ECONOMIC ANALYSIS OF POST-HARVEST LOSSES OF SELECTED VEGETABLES IN NOTHERN UGANDA

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NOVEMBER 2023

DECLARATION

I, Neema Kasilo John, hereby declare to the best of my knowledge that the work presented in this dissertation is my original work and has not been presented or submitted for consideration of any certification at this or to any academic institution of higher learning or University. This work has been complemented by referenced sources duly acknowledged.

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DEDICATION

I dedicate this research work to my beloved mom Rosina Silla and siblings Theresia Kasilo and Mariam Kasilo.

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LIST OF ABBREVIATIONS / ACRONYMS

ANOVA	Analysis of Variance
AUC	African Union Commission
EAC	East African Community
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GUREC	Gulu University Research and Ethics Committee
KG	Kilograms
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MLR	Multiple Linear Regression
OLS	Ordinary Least Square
PHH	Postharvest Handling
PHL	Postharvest Losses
SSA	Sub-Saharan Africa
UBOS	Ugandan Bureau of Statistics
UGX	Ugandan Shillings
UNHS	Ugandan National Household Survey
VIF	Variable Inflation Factor
WHO	World Health Organization of the United Nations
WWF	Word Wide Fund

ABSTRACT

Vegetables constitute an important part of the human diet due to their high nutritional value including vitamins, minerals, and dietary fiber. However, high moisture content makes vegetables highly susceptible to Post Harvest Losses (PHL) which result in reduced incomes and increased risk of food insecurity for vegetable value chain actors. There is inadequate empirical data on the magnitudes and distributions of these losses. This study sought to quantify economic PHL in tomatoes, kale, and carrots for farmers, wholesalers, and retailers, estimate the factors driving these losses, and ascertain the determinants of the choice of postharvest handling techniques and practices in Gulu district and Gulu city of northern Uganda. Data were collected from 240 respondents using random and purposive sampling and analyzed using descriptive statistics, multiple linear regression, and Multivariate Probit. The results revealed that economic PHL were highest in tomatoes; Ugx 311,444 per farmer per season, Ugx 59,357, and Ugx 29,852 per actor per week for wholesalers and retailers respectively. Carrot losses were Ugx 320,953 per farmer per season, Ugx 16,678, and Ugx 9,681 per actor per week for wholesalers and retailers respectively. Kale losses were worth Ugx 448,668 per farmer per season, Ugx 75,045, and Ugx 62,038 per actor per week for wholesalers and retailers respectively. Production system, quantity harvested/or purchased, loading /or offloading, distance to the market, mode of transport, pests and diseases, and membership to an association/or cooperative had a significant influence on PHL in the selected vegetables. Age of the respondents, access to credit, membership to an association/or cooperative, income from vegetables, distance to the market, and the quantity of vegetables harvested /or purchased influenced the likelihood of the adoption of maturity index, shade and sorting or grading by the value chain actors. This study recommends that adequate fresh vegetable tailored training and capacity-building programs on postharvest handling should be organized by government and other development agencies to reduce selected vegetable losses to improve food security income levels for vegetable value chain actors.

Keywords: ***Vegetables, postharvest losses, value chain actors, postharvest handling techniques***

CHAPTER ONE: INTRODUCTION

1.1 Background

Agricultural postharvest loss (PHL) is one of the key challenges facing food and nutrition security across the globe. It causes food insecurity through food loss and waste that contribute 8% of the total planet's annual greenhouse emissions representing wasted natural and economic resources (Snel *et al*., 2018). In the context of this study, PHL refers to the reduction in food quantity and/or deterioration of its quality from farm gate to final consumption and it can be categorized as "food loss" and "food waste". According to FAO (2011) food loss entails all losses at the lower stages of the value chain particularly farm, collection, wholesale, and retail while food waste is food loss that occurs at consumption level. Farm-level losses are estimated at 1.2 billion tonnes annually, which is equivalent to $370 billion (FAO, 2011; WWF & Tesco, 2021). According to Ziv & Fallik (2021) PHL for fresh produce is more severe in low-income countries compared to middle and high-income countries ranging between 25-50% and 5-25 % respectively. PHL can occur at any stage of the agricultural value chain and therefore, is highly variable due to socioeconomic, environmental, and institutional factors of each value chain key node (Sheahan & Barrett, 2017).

In developing countries, more than 40% of PHL in terms of food losses occur at postharvest and processing levels while in developed countries over 40% of food losses occur at retail and consumption levels. This causes both quantitative and economic losses.

PHL in Sub-Saharan Africa (SSA) are s estimated around 100 million tonnes which represents 30% of total annual food production (FAO, 2011). The economic grain losses alone equate to $4 billion per year which if resolved could meet the annual food requirements of about 48 million people, reducing grain imports, and the need for food aid in Africa (AUC, 2018). Approximately

16-40% of the losses occur in fresh produce particularly fruits, vegetables, roots, and tuber crops which is higher compared to 17% reported in grains (Beye & Komarek, 2020; Ndindeng *et al*., 2021). In East Africa PHL estimates for fruits and vegetables, roots and tubers and cereals stand at approximately 70, 50 and 30 % respectively (EAC, 2022). In Uganda PHL for fruits and vegetables range from 30 to 50%, and 30 to 40 % for grains and other staples (FAO, 2020).

Uganda is the second-largest producer of fresh vegetables and fruits in SSA with a total production of 5.3 million tonnes per year (Dijkxhoorn *et al.*, 2019). Horticultural production accounts for 14.4% of the country's GDP and acts as an important source of rural income, employment, source of raw materials, and foreign exchange earnings. Uganda earns about $35 million per year from horticultural exports (Lwakuba, 2018). The country produces a wide range of vegetables such as tomatoes (*Lycopersicon esculentum)*, crucifers, amaranth (*Amaranthus spp*.), hot pepper (*Capsicum spp)*, onions (*Allium cepa*), green beans (*Phaseolus vulgaris)*, lima bean (*Phaseolus lunatus)*, black-eyed pea (*Vigna unguiculata*), cassava (*Manihot esculenta*), *Cucurbita* spp, bitter tomato (*Solarium aethiopicum)*, sesame (*Sesamum indicum)*, okra (*Abelmoschus esculentus*) and garden egg (*Solanum melongena*) (Atuhaire *et al*., 2018). Vegetable production is undertaken all over the country with evidence from 2017's statistics showing a total production area of 250,000 hectares. Given the favorable climatic conditions in the country, vegetable and /or fruit farming is a source of income for more than 20,000 smallholder Ugandan farmers (Allbritton *et al*., 2017). From a nutritional perspective, vegetables constitute a significant portion of the human diet across different parts of the world due to their high nutritional components such as minerals, vitamins, dietary fiber, and antioxidants. Regular vegetable consumption is associated with lower risks of non-communicable diseases such as cardiovascular diseases and cancer (Varajaradu & Patel, 2019). The increased awareness about vegetables' health and economic benefits has led to a

growing demand for vegetables, and consequently farming and trading as some of the most important economic activities both in rural and urban areas (Guloba & Ogwal, 2021). Given the economic and nutritional significance of vegetables, it becomes vital to reduce PHL to increase the competitiveness of this agricultural sub-sector and promote food security especially for small holder farmers (Murthy *et al*., 2011). The reduction of PHL however, requires an understanding of their causal factors, magnitudes as well as their distributions. It is against this background that this study sought to explore the extent and drivers of PHL at the key nodes of some selected vegetable value chains.

1.2 Statement of the problem

PHL is still a big challenge to smallholder vegetable farmers in Uganda and it accounts for a loss of 30 to 50 % of total vegetable production. It is important to note that vegetable production is a source of employment to over 20,000 small holder farmers (Allbritton *et al*., 2017), and has enormous potential for poverty alleviation through regular income generation to farmers and marketers, improved household food and nutrition security, and foreign earnings (Surni *et al.,* 2020). Besides the above, vegetables are a source of vital nutrients including phyto chemicals such as antioxidants (Harling, 2017) that are essential in preventing the risk of developing NCDs such as cancers and high blood pressure among others (Collins *et al*., 2022). Despite the above benefits, a lot of vegetables do not reach the final consumer due to losses along the PHL vegetable value chain. A number of studies have been conducted on the causes of PH losses in vegetables (Etefa *et al.*, 2022), strategies to minimize PHL in vegetables (dos Santos *et al.*, 2020), and knowledge and practices on PH handling of vegetables (El-Ramady *et al.*, 2015). Additionally, several strategies including training of farmers on PHL handling of fresh produce, extension of shelf life of fresh produce have been put in place to minimize PHL in vegetables. Despite the above efforts,

PHL in vegetables remain high. This could be due to the lack of clear and empirical evidence on the magnitudes, distribution, and determinants of such losses (Kikulwe *et al*., 2018). It is against this background that this study focused on quantifying the economic value of PHL, their determinants at key nodes along tomatoes, carrots, and kale (sukuma) value chains as well as the drivers of the choice of postharvest handling practices for farmers, wholesalers and retailers in Gulu district and city.

1.3 Main Objective

To establish the extent of postharvest losses in vegetables in Gulu district and Gulu city of Uganda.

1.4 Specific Objectives

1. To determine the total economic value of PHL measured by actors in selected vegetable value chains.
2. To ascertain the drivers of PHL along the selected vegetable value chains
3. To assess the determinants of the choice of postharvest handling techniques in the selected vegetable value chains

1.5 Research questions

The following research questions guided the study:

1. What is the economic value associated with postharvest losses in the tomatoes, carrots, and kale value chains in Gulu district and Gulu city?
2. What are the drivers of vegetable postharvest losses in Gulu district and Gulu city?
3. What are the determinants of the choice of postharvest handling techniques and practices of vegetable farmers in Gulu district and Gulu city?

1.6 Conceptual framework

PHL under the category of food losses refers to all losses that occur at the lower stages of the value chain (FAO, 2010). In this study, only food losses at the farm, wholesale, and retail levels were taken into consideration. These types of losses are hypothesized to be caused by different factors ranging from social, economic, and infrastructural factors as shown in Figure 1. The social-economic characteristics of the value chain actors such as age, gender, and education level are hypothesized to influence the choice of postharvest handling techniques as well as the level of returns, which significantly affect PHL.

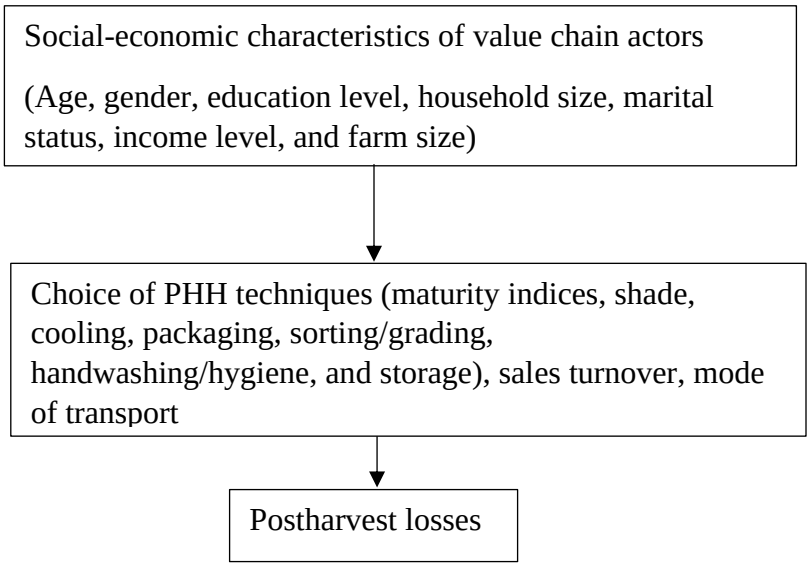


Figure 1. Conceptual framework relating selected variables to postharvest losses in vegetables Adapted from Mtui (2017)

1.7 Scope of the study

In terms of the geographical scope, the study was conducted in Gulu district and Gulu city of northern Uganda. Contextually, this study aimed to analyze and document the economic value of PHL in tomatoes, carrots, and kale. The study considered the physical (quantitative) losses of the vegetables which is the physical reduction in the vegetable quantity due to different factors along

the postharvest system. Although there were many species of vegetables, this study focused on tomatoes, carrots, and kale since they were among the most important high-value vegetable crops cultivated in the study area.

1.8 Significance of the study

The findings of this study aim to inform and guide the formulation of PHL policies and strategies that will attract more investors and actors in the vegetable value chain as well as contribute to current global discussions on postharvest losses in food systems.

The results of the study will help government institutions as well as policymakers to understand the stages along the selected vegetable value chains where significant losses occur and thus, develop appropriate strategies for preventing or reducing such losses.

CHAPTER TWO: LITERATURE REVIEW

Understanding the magnitudes of postharvest losses in agricultural value chains, their distribution, and the driving factors behind them is crucial for addressing food insecurity, promoting economic sustainability, and optimizing resource utilization. However, the existing body of literature on this subject remains inadequate, leaving a significant knowledge gap. This study seeks to address the problem of insufficient research and data regarding the quantification of PHL and the evaluation of their determinants with a particular focus on three vegetables namely tomatoes, carrots, and kale. The primary aim of this study is to develop a comprehensive understanding of relevant literature relating to PHL, methodologies, and challenges involved in quantifying postharvest losses, and to explore innovative approaches for more accurate measurement and analysis. By addressing this gap in the literature, this research aims to provide a foundation for improved postharvest management practices, policy development, and sustainable agricultural systems that can mitigate losses and enhance food security and nutrition.

2.1 An overview of tomatoes, carrots, and kale

Tomato (*Lycopersicum esculentum*) is one of the most important vegetables in the world and is a member of the Solanaceae family. Other important species of this family include potato *(Solanum tuberosum,* pepper (Capsicum *annum*), and tobacco (*Nicotiana tabacum*)(Haňcinský *et al.*, 2020). Tomatoes originated in South America and were later introduced in Europe, Asia, Africa, and the Middle East (Balemi *et al*., 2005). According to the Food and Agriculture Organization (FAO), the world's tomato production estimate in 2020 was about 187 million tonnes in a total area of 5 million hectares (FAO, 2020). Tomatoes have many nutritional components such as lycopene, iron, potassium, folate, vitamin C, and dietary fiber which offer many health benefits including

reduced risk of cancer and cardiovascular diseases (Collins *et al.*, 2022). In addition to its health benefits, tomato is a short-duration crop and gives a high yield (Noonari *et al.*, 2015). This has made tomato production one of the most important economic activities for many rural and urban dwellers across different countries in the world. In Uganda, tomatoes are cultivated as a priority vegetable crop, and generally, they generate a higher income of about $ 250 per growing season compared to other crops (Goldman & Heldenbrand, 2002; Tusiime *et al*., 2019).

Carrots (*Daucus carota*) are a root vegetable and the most important crop of the *Apiaceae* family. Orange carrots which are the most common originated in central Europe between the 15th and 16th centuries(Dias & Imai, 2017). Carrots constitute a higher nutritional value than most vegetables as they have a wider range of nutritional components such as vitamins, minerals, polyacetylenes, dietary fiber, and antioxidants such as carotenoids, and flavonoids (Harling, 2017). These nutrients play essential roles in the body by enabling it to perform vital functions such as the production of hormones, enzymes, and energy (Wishart, 2017). The World's biggest carrot producers are China, Russia, U.S., Uzbekistan, Poland, Ukraine, the United Kingdom, Japan, and Turkey (Acar & Gül, 2016). In addition to their health benefits, carrots have a higher economic value due to their higher demand and benefit cost-ratio 1:52 and thus possess an outstanding potential for improving the incomes of the value chain actors engaging in the enterprise (Sapkota *et al*., 2020). Uganda is the second-largest producer of fresh vegetables and fruits including carrots in Sub-Saharan Africa and exports most of them to the EU, particularly Belgium and the Netherlands.

Kale **(**Brassica oleracea *L*.) or locally known as sukuma, is a leafy vegetable that originated in the Eastern Mediterranean. Other vegetables in this family include cabbage, radish, cauliflower, and Broccoli. Kale has many nutritional benefits as it is rich in minerals and vitamins such as Mg, K, Ca, riboflavin, folate, and vitamin C (Šamec *et al.*, 2019). It is also an excellent source of dietary

fiber and has strong medicinal properties that are associated with low risks of cancer and other chronic diseases (Šamec *et al*., 2019). Kale can be grown in a wide range of environments but performs better under cool climatic conditions, well-drained soils with high organic matter content, and sufficient moisture (Idd *et al.,* 2018). Kale production is a lucrative business in Uganda due to its high growing demand, with Gulu district being one the major growing areas (FOA, 2013).

2.2 Importance of vegetables and vegetable farming

Approximately 402 vegetables are cultivated globally, out of which leafy vegetables take the highest proportion (53 %), followed by fruit vegetables (15 %), and roots and tuber vegetables (17 %) (Dias, 2011). Due to their adaptability to a wide range of edaphic and climatic conditions, vegetables are grown in over 200 countries across the globe and they constitute a crucial part of the human diet (Varadaraju & Patel, 2019). Most of the vegetables are marketed fresh with only a small portion processed. The world's largest vegetable producer is China with more than 50 % of the total production (Dias, 2011).

Vegetables are cheap yet with high nutritional value that's associated with lower risks of non-communicable diseases. Despite their health benefits and accessibility, over 1.5 million premature deaths per annum are attributed to heart diseases some of which are caused by inadequate intake of vegetables (Feng *et al.,* 2022). It is on such basis that the World Health Organization (WHO), recommends a daily intake of 400 g of vegetables and fruits per person per day for the prevention of non-communicable diseases; this excludes roots and tubers such as cassava, potatoes, and sweet potatoes (FAO, 2021).

Vegetables, being cheap and readily available, have the highest potential to mitigate malnutrition and mortality among pre-school-going children in developing countries (Iqbal *et al.*, 2019). In

addition to health and nutritional benefits derived from vegetables, vegetable farming and other related activities such as marketing and processing can significantly reduce unemployment rates, especially among the youth (Schreinemachers *et al.*, 2018). Increased urbanization and awareness of the enormous health benefits of vegetables have resulted in the rise in demand for vegetables over the years thus giving the vegetable sub-sector great economic significance (Gurung *et al.*, 2016). The expansion of the regional market in East Africa has encouraged about 50, 000 to 80,000 smallholder farmers to engage in the production of vegetables for export (Lenné & Ward, 2010). Research findings from studies conducted in Cambodia, Niger, and Vietnam showed that vegetable farming per hectare is more profitable than rice production. Additionally, vegetable production being more labor-intensive provides more employment opportunities than cereals (Joosten *et al.*, 2015). To optimize the potential of the vegetable sub-sector, there must be a joint effort by both policymakers and all value chain actors to promote competitiveness in the sub-sector which will result in improved income levels, profitability, food, and nutrition security, and ultimately poverty alleviation.

This study focused on three major vegetables which are tomatoes, carrots, and kale. The choice of the three vegetables was based on their economic significance in the study area and the need to have a representation of different vegetable categories; that is, fruit vegetables represented by tomatoes, root vegetables represented by carrots, and leafy vegetables represented by kale.

2.3. Quantifications of selected vegetables' postharvest losses

Postharvest losses can be classified as quantitative, qualitative, and economic. Quantitative losses refer to the physical reduction of food from the postharvest system and they may include weight and/or volume losses and discards due to physical deterioration or decay (FAO, 2016). On the other hand, qualitative losses include the loss of edibility, acceptability, nutritive or calorific value

due to food spoilage, loss of freshness, changes in color, moisture loss, and decay symptoms (Kader, 2005; Gogo *et al*., 2017). Quantitative and qualitative postharvest losses culminate in economic postharvest losses which can be referred to as the monetary value of such losses (Kitinoja *et al.,* 2018). The losses are attributed to both biotic and abiotic factors such as insects and high temperatures coupled with poor post-harvest handling techniques and practices during harvest, storage, packaging, transportation, and processing (Kitinoja & AlHassan, 2012; Kumar & Kalita, 2017).

Over the years, it has been observed that research studies on PHL have focused on the storage stage of the postharvest system (Edoh Ognakossan *et al.*, 2016; Mwangi *et al.,* 2017; Chegere, 2018). This has resulted in leaving out other important stages such as harvesting, processing, and transportation and thus providing incomplete information about the aspect (Aulakh *et al*., 2013)

According to Sharma & Sharma (2019), there is no universally accepted technique for measuring postharvest losses. This can be attributed to the environmental, social, political, and economic differences across countries and regions around the globe (Aulakh *et al.,* 2013). One of the most widely used methods for evaluating postharvest losses is known as Commodity system analysis. This method evaluates postharvest losses by assessing specific activities in the key nodes of the postharvest system, their causing factors, and overall contributions to total loss (Kwami & Nitty, 2014).

In a study conducted by Genova *et al*. (2006) in Cambodia, post-harvest losses at the farm level determined among four vegetables namely, cucumber, chili, yard-long bean, and tomatoes were quantified and calculated as a percentage based on the total harvested quantity. At collection, wholesale, and retail levels, the loss estimates were calculated as the difference between the quantity purchased and the quantity sold to the total quantity purchased. The monetary value of

the losses was expressed as the product of the physical loss and the average selling price of the vegetables. Likewise, in another study conducted in Vietnam, Cambodia, and Laos by Weinberger *et al*. (2008) post-harvest losses in tomatoes, chili peppers, and leafy vegetables at the farm level were quantified and calculated as a percentage based on total harvested quantity. At collection, wholesale, and retail levels, the losses were estimated as the difference between the quantity purchased, and quantity sold to the total quantity purchased. To obtain the monetary value of the losses, the physical loss calculated in kilogram (kg) was multiplied by the average selling price of the vegetables. Similarly in Ghana, Amartey (2013) estimated the value of postharvest losses for farmers as the product of the average estimated quantity lost and the unit selling price.

According to Murthy et al. (2009), the estimation of the economic value of postharvest losses must consider the selling prices of the agricultural produce at the different stages of the supply chain instead of using the general market price as the former tends to overestimate the losses. In a study conducted by Khatun & Rahman (2019) in the Jamalpur and Rangpur districts of Bangladesh, the total post-harvest loss in brinjal was determined by adding up the quantitative and qualitative losses which were categorized as full and partial physical losses respectively. Full physical losses are those that resulted in the quantitative reduction of brinjal while partial losses resulted in the reduction of their monetary value. The losses were estimated at different stages of the postharvest system, from the farm to retail levels. PHL were determined during collection, cleaning, sorting, grading, packaging, storage, and transportation and were grouped based on their drivers. The most important causes of the losses that were assessed included insect pests, rotting due to pathogen infection, diseases, spots, bruising, shrinking, and overripening of the fruits.

Kumar *et al.* (2006) quantified PHL in onions and potatoes in Karnataka, India. The losses and their causing factors were assessed at the farm, wholesale, and retail levels. Descriptive statistics,

particularly averages and percentages were used to estimate PHL. To examine the factors affecting PHL at the farm level a multiple linear regression model was used. The postharvest loss at the farm level was defined as a function of the socio-economic factors of the farmers, age, education level, type of family, and total production of the selected vegetables.

It's not known whether the aforementioned studies took into consideration the quantity of vegetables used by the value chain actors for food or other purposes. If such quantities were ignored there might be a problem of overestimation of the losses. In addition, some of the studies considered only one stage of the vegetable value chain thus providing an incomplete evaluation of the losses. To bridge these gaps, this study adopted a commodity assessment approach to evaluate postharvest losses at the farm, wholesale, and retail levels of the selected vegetables. The study assessed the most important activities in each stage, and their contributions to the total loss. To avoid overestimation of both physical and economic losses, the quantity of vegetable losses in each postharvest handling operation, the quantity harvested/or purchased, the quantity sold as well as the quantity used for food or other purposes were captured instead of taking into consideration only the quantity harvested/or purchased and the quantity sold. Economic losses were computed by using the average price in each value chain key node.

2.4 Factors influencing postharvest losses along the vegetable value chains

Due to their high moisture content, fruits and vegetables are highly perishable resulting in high PHL ranging from 30% to 50% in Uganda (FAO, 2020). The causes of postharvest losses can be categorized into biological, environmental, and socioeconomic (Wakholi *et al*., 2015). The environmental and biological factors include relative humidity, temperature, moisