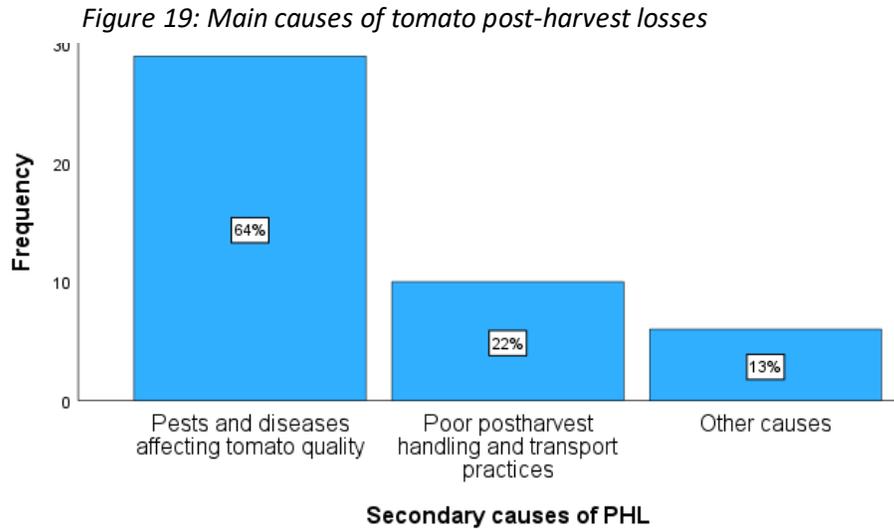
The tomato value chain experienced an estimated total post-harvest loss of 159,915.6kg with an estimated financial loss of UgShs. 228,974,040 (€ 57,401) both by farmers and traders. The estimated post-harvest losses at farmer level was estimated at 59,757.6kg (28% of the total production) which was translated into monetary value of UgShs. 68,721,240 (€ 17,227). On the other hand, the losses on traders side the losses was estimated at 100,158kg (19% of the quantity bought) which was translated to monetary value of UgShs. 160,252,800 (€ 40,173).

Table 2: Quantitative and monetary post-harvest losses along the tomato value chain

Particular	Farmer	Traders (wholesalers)	Total
Total Production/Quantity bought	213,420kg	527,147.4kg	-
Post-harvest losses	59,757.6kg (28%)	100,158kg (19%)	159,915.6kg
Selling price per kg	1,150	1,600	
Amount lost (UgShs)	68,721,240	160,252,800	228,974,040

4.4.1 Main causes of postharvest losses along the tomato value chain

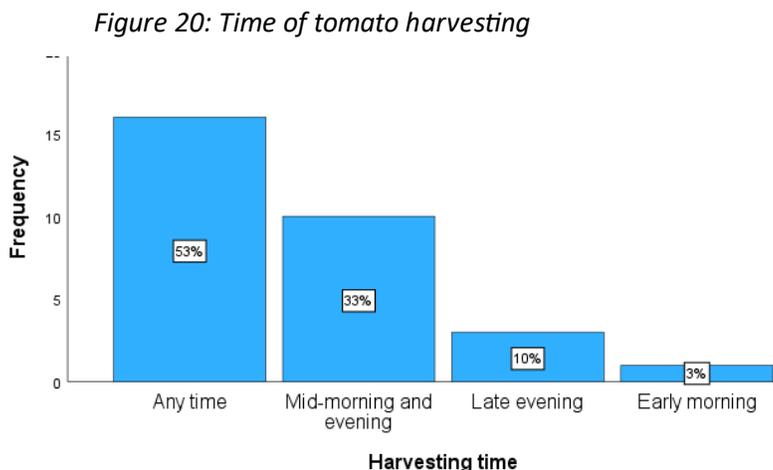
According to the survey findings, the main form of post-harvest losses was fruit decay although from the FGD other forms of post-harvest losses were reported which include cracked fruits, immature fruits that failed to ripen fully and mechanically damaged fruits while the main causes were numerous. Most respondents (62%) reported pests and disease, 22% of respondents reported poor post-harvest handling and transportation while the remaining respondents (16%) reported other causes which include inappropriate storage, weather, and knowledge on handling tomatoes.



4.5 Current post-harvest handling practices along the tomato value chain

4.5.1 Time of tomato harvest

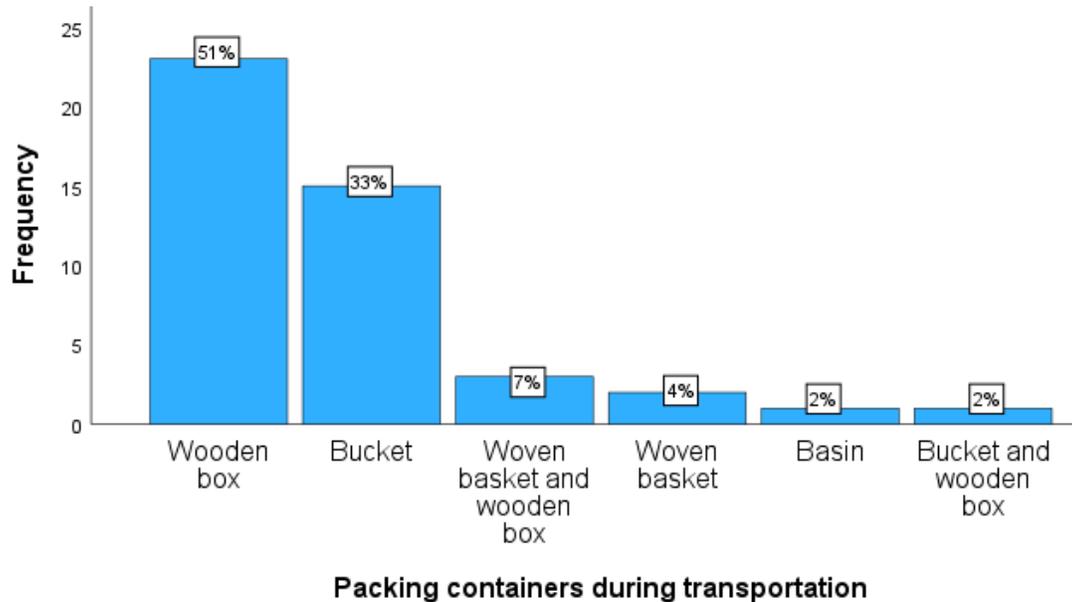
The findings show that most farmers (53%) harvest tomatoes at any time of the day, 33% harvest mid-morning and early evening, with only a small number 3% and 10% picking exclusively in the early morning and late evening respectively, as shown in figure 14. This high implication on post-harvest losses in the value chain.



4.5.2 Packaging material/containers

The results show that a variety of materials are used to pack tomatoes before they are transported which include (1) wooden boxes, (2) buckets, (3) woven baskets, (4) basins. The majority (51%) use wooden boxes, (33%) use buckets, (7%) use combination of wooden boxes and woven baskets, (4%) use woven baskets, (2%) use basins and (2%) use combination of bucket and wooden boxes (figure 21)

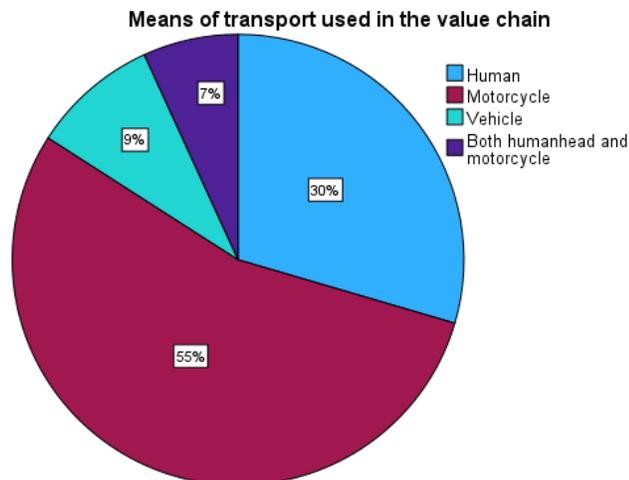
Figure 21: Packaging containers during harvesting and transportation



4.5.3 Means of transporting tomatoes to the point of sale.

The findings showed that there are three types of transport means used in the value chain: (1) Human, (2) motorcycles, (3) vehicles. Majority of farmers (55%) use motorcycles to transport their tomatoes to the point of sale, 30% use human (carry on their heads) and a small number (9%) use vehicles, while the minority (7%) utilize both motorcycle and human transport (Figure 22).

Figure 22: Transport means used to deliver tomatoes to point of sale.

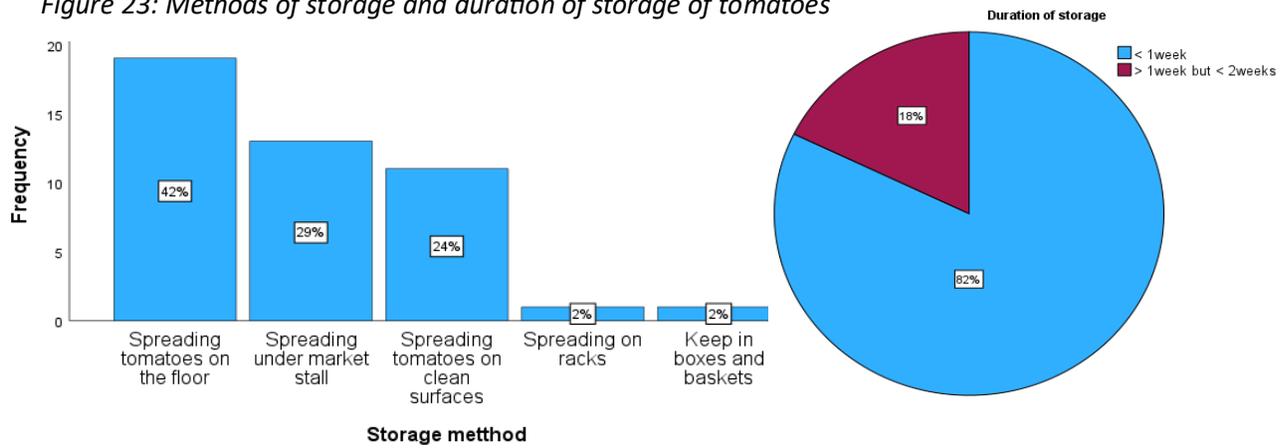


4.5.4 Storage of tomatoes

The findings show that various method are used to store tomatoes which include (1) spreading on the floor, (2) spreading under market stall (3) spreading on clean surfaces in the room, (4) spreading on raised racks in the room, and (4) keep in boxes or baskets. Majority (42%) of farmers spread tomatoes on the ground, 29% spread under the market stall in the market (traders), 24% spread on clean surfaces like tarpaulins, polythene, and mats, with a smaller percentage (2%) keep tomatoes in boxes and baskets and (2%) spread tomatoes on raised racks.

On the other hand, the finding show that the most actors (82%) store tomatoes for less than a week while the minority (18%) store tomatoes beyond 1week, but less than two weeks practiced mainly by some traders as they sell in the market.

Figure 23: Methods of storage and duration of storage of tomatoes

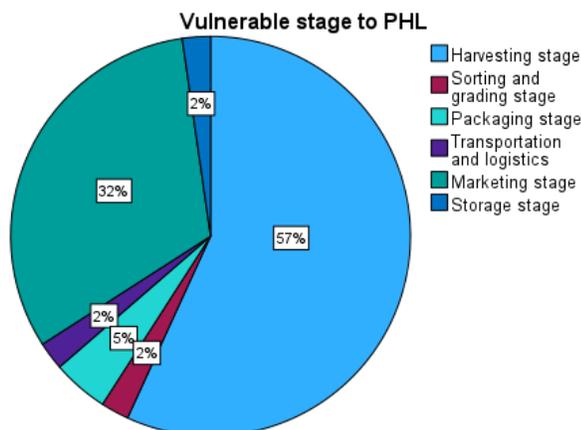


4.6 Perception of the actors on post-harvest losses in the tomato value chain

4.6.1 Vulnerable stage to postharvest losses in the tomato value chain

The findings show that vulnerable stages of postharvest losses are (1) harvesting, (2) sorting, (3) packaging, (4) transport and logistics, (5) storage and (6) marketing. Majority (57%) of respondents mentioned harvesting as the most vulnerable stage in the tomato value chain susceptible to postharvest losses, followed by marketing stage (32%), with only a small minority mentioning storage (2%), sorting (2%), packaging (5%) transport, and logistic stage (2%) as presented in figure 24.

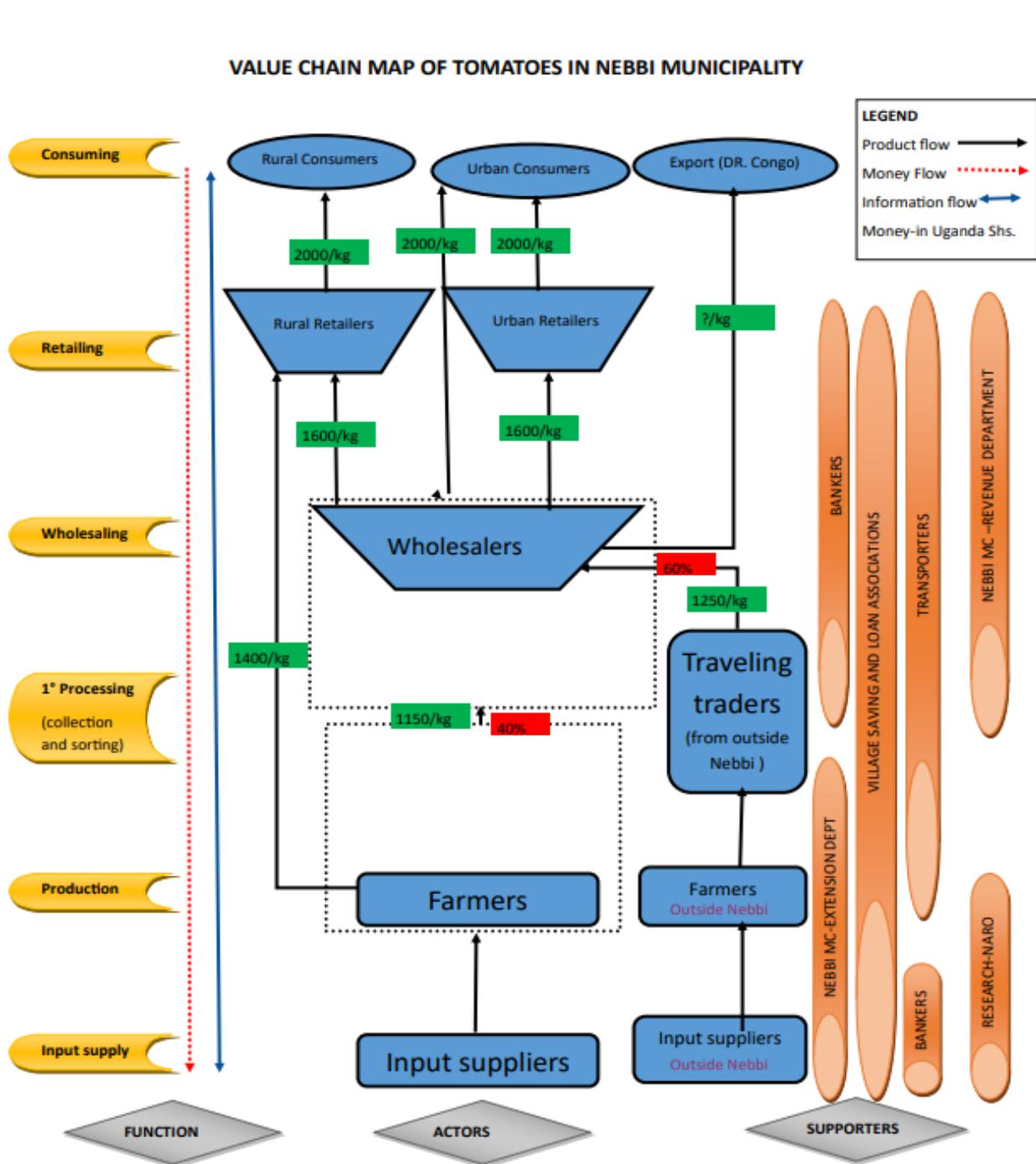
Figure 24: Vulnerable stages of tomato value chain to post-harvest losses



4.7.1 Contribution of Governance structure to postharvest losses along the value chain

The tomato value chain is made up of Actors and Supporters outlined in Figure 25 below.

Figure 25: Tomato value chain map of Nebbi Municipality



Source: Survey data

From figure 25 above it was observed that traders paid higher prices for tomato sold by out-of-region traveling traders than those sold by the farmers from within the Municipality which they attributed to comparison in terms of “quality of the tomatoes” though there is was no formal quality standards for the tomatoes in market.

Stakeholders and their roles along the tomato value chain

Table 3: Stakeholder analysis

STAKEHOLDERS	ROLES
Input suppliers	Sell tomato seeds, agro-chemicals, and equipment. Provide advises to producers after sell of their seeds and agro-chemicals.
Producers	Sourcing of agricultural inputs, growing tomatoes, sorting, transporting to the market and selling to other intermediaries
Traders (wholesaler, retailers, out-of-region traveling traders)	Sorting of tomatoes, buying tomatoes from farmers, selling tomatoes to other intermediaries or consumers, transporting to point of sale.
Consumers	Consumption of the products
Nebbi MC Production and marketing department	Training farmers on production and postharvest handling
Research institutes	Release of varieties, Pest and disease surveillance, regulation of input in the market
Financial institutions	Provision of credit facilities to actors

From the key informant interview, it was reported that Nebbi Municipality tomato value chain is not in organized, with many actors functioning independently of one another and relationships based solely on transactions.

4.7.2 The chain governance

The three primary aspects of value chain governance—chain resilience, robustness, and reliability—were the focus of this study. These were further examined in terms of their impacts on postharvest losses in the tomato value chain and their role in lowering postharvest losses.

Tomato value chain resilience in Nebbi Municipality

The term "chain resilience" describes a system, network, or process's capacity to resist and recover from interruptions, shocks, or unanticipated occurrences while preserving its core operations and limiting adverse effects. According to the study, there is no mechanism in place to manage shocks such as adverse weather or influx of tomatoes from outside the area during those periods, post-harvest losses increase, and dumping becomes the norm.

Although the government agencies are involved in the chain, there is little support directed towards reducing post-harvest losses because the government extension agency is mainly concerned with raising production and ignoring after-harvest operations as reported by the farmers during focus group discussion.

Tomato value chain reliability in Nebbi Municipality

During the focus group discussion with traders, it was mentioned that the regulatory framework necessary to regulate tomato quality requirements is absent from the tomato value chain. Some traders expressed displeasure about a group of traveling dealers and their market agents who set pricing and take advantage of other traders by forbidding them from haggling with wholesalers including checking the quality of tomatoes in the boxes before making payments.

It was also observed during the research process that there are no consumers preferences, some consumers decide to buy low-quality tomatoes (the partially damaged fruits) due to the low prices (UgSh.800/kg) they pay which is a major hindering factor to reducing post-harvest losses. This makes traders to pay less attention to qualitative postharvest losses. Additional, quality of tomatoes is not at all a concern in the market as tomato with a lot of chemicals are allowed in the market as shown in figure 26.

Figure 26:Level of pesticide residues on tomatoes

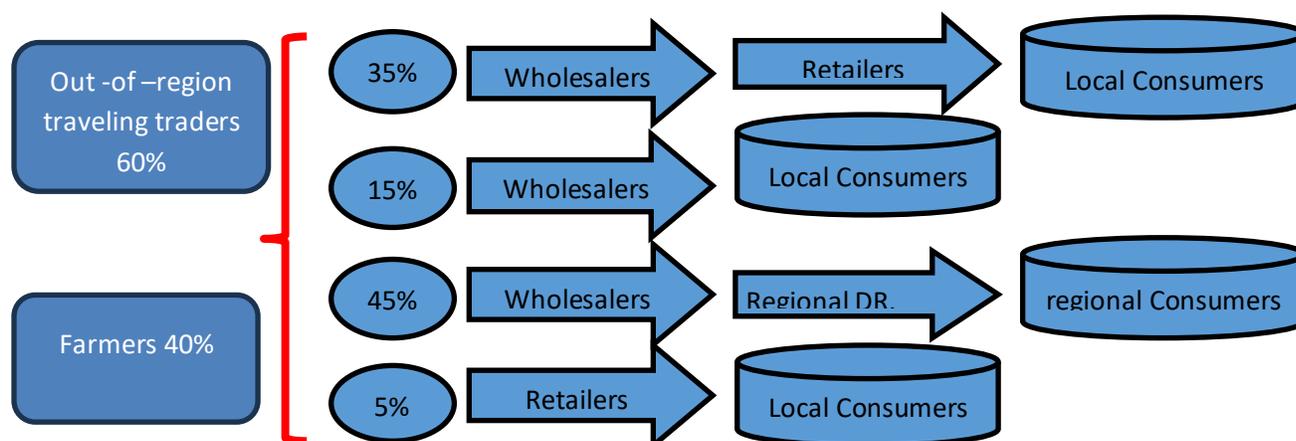


Tomato value chain robustness in Nebbi Municipality

Chain robustness describes a system's or process's capacity to continue functioning and performing even in the face of setbacks, failures, or unforeseen circumstances that could endanger its operations. The farmers mentioned during FGD that they face many challenges in the chain, and their products are bought at the mercy of the wholesalers who decide the prices for them with little room for negotiation for their produce. In addition, during the survey 73% of producers reported that traders decide on the price of the tomatoes while only 27% reported that they negotiate prices with traders and non-reported that they determine the price of their tomatoes. However, the organized traveling traders set the prices for the tomatoes for the wholesalers, making the Nebbi tomato chain weak and less able to withstand competition from other traders from other regions. This was mentioned during the study. There are no contracts in the chain, and all actors only interact while transactions are happening; otherwise, there is no way for them to communicate with one another regarding postharvest losses. All stakeholders need to pay urgent attention to the major threats to the sustainability of the tomato value chain.

4.7.3 Main product flow through the chain

Figure 27: Main product flow in the value chain



4.8. Strategies to reduce postharvest losses along the tomatoes value chain.

From the focus group discussions and key informant interviews, a few strategies that can reduce post-harvest losses in the tomato value chain were identified by the stakeholders. These strategies included the following:

- i. Establish market information centers to provide farmers with up-to-date information on market demand, prices, and trends.
- ii. Formation of tomato producers' and traders' associations and/or cooperatives to for networking of the trade business by improving social capital. This will improve the governance and power balance between the actors.
- iii. Create collaborative platforms where stakeholders can exchange information and collaborate on projects. These platforms can be physical, such as regular meetings, or virtual, like online forums and social media groups.
- iv. Increase training on agronomy of tomatoes (especially focusing on field pest and disease control) to improve the quality of tomatoes at harvest and decrease losses at harvesting stage and after.
- v. Creating more awareness about post-harvest losses and techniques for reducing post-harvest losses along the tomato value chain.
- vi. Training of stakeholders on good post-harvest handling practices and encourage all actors to use recommended packaging containers like wooden boxes (with better design that can reduce fruit crashing) or crates that exert limited impact on packed tomatoes across the whole value chain.
- vii. Advocating for construction of an appropriate storage facility which can provide low temperature to increase the shelf life of tomatoes.

4.9 Analysis of tomato value chain of Nebbi Municipality

A SWOT Analysis was done, and the findings are presented below.

Figure 28: SWOT analysis of tomato value chain

<p>STRENGTHS</p> <ul style="list-style-type: none"> ○ Availability of technical staff in the Municipality ○ Willingness of chain actors to reduce PHL ○ Presence of input suppliers in the Municipality ○ Availability of market for tomatoes (domestic and regional) 	<p>WEAKNESSES</p> <ul style="list-style-type: none"> ○ Absence of quality standards for tomatoes in the market ○ Weak collaboration among value chain actors ○ Limited knowledge on PHL ○ Limited knowledge PHL reduction strategies ○ Lack of appropriate postharvest handling facilities ○ Lack of processing/value addition facility ○ Lack of capacity building programme on PHL for tomato farmers
<p>OPPORTUNITIES</p> <ul style="list-style-type: none"> ○ Presence of research activities by research institute on postharvest loss reduction strategies. ○ Availability of two growing season for tomatoes ○ Presence and willingness of numerous supporters in the tomato value chain to support PHL reduction. ○ Availability of hybrid varieties that are less prone to PHL 	<p>THREATS</p> <ul style="list-style-type: none"> ○ Price fluctuation in the market ○ Incidences of pests and diseases ○ Changing weather patterns ○ Perishability of tomatoes

From the analysis, it is clear that the biggest weaknesses are weak collaboration among actors and limited knowledge on PHL reduction strategies, but it is not insurmountable. We can leverage on the following strengths to ensure success.

- i. Availability of extension staff at the Municipal council. This will help to provide the technical support to the acts in the value chain in reducing post-harvest losses through creation of awareness and training the stakeholders on proper post-harvest handling and use of appropriate tools and containers to minimize the losses.
- ii. Willingness of actors reduce PHL. This will facilitate adoption of recommendation and consequent reduction of post-harvest losses will be achieved.
- iii. Availability of market for tomatoes (domestic and regional). This provides a stable market for local producers and avoid spoilage due to limited market.

- iv. Availability of hybrid varieties that are less prone to post-harvest losses due to the storability attributes and withstanding the harsh weather conditions.

Stakeholders, such as government agencies, farmers, researchers, financial institutions and traders, can use these outputs to build strategies to improve the competitiveness, sustainability, and resilience of the tomato value chain in the face of challenges of post-harvest losses.

5.0 DISCUSSION OF RESULTS

This chapter argues that current post-harvest handling procedures and tactics to lower post-harvest losses in the tomato value chain should be changed.

5.1 Overview of the estimated post-harvest losses along the tomato value chain in Nebbi Municipality.

The findings show that the main form of quantitative loss is fruit decay/rotting, mechanically damaged fruits, and immature fruits that do not ripen. This finding corresponds to the result of Emanu et al. (2017) that indicated that the prevalence of various forms of damages including mechanical damage, disease and insect attack; poor shape and sun burn among others along the value chain.

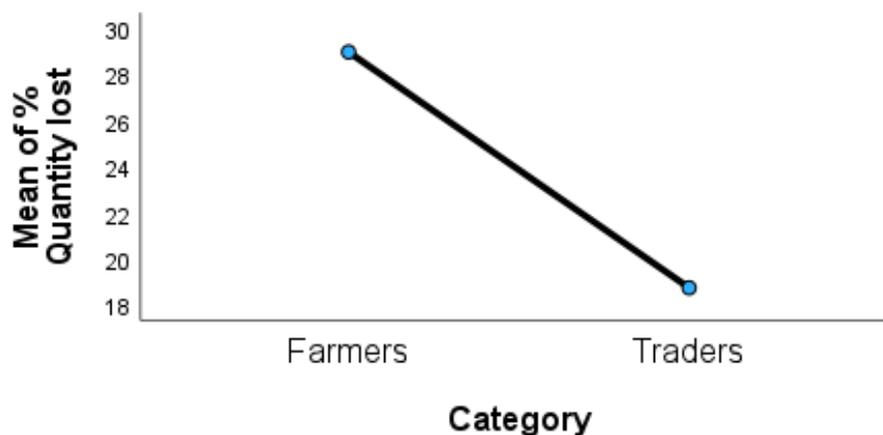
The average loss at the farm level was 28% with the lowest at 5% and the highest at 50% while on the other hand, the average losses at the marketing side was 19% with the lowest at 8% and the highest at 38%. Which corresponds to the finding by Khatun et al. of 2014 who reported the percentage loss to range from 20% to 50%.

During focus group discussion, the traders attributed the difference in losses to the attention farmers give to the tomatoes while in the field especially in terms of management of field pest and diseases, pruning among others and the experience in growing of tomatoes this was supported by the analysis which also reflected that there less loss incurred by actors who have taken more than five years in the tomato value chain. In addition, losses were also higher among the less educated. Given that the majority (71%) of the respondents were semi-literate, more effort should be invested in practical training so that they get appropriate knowledge and skills to manage post-harvest losses.

In addition, post-harvest loss was found to be lower on bigger farms where the owners invested more resources to control losses. This underscores the need for an appropriate level of investment along the value chain. The tendency of small-scale farmers to neglect or underrate the need to invest optimally in production and post-harvest handling should be addressed.

The variety of tomato also matters. Hybrid tomatoes fruits store longer than the non-hybrid varieties because longevity in storage are some of the attributes that they were bred for. These attributes were also mentioned by the traders during FGD that most hybrids tomatoes fruits store longer than the non-hybrid varieties. The survey results confirmed that producers suffer the greater losses than the traders as illustrated in figure 29.

Figure 29: Comparison of mean percentage losses between farmers and traders



The study findings shows that there is limited attention given to the post-harvest losses by the actors due to the limited knowledge on the mitigation measures. At the same time there is no consideration given to loss in quality of tomatoes as any form of tomatoes are bought by the different classes of consumers as long as they have not decayed. It was observed that some consumers preferred to buy the tomatoes of low quality (partially damaged or deformed during the transportation process). This finding corresponds to the findings by Abera et al. (2020). That indicated that post-harvest problems are not given due attention by consumers, and they give no preference to buy produce poorly handled and with less quality.

The variation in losses across the different seasons was attributed to weather conditions, when there is too much rainfall the incidence of field pests and diseases are high. Secondly it was attributed to the volume of tomatoes that flood the market and lead to fall in prices. This corresponds with findings by Khatun et al. (2014).

5.2 Causes of postharvest losses along the tomato value chain

5.2.1 Main causes of postharvest losses along the tomato value chain

The main cause of PHL is pests and diseases (62%) including bacteria, fungi, and viruses, are responsible for substantial postharvest losses in tomatoes. Common diseases such as bacterial soft rot, gray mold, and late blight can lead to significant decay during storage and transportation (Hong et al., 2016 and Lahlali et al., 2017). Therefore, effective disease management practices, including proper sanitation, fungicide applications, and postharvest treatments, are essential to minimize these losses. Destruction starts in the field hence strategies for loss reduction should start in the field.

It is common for farmers to include in the basket fruits that are “not too bad”. This is especially true for fungal infection which results into watery discharges that can easily affect good fruits. Pests cause visible wounds on the flesh of the fruits. If such fruits are not sorted out, they get squashed during transport and therefore reduce the quality and value of the whole container (Obenland et al., 2015; Valero et al., 2019).

The second most important cause of loss at 22% is poor handling. During picking, some farmers do not take care to remove all peduncles (stalks of the fruits) which end up damaging other fruits. Time of harvest is also not taken into account. Fruits are supposed to be harvested when the weather is cool. However, it is common for farmers to harvest at midday when the heat is maximum. This reduces shelf life. Implementing proper harvesting techniques is crucial to minimize postharvest losses (Abera et al., 2020).

Other causes (16%) include excessive heat especially during the dry season which drastically reduces shelf life in the absence of appropriate storage facilities and lack of appropriate knowledge and skills in handling tomatoes after harvest. The finding is consistent with the report by (Wongnaa et al., 2023).

Farmers lack on-farm facilities for disinfecting their tomatoes. Additionally, sorting is not done from the field, resulting in the mixing of good fruits with decaying fruits that may contain germs that accelerates degradation (Arah et al., 2015).

During the focus group discussion, it was reported that the markets are constructed in such a way that don't offer full protection from sunshine and/or rain at the market. This causes significant market losses owing to rotting and physical damage by insects and rat infestation. Sunlight and fruit softening are the primary causes of significant loss-causing spoiling. In addition, fruit exposure to sunshine results in water loss through transpiration, changing the fruit's quality, and fruit rotting from rain, which adds moisture to the fruit (Gudila et al., 2013).

5.3 Tomato varieties

The level of losses was directly related to the varieties of tomatoes grown by farmers. Less losses were reported among farmers who use hybrid seeds compared to those that use non-hybrid seeds and locally and mechanically extracted seeds. This was consistent with finding by Aidoo et al. (2014) who states that cultivation of improved varieties was associated with lower levels of losses. During the focus group discussion, it was mentioned that most starters make use of locally processed seeds and gradually keep changing to improved non-hybrid then eventually move to growing hybrid seed. This was attributed to some key factors as summarized in table below.

Table 4: Comparison between the different type of seeds used by farmers.

Expenditures	Hybrid	Improved non-hybrid seeds	Locally processed
Cost of seeds (50g)	Ugsh. 800,000 (€200)	Ugsh. 30,000 (€7.5)	Ugsh. 10,000 (€ 2.5)
Labor demand	High	Moderate	Low
Yield/acre	3,000kg	1,800kg	1,200kg

Source: FGD

Poor pre-harvest measures, such as adoption of low production techniques (old varieties with short shelf-life are some of the factors that lead to postharvest losses (Zhang Duoyu, 2009). This was also mentioned during FGD that there are low percentage losses among the farmers with more years of experience than those with less years of experience in the tomato value chain. This finding is consistent with that of Kuranen-Joko et al. (2018) which indicated that increase in farming experience reduced the quantity of postharvest losses in tomato.

5.4 Postharvest operations by the actor along the tomato value chain

5.4.1 Harvesting and transportation containers

From the survey findings and FGD, it was discovered that producers and traders use a number of containers which include basins, buckets, woven baskets, and wooden crates. Which is contrary to the findings by Khatun et al. (2014) where the packaging materials used were bamboo case, plastic crate and bamboo case etc.

These containers are inappropriate for harvesting and transportation of tomatoes because they lead to damages and contamination of tomatoes due to limiting the air circulation and increasing heat buildup in containers due to respiration taking place and do not prevent mechanical damages of fruits due to fruit crushing especially when overloaded (Arah et al. 2015). Appropriate packaging materials and advanced packaging systems need to be developed such as plastic baskets to reduce post-harvest losses and increase the shelf life of fresh fruit and vegetables (Aysel, et al., 2019).

From FGD, it was mentioned that different containers are used at different stage, basins are used mostly at harvesting and the tomatoes poured into larger containers such as wooden boxes or buckets. This frequent changing of tomatoes from one container to another, results into mechanical damages and bruising of fruits in addition, the wooden containers have harsh sharp edges that inflict injuries on fruits. This finding corresponds with Arah et al. (2015) and Eskindir et al. (2022).

Figure 30: Packaging containers used in the value chain.



During the FGD the traders reported that fruits at the bottom of the containers experience more damages, and this was caused by the weight of fruits that sit on the top of each other and exert a lot of pressure that result into fruit crushing because of the improper depth of the packaging containers (Arah et al., 2015). To prevent overloads, flat surfaces and shallow containers should be used to reduce mechanical damage and fruit shredding (Tiwari et al., 2020).

Figure 31: Depth of wooden crates



5.4.2 Mode of transport

A variety of transport means are used in the tomato value chain including Humans, motorbikes, and vehicles. In most cases, the players use a combination of these transport means. These modes of transport are not appropriate for transportation of tomatoes which are perishable that require regulated

temperatures and gentle handling. In addition, the bad road conditions (potholes and undulations) also increase injuries to fruits due to bumping and heating of fruits which was mentioned during FGD. Additionally, the motorist who transports the tomatoes have no experience of transporting fresh produces because they are just motorist who offer regular transport to people within the town and the outskirts. Therefore, this results into postharvest losses due to softening of fruit and bruises which facilitates the decay processes.

This finding coincides with that of Arah et al. (2015) who disclosed that one of the main causes of post-harvest losses to most fruits and vegetables, notably tomatoes, is vibration and impact during transportation because of road undulations. Poor roads, a lack of suitable transportation, and ineffective logistics management make it difficult for underdeveloped nations to effectively preserve perishable crops. Additionally, in these nations, untrained, uneducated employees who typically handle goods carelessly do loading and unloading activities, tomatoes are harmed mechanically as a result (Aysel et al. 2019).

It was mentioned during FGD that tomatoes are transported mainly by humans from the field and delivered to points which can be accessed by either motorcycles or vehicles because most paths to the field are not motorable. This increases the time the tomatoes are exposed to more heat that increases the rate of respiration resulting into faster ripening of fruit thus leading to spoilage. This corresponds to Arah et al. (2015) findings.

5.4.3 Storage of tomatoes

The producers store the tomatoes temporarily for less than 7 days as the aggregate while traders also store temporarily for less than 14 days as they sell by spreading them in their house and under the market stall respectively (figure 32). This finding corresponds to the findings by (Khatun et al., 2014). Farmers have no proper facilities for storage of highly perishable tomatoes. Therefore, there are huge losses of fresh tomatoes every year due to this (Tiwari et al., 2020).

The storage facilities do not offer the right temperatures to the fruits which implies the physiological processes continue taking place that leads to deterioration of fruits and thus losses. Besides these types of storages also expose the tomatoes to insect damage during the process of storage. The producers are forced to cover the tomatoes while in storage that further increases the rate of heat buildup thus postharvest losses.

Both at the production side and marketing side, the players disclosed that they sort while cleaning the tomatoes with clothes after every two days by sifting the fruits to avoid the fluid exuding from rotting fruits from coming into contact with healthy fruits. This finding is contrary to the research findings by Arah et al. (2015) who disclosed that African farmers do not sort rotten fruits from healthy ones which may be carrying disease causing pathogens that result into high deterioration. This practice of frequent turning of the fruits results into mechanical damages fruits.

Figure 32: Methods of storing tomatoes.



5.4.4 Marketing of tomatoes

The research findings show that during times of marketing oversupply in Nebbi Central market, some traders exported tomatoes to the Democratic Republic of Congo. Tomatoes are also sold in rural markets including Namwodho and Thatha markets in Thatha Division. The producers mentioned that during the primary growing season for tomatoes, which runs from mid-October to mid-December, there is typically over production that leads to a high supply of tomatoes on the market resulting into increase in post-harvest losses and growers lose more tomatoes during the major seasons. This result is consistent with that of Khatun et al. (2015). On the other hand, unreliable market has a positive relationship with the proportion of postharvest loss (Wongnaa et al., 2023). There is also a paucity of market knowledge and insufficient producer-consumer dialogue. Therefore, to avoid a complete loss, producers must sell their yield at very cheap prices (Arah et al. 2015).

5.5 Perception on postharvest losses

The actors in the value chain had varying perceptions about the extent of postharvest losses in the tomato value chain, but because the chain is not organized, they are unaware of the losses at all stages, except for the ones in which they are directly involved. Additionally, from the survey, the finding show that 71% of the value players did not go beyond primary level of education this implies they have limited knowledge pertaining postharvest and are not able to critically analyze the cause of postharvest losses in the chain.

It was also mentioned during FGD that the Production and Marketing department only concentrates on educating farmers about agronomic practice and pays little attention to addressing issues of post-harvest losses and only 16% of respondents reported that they received advisory services related to tomatoes. Despite the extent of the post-harvest losses along the tomatoes value chain, 90% of producers are willing to increase level of tomato production.

5.6 Governance structure along the tomato value chain

5.6.1 Actor relations

From the key informant interview, it was mentioned that the chain relationships are merely informal; the players only sparingly exchange information regarding the quality of tomatoes and consumer preferences of when conducting transactions before splitting off. The participants in the value chain for tomatoes are unaware of the value chain approach and view one another as independent businesses.

The producers are most times affected by landlords where they hire land for production especially near water sources. After one season of good harvest, they are made to abandon their field because the landlords refuse to offer their land for hire. This forces the farmers to produce only during main production season that depends on rainfall that lead to glut in the market hence the increase in losses.

The out-of-region traveling traders are organized into an association called Kampala Tomato Traders Association who transport tomatoes in trucks under the guidance of their leaders. These traveling traders keep all information to themselves and deal with only their agents and the wholesalers who buy from them are not allowed to check for the quality of tomatoes before making payment even after finding a lot of damage tomatoes the traders in Nebbi market should be the ones to bear the losses. This power imbalance has a great impact on the reduction of post-harvest losses.

5.6.2 Chain co-ordination

In Nebbi Municipality tomato value chain, wholesalers are the chain coordinators. They always have access to market information, which smallholder farmers do not. They have connections with the retailers within the Municipality and the local farmers supplying Nebbi market with tomatoes. The finding show that they are the major determinant of prices for tomatoes in the tomato value chain although they face challenges from out-of-region traveling traders to fix their own prices and dictate on the quality of tomatoes they deliver to the market unlike the farmers. This has a negative impact on the reduction of poor-quality tomatoes in the market.

Wholesalers have a lot of power, being the main players in the supply chain, they sometimes establish the pricing at which they buy from farmers and sell to retailers. Because they participate in the collecting of tomatoes in the central market and collaborate closely with out-of-traveling traders, wholesalers have the most control over the tomato value chain. The unequal power in the chain affects the producers because they have no appropriate storage facilities, and they have to sell at low prices. This finding corresponds the finding by Emanu et al. (2017) who reported that lack of ability and facilities to store tomato for long, makes wholesalers put pressure on producers to sell at low prices. This reduces the ability of producers to afford the expensive inputs for the next growing season.

5.6.3 Information flow in the value chain

From the KII it was confirmed that value chain's information flow is not efficient and is restricted to produce pricing and the meager amount of local media information on produce prices, which gives wholesalers who work with other traders from other markets an advantage. Small-scale producers frequently don't know tomato prices or potential in other marketplaces (Zhang Duoyu, 2009). The producers end up selling their tomatoes for low prices (Ugsh.1150/kg €0.29/kg), which tends to deter them from paying more attention to their tomatoes in the field and after harvest because they believe they are spending more money and earning less. This finding corresponds to that by Khatun et al. (2014) who reported that producers occasionally keep the crop in the field without harvesting in the years when the demand for the crop is very low and marketing is difficult.

In addition, limited technical knowledge, has led to farmers being exploited by traders and fall prey buying low-quality seeds extracted from rotting or damaged tomato fruits. According to the survey, only 24% of respondents mentioned that they received technical information from the Government extension workers and 76% of respondents indicated they only received market information.

5.6.4 Quality standard of tomatoes

According to the research findings, there is little attention given to quality standard in the market, both at the upstream and downstream in the supply chain and tomatoes products marketed by the sub-sector is below the standards and the chemical residue is high (Zhang Duoyu, 2009). Consumers lack quality preferences for tomatoes. Both the traders and growers separate tomatoes into healthy and rotting/decaying fruit, but there is no grading of the fruits according to sizes, shapes, and colors.

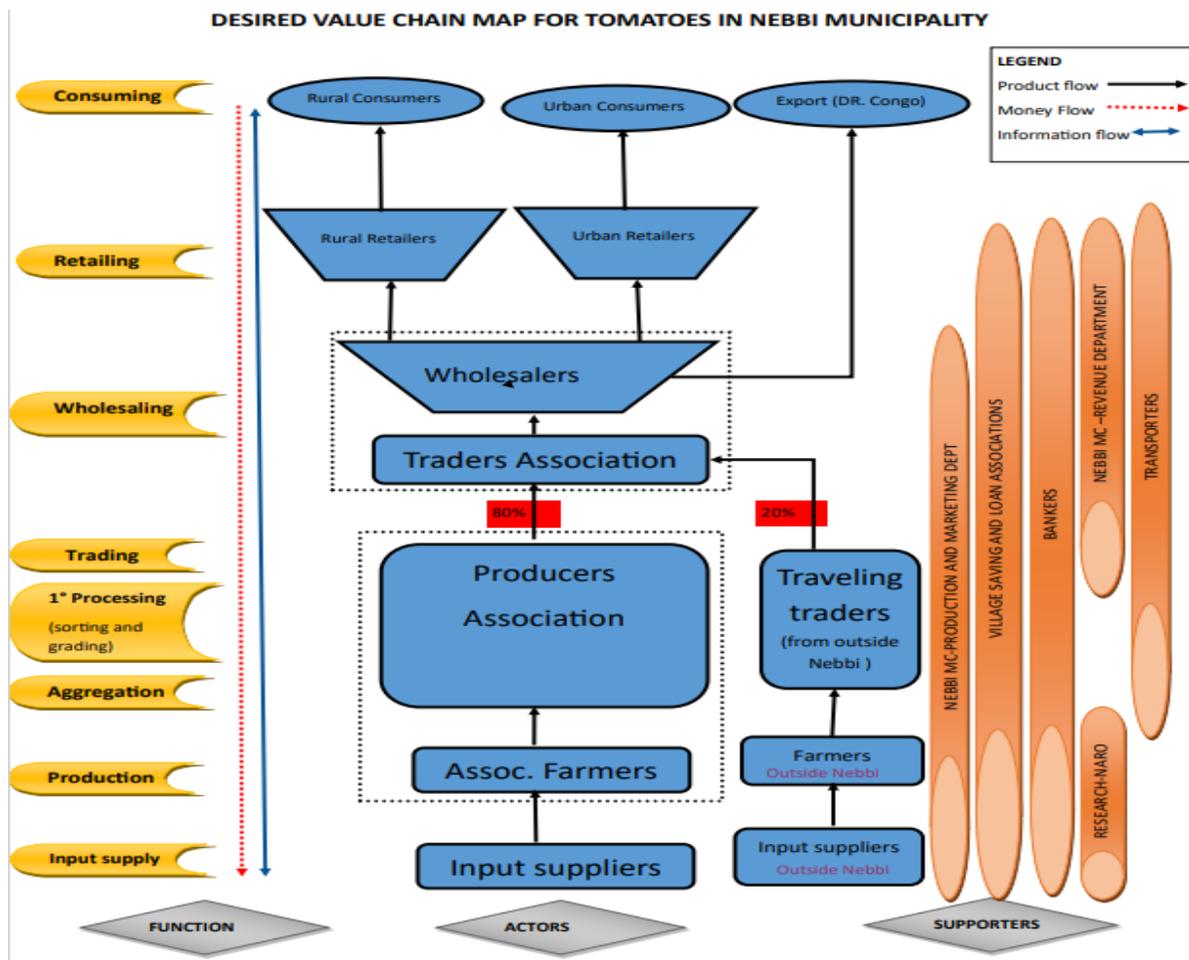
On the other hand, the vendors prefer to buy tomatoes which are stained with fungicide because they perceive that they producers adequately applied fungicides and this would extend the shelf life of the tomatoes. This has prompted some producers (20%) to apply fungicides to their tomatoes while in storage prior to selling to the traders. When asked about the health effect, they had no knowledge about this kind of misuse of fungicide on human health.

Quality standards remains a big challenge in the value chain. This issue is recommended for another research in order to come up with possible recommendations to address it.

5.6.5 Value chain governance

The producers and the traders should organize into associations or cooperatives in order to improve the tomato value chain and develop the intended business model. Secondly, to improve the quality of tomatoes, the value chain should be upgraded through vertical and horizontal integration, which will help reduce food loss and improve profits for small-scale farmers (figure 33).

Figure 122: Desired tomato value chain for Nebbi Municipality



5.7 Reflection as a researcher.

I had a topic in mind when I started my research, but the lecturer offered some concepts during pitching that I had to consider. I kept the enterprise, though, and after reflecting on the nature of the community where I work, I realized that postharvest is a real and significant challenge for smallholder farmers. After speaking with my commissioner, he agreed to provide the support I would need to carry out the research.

After completing all of these steps, I sat down to work on the problem statement with my peers and then emailed it to my supervisor for additional guidance. My supervisor's approval of the problem statement made me feel relaxed and encouraged me to move forward with the development of my proposal. I had been a little bit concerned about the input I would get from him.

Even though I conducted research as an undergraduate, once I became aware of the conceptual framework, the nature of research was somewhat different. The conceptual framework for my research was a bit difficult to build; I had to sit down with two peers, and we had days of conversation before I could do so, even after reading a number of literatures on the subject. I came to the realization that I needed

sufficient background knowledge on the subject before I could start creating a conceptual framework to guide my research.

It was difficult to choose the research method to be used, but after developing the conceptual framework and research question, it became evident that both qualitative and quantitative data would be needed. As a result, I was able to choose the method to be utilized throughout the research process. I made the decision to use the survey, key informant interviews, focus groups, and observation techniques. My supervisor's approval of my methodology after I submitted the project provided me even more confidence to move forward with my research.

Since the research was conducted during the growing season, making appointments with respondents was challenging. However, I had to use some youth to contact the tomato farmers and let them know about the planned visit in order to guarantee that I would get the respondents on the scheduled days. In order to successfully conduct the FGD, the trader had to choose a weekend when their kids are at home to help with household chores. This was somewhat difficult to schedule because the farmers had different programs, but I had to consult with them and come to an agreement on a date and time. On the basis of their understanding of the value chain and prior experience with tomatoes, the participants were specifically chosen. Even though the exercise was a little stressful, it was completed, and all the required data was gathered despite the traveling traders' refusal to take part in the phone poll for reasons they knew only to themselves.

After the data gathering was complete, there was one more hurdle to clear: transcription of the data and categorization of the responses to give the data collected meaning. In order to construct the meaning of the facts gathered and continually compare with the literatures, I had to sit down and read additional literature. After thus many days of investigation, I was able to produce the results and provide the conclusions. These discoveries aided me in drawing conclusions and formulating recommendations for the Nebbi Municipality's underdeveloped tomato value chain. My understanding of postharvest handling procedures and value chain losses has significantly increased as a result of the entire study, and I am confident that these newfound skills and knowledge will help me provide better service, mentor my department's staff on value chain principles, and promote community growth.

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Postharvest loss is still significant challenge in the tomato value chain in Nebbi municipality with an estimated post-harvest loss of 159,915kg and estimated monetary loss of UgShs. 228,974,040, but it has mostly gone unattended to by stakeholders due to a lack of information about the magnitude of the losses. Reducing the post-harvest losses to 15% on the production side could save up to UgShs. 31,906,290/= and reducing postharvest losses on traders' side to 10% could save up to UgShs. 75,909,225.6/= which will help to combat poverty, provide food security, and invest in preserving the quality of the produce.

6.1.1 Causes of postharvest losses in tomato value chain

The losses occur in form of fruits rotting, mechanical damages and immature fruits that fail to ripen which are mainly caused by pests and diseases, mechanical damages to fruits due poor postharvest handling, overloading during transportation, inappropriate means of transport that results into crushing of fruits, use of inappropriate containers that lead to cutting and bruising of fruits among others, lack of appropriate storage facility that expose the fruits to harsh weather which accelerate degradation and pest destruction and the limited knowledge on postharvest handling.

6.1.2 Chain Governance

According to the research findings, there is weak chain governance, with traders having significant influence over producers and organized traveling traders taking advantage of wholesalers by limiting their access to market information and operating through two agents to establish prices for other wholesalers. This has strong associations with chain-wide tomato losses.

6.1.3 Current postharvest handling practices in the value chain

The study's findings indicate that a variety of techniques are employed by the actors to lessen post-harvest losses. These techniques include sorting tomatoes to remove diseased fruits and prevent further infection, using fungicides intended for pre-harvest, and packaging tomatoes in wooden boxes. Despite application of these techniques, there are still significant losses experienced along the value chain with average losses of 28% and 19% on production and marketing side respectively which translates into very high financial losses to the value chain actors.

Additionally, the actors' perceptions of postharvest losses suggested lack of information about the losses that occur along the value chain, coupled with inadequate communication among the stakeholders are some of the hindering factors to postharvest loss reduction.

6.2 RECOMMENDATIONS

Postharvest losses in the tomato value chain impacts significantly on food security and economic sustainability. Implementing effective strategies to minimize these losses is crucial. The following are some suggestions to lessen post-harvest losses along the tomato value chain:

- Training the producers on proper harvesting techniques to minimize physical damage to tomatoes such as harvesting at the right stage of maturity to prevent bruising and reduce susceptibility to decay. In addition, conduct training programs and workshops for farmers, traders, and other stakeholders on

best practices for postharvest handling, storage, and transportation to raise awareness and knowledge.

- Sensitization of farmers on use of appropriate tools for harvesting, such as sharp knives or scissors, to avoid unnecessary damage. Additionally, use appropriate packaging materials that protect tomatoes from physical damage and provide proper ventilation to prevent moisture buildup and decay.
- Educating farmers on sorting and grading to facilitate separation of tomatoes based on size, color, and quality. This will ensure that only high-quality tomatoes reach the market, reducing the chances of lower-grade tomatoes getting wasted.
- Training the stakeholders in the tomato value chain on safe food handling which should include use of clean, well-maintained, and proper ventilated vehicles for transportation, avoiding overloading and rough handling of tomatoes.
- Construction one cold storage facility in the market and encourage adoption of cold chain logistics to maintain low temperatures throughout the supply chain, from farm to market. This will help to preserve the quality and extend the shelf life of tomatoes.
- Organizing a periodic trade Fair in the Municipality that will bring together the different actors in the value chain in order to share contacts and facilitate market linkages.
- Providing in time market information, demand forecast, and price trends to farmers to help them make informed decisions about when and how much to harvest, preventing overproduction.
- Establishing a multi-stakeholder platform that will brings together different stakeholders such as farmers, researchers, government agencies, NGOs, and private sector to enable them to collaborate and collectively address postharvest challenges in the chain and implement effective solutions.
- Encouraging farmers to grow hybrid tomatoes varieties because they are less prone to postharvest losses.

Postharvest losses can be lowered considerably if stakeholders in the tomato value chain adopt one or a combination of the above recommendations, this will lead to an increase in financial rewards, and support more sustainable agricultural systems.

ISSUES

Research should be done on quality standards of tomatoes and the willingness of consumers to pay for high quality tomatoes.

REFERENCES

- Isaac Kojo Arah, Ernest Kodzo Kumah, Etornam Kosi Anku, Harrison Amaglo, 2015. An Overview of Post-Harvest Losses in Tomato Production in Africa: Causes and Possible Prevention Strategies, *Journal of Biology, Agriculture and Healthcare*, 5 (16)
- M. Khatun, M. R.Karim, S. Khandoker, Tanvir.M.B.Hossain and S. Hossain, 2014. Post-harvest loss assessment of tomato in some selected areas of Bangladesh, *International journal of business, social and scientific research*, 1(3) pages 209-218
- Famuyini Monday John, Olalusi Ayoola Patrick, Sedara Adewale Moses, 2020. Effect of maturity stage on quality and shelf life of tomato (*lycopersicon esculentum* mill) using refrigerator storage system, *Eurasian Journal of Agricultural Research*, 4(1), pp: 23-44
- Injila Tiwari, Kabita Kumari Shah, Subina Tripathi, Bindu Modi, Jiban Shrestha, Hari Prasad Pandey, Bishnu Prasad Bhattarai and Binayak Prasad Rajbhandar, 2020. post-harvest practices and loss assessment in tomato (*Solanum lycopersicum* L.) in Kathmandu, Nepal, *Journal of Agriculture and Natural Resources*, 3(2), pp 335-352
- Gudila A. Kereth, Monica Lyimo, Hadijah A. Mbwana, Richard J. Mongi and Carlyne C. Ruhembe, 2013. Assessment of Post-harvest Handling Practices: Knowledge and Losses of Fruits in Bagamoyo District of Tanzania, *Food Science and Quality Management*, 11
- Davuluri G, Isaac O1, Kiryowa M, Akullo R, Ajero M, Logoose M, Otim A, Masika F, Mundingotto J, Matovu M and I Ramathani, 2021. Practices and constraints of tomato production among smallholder farmers in Uganda, *African Journal of Food Agriculture, Nutrition and Development*, 21 (5).
- Sharon. M. Tusiime, 2020. Tomato seed value chain analysis and seed conditioning among seed companies in Uganda, *International Food and Agribusiness Management Review*: 23 (4)- Pages: 501 – 514
- Tadesse, E.E., Assaye, H., Delele, M.A., Fanta, S.W., Huluka, D.F., Alemayehu, M., Alemayehu, G. and Adgo, E., 2022. Assessing tomato postharvest loss through the supply chain using load tracking technique in Northwest Ethiopia', *International Journal of Postharvest Technology and Innovation*, 8 (4), pp.360–381.
- Abera, Gezai, Ali M. Ibrahim, Sirawdink Fikreyesus Forsido, Chala G. Kuyu, 2020. Assessment on post-harvest losses of tomato (*Lycopersicon esculentem* Mill.) in selected districts of East Shewa Zone of Ethiopia using a commodity system analysis methodology', *Heliyon*, Elsevier Ltd, 6(4)
- Aggrey Atuhaire, David Ocan and Erik Jørs, 2016. Knowledge, Attitudes, and Practices of Tomato Producers and Vendors in Uganda, *Advances in Nutrition & Food Science*, 1(1).
- Hong, J. K., Choi, H. W., Hwang, I. S., & Hwang, B. K., 2016. Role of a novel pathogenesis-related protein, Zrp3, in the control of hypersensitive cell death caused by pathogen infection and abiotic stresses. *Molecular Plant Pathology*, 17(3), 251-264.
- Lahlali, R., Hijri, M., & Barreda, D. R., 2017. Ascorbate-glutathione cycle and stress tolerance in tomato plants subjected to tomato yellow leaf curl virus (TYLCV) infection. *Plant Physiology and Biochemistry*, 112, 172-179.

- Aysel Elik, Derya Kocak Yanik, Yildiray Istanbulu, Nurcan Aysar Guzelsoy, Arzu Yavuz, Fahrettin Gogus, 2019. Strategies to Reduce Post-Harvest Losses for Fruits and Vegetables, *International Journal of Scientific and Technological Research* 5(3)
- Adenuga, A.H., Muhammad-Lawal, A., & Rotimi O.A., 2013 Economics and Technical Efficiency of Dry Season Tomato Production in Selected Areas in Kwara State, Nigeria. *Agris on-line Papers in Economics and Informatics* 5(1): 11-19.
- Obenland, D., Collin, S., Sievert, J., & Arpaia, M., 2015. Understanding the impact of maturity, handling, and storage on tomato flavor. *Postharvest Biology and Technology*, 107, 81-90.
- Valero, D., Díaz-Mula, H. M., Zapata, P. J., Castillo, S., Guillén, F., Martínez-Romero, D., & Serrano, M., 2019. Postharvest treatments with nitric oxide to reduce chilling injury and improve overall quality of tomatoes stored at cold temperatures. *Food and Bioprocess Technology*, 12(11)
- Singh, A. K., Chauhan, S. V. S., & Verma, O. P., 2017. Studies on postharvest losses of fruits and vegetables in India: A review. *Agricultural Reviews*, 38(2), 113-119.
- Zhang, M., Li, D., Li, X., Gao, F., & Zhang, Y., 2019. Recent advances in postharvest technologies to extend the shelf life of fresh fruits and vegetables. *Critical Reviews in Food Science and Nutrition*, 59(4), 505-521
- G. Siam, T. Abdelhakim, 2018. Analysis of the tomato value chain in Egypt and establishment of an action plan to increase its efficiency, Research Report, pp.118
- FAOSTAT Online Statistical Database of the Food and Agriculture Organization of the United Nations. able online: <http://www.fao.org/faostat/en/#data/TP> (accessed on 24 May 2023).
- Zhang Duoyu, 2009. Assessment of factors influencing unstable and low prices for small-scale farmers in the tomato value chain in the changji district, china, Wageningen.
- Bezabih Emanu, Victor Afari-Sefa, Ngoni Nenguwo, Amsalu Ayana, Dereje Kebede and Hedija Mohammed, 2017. Characterization of pre- and postharvest losses of tomato supply chain in Ethiopia, *Agriculture & Food Security*: DOI 10.1186/s40066-016-0085-1
- Kuranen-Joko, D. N., & Liambee, D. H., 2018. Determinants of postharvest losses among tomato farmers in gboko local government area of Benue State. *International Journal of Agricultural Research and Food Production*, 3(4)
- Camillus Abawiera Wongnaa, Emmanuel Dapaah Ankomah, Temitope Oluwaseun Ojo, Emmanuel Abokyi, Gifty Sienso and Dadson Awunyo-Vitor, 2023. Valuing postharvest losses among tomato smallholder farmers: evidence from Ghana, *Cogent Food & Agriculture*
- Adel A. Kader, 2002. Postharvest Technology of Horticultural crops, Third Edition, University of California.
- Aidoo, R. A, Danfoku, R., & Mensah, J. O., 2014. Determinants of postharvest losses in tomato production in the Offinso North district of Ghana. *Journal of Development and Agricultural Economics*, 6(8), 338–344, <https://www.researchgate.net/publication/287343539>

ANNEXES

ANNEX 1

Planned activities	Implementation timeline in months and weeks																		
	May		June				July				August				September				
	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Desk study and proposal development		■	■	■	■														
Submission of proposal					■														
Pitching						■													
Traveling to home country							■												
Data collection planning							■												
Stakeholders' interviews								■	■										
Administering questionnaires								■	■										
Focus group discussion										■									
Data processing										■	■								
Data analysis												■							
Thesis writing													■	■					
Submission of thesis														■	■				
Thesis defense																■			
Graduation																		■	

Source: Author

QUESTIONNAIRE: FARMERS

Dear respondent

This is research on postharvest losses along tomatoes value chain in Nebbi Municipality by a master student of van Hall Larenstein University of Applied Sciences studying Agricultural Production Chain Management. I hereby request your cooperation during the data collection and the outcome of the results will be shared with you after the research. This questionnaire takes about 15-20minutes and all the information gathered will be confidential and only used for the purpose of research.

Section A:

1. Age of respondents
.....
2. Sex of respondent
 Female Male
3. What is your highest level of education?
 Informal educ Primary Secondary Tertiary Institution University
4. Name of Division.....

Section B:

1. What was the size of your tomato farmland in the last 12 months?
 Below 0.5 acres 0.5-1.5acre 1.5 - 2acres 2-3acres above 3 acres
2. What tomato varieties do you grow?
 Local varieties Improved (Open Pollinated Varieties) Hybrid varieties
3. How many years have you been growing tomatoes?
 Less than 1 year 1-3years 3-5years above 5years
4. How do you determine the maturity of your tomatoes before harvesting?.....
5. What time of the day do you harvest your tomatoes?
 Morning hours Late afternoon Any time of the day
6. What do you use to collect tomatoes from the field?
7. What do you use to pack tomatoes before transporting to the market?.....
8. What means do you use to transport tomatoes to the market?.....
9. Where do you sell your tomatoes?.....
10. To whom do you sell your tomatoes?
11. What quantity (kilograms) of tomatoes did you harvest in the last 12 months?.....

12. What quantities (kilograms) of tomatoes did you sell in the last 12 months?.....
13. What percentage quantity of tomatoes did you lose in the last 12 months (estimates)?.....
14. What was the causes of the losses?
15. What measures did you take to reduce the losses?.....
16. How do you store your tomatoes?
17. How long do store the tomatoes before selling?.....
18. What kind of support do you receive related to postharvest losses of tomatoes?.....
19. Who determines the price of your produce?
- You You and traders Traders alone
20. What kind of interactions do you experience most in the value chain?
- Sharing technical knowledge Partnerships Market information
- Regulation and standards in the chain Financial support
21. Do you desire to increase your production?
- Yes No
22. If yes, what is the level of your desire?
- Low Medium High Very high
23. On a scale of 1 to 5, where 1 represents "Very Low" and 5 represents "Very High," how would you rate the level of postharvest losses in the tomato value chain?
- Very Low Low Moderate High Very High
24. What is the main factor that contributes to your postharvest losses in the tomato value chain?
- Poor handling and transportation practices
- Lack of proper storage facilities
- Insufficient access to market information
- Inadequate infrastructure for processing and packaging
- Lack of training and awareness among farmers and stakeholders
- Pests and diseases affecting tomato quality.
- Climate change and unpredictable weather conditions
- Other (please specify):
25. In your opinion, which stage of the tomato value chain is most vulnerable to postharvest losses?
- Harvesting stage Sorting and grading stage Packaging stage
- Transportation and logistics stage Processing stage Marketing stage
- Other (please specify):

ANNEX 3

QUESTIONNAIRE: TRADERS AND TRANSPORTERS

Dear respondent

This is research on postharvest losses along tomatoes value chain in Nebbi Municipality by a master student of van Hall Larenstein University of Applied Sciences studying Agricultural Production Chain Management. I hereby request your cooperation during the data collection and the outcome of the results will be shared with you after the research. This questionnaire takes about 15-20minutes and all the information gathered will be confidential and only used for the purpose of research.

Section A:

1. Age of respondents
.....
2. Sex of respondent
 Female Male
3. What is your highest level of education?
 Informal educ Primary Secondary Tertiary Institution University
4. Location of respondent.....

Section B:

1. What role do you play in tomato value chain?
 Production Collection Transportation Trading Primary processing
2. If trader, are you
 Wholesaler retailer
3. How many years have you been in that role?.....
4. What do you use to pack tomatoes before transporting to the market?.....
5. What transport means do you use to transport tomatoes to the point of sell?.....
6. Where do you sell your tomatoes?.....
7. To whom do you sell your tomatoes?.....
8. What quantities (kilograms) of tomatoes did you buy in the last 12 months?.....
9. What quantities (kilograms) did you sell in the last 12 months?.....
10. What percentage quantity of tomatoes did you lose in the last 12 months (estimates)?
.....
11. What were the causes of the losses?

12. What did you do to reduce the losses?.....

13. How do you store your tomatoes?
14. How long do you store tomatoes before you sell all the stock?.....
15. What support do you get on tomatoes?.....
16. How do you obtain market information?.....
17. Who determines the price of tomatoes?
 Farmer Farmer and traders Traders alone
18. Do you desire to increase your trade in tomatoes?
 Yes No
19. If yes, what is the level of your desire?
 Low Medium High Very high
20. What kind of interactions do you experience most in the value chain?
 Sharing technical knowledge Partnerships Market information
 Regulation of standards in the chain Financial support
21. On a scale of 1 to 5, where 1 represents "Very Low" and 5 represents "Very High," how would you rate the level of postharvest losses in the tomato value chain?
 Very Low Low Moderate High Very High
22. What factors do you believe contribute to postharvest losses in the tomato value chain?
 Poor handling and transportation practices
 Lack of proper storage facilities
 Insufficient access to market information
 Inadequate infrastructure for processing and packaging
 Lack of training and awareness among farmers and stakeholders
 Pests and diseases affecting tomato quality.
 Climate change and unpredictable weather conditions
 Other (please specify):
23. In your opinion, which stage of the tomato value chain is most vulnerable to postharvest losses?
 Harvesting stage Sorting and grading stage Packaging stage
 Transportation and logistics stage Processing stage Marketing stage
 Other (please specify):

24. Where do you source tomatoes?

- Farmers within Municipality Traveling traders Both from farmers and traveling traders
 specify.....

Thank you for participating in the research.

ANNEX 4

KEY INFORMANT INTERVIEW

Interview check list

1. Introduction
2. Opening remarks
3. Brief about the tomato industry
4. Key stakeholders in the tomato industry
5. Roles of the different stakeholders
6. Relationships between stakeholders in the value chain
7. Mode of market information sharing in the tomato value chain
8. Causes of tomato postharvest losses in Nebbi Municipality
9. Postharvest loss reduction practices in tomato value chain.
10. Affordable (Potential) postharvest loss reduction strategies

Perception

11. On a scale of 1 to 5, where 1 represents "Very Low" and 5 represents "Very High," how would you rate the level of postharvest losses in the tomato value chain?

Very Low Low Moderate High Very High

ANNEX 5 CALCULATION OF LOSSES

Farmers

Number of respondents =30

Estimated total population of tomato farmers in the municipality =120

Average production per farmer = 1,778.5kg (from survey data)

Total production $120 \times 1778.5 = 213,420$

Average price per kilogram is 1,150/= (survey data)

Value of tomato produced is $213,420 \times 1150 = 245,433,000$

Reported percentage loss of 28%

Quantity lost is $213,420 \times 0.28 = 59,757.6\text{kg}$

Monetary value of postharvest loss by farmers $59,757.6 \times 1150 = \text{UgShs. } 68,721,240/=$

Of the total production only 95% is sold and 5% is for consumption. Therefore, only 202,749kg is sold to the traders which accounts for 40% of supply in the market.

Traders

Quantity bought from farmers is 202,749kg.

Quantity from out-of-region traveling traders is 324,398.4kg which accounts for 60%

Therefore, estimated total quantity bought by traders is 527,147.4kg

Average price per kilogram is 1,600/=

Total value of tomatoes bought is $527,147.4 \times 1600 = 843,435,840/=$

Reported loss of 19%

Total quantity lost by traders is $527,147.4 \times 0.19 = 100,158\text{kg}$.

Monetary value of postharvest losses by traders $1600 \times 100,158\text{kg} = 160,252,800/=$

Total

Total quantity lost in the value chain is $59,757.6\text{kg} + 100,158\text{kg} = 159,915.6\text{kg}$

Total monetary losses are $68,721,240 + 160,252,800 = 228,974,040$

ANNEX 6

Photos of postharvest losses at the market



Postharvest losses in the market



Tomatoes displayed for sale in the market.

PHOTOS



One farmer with his seedlings in the nursery bed



One farmer with his tomatoes in his store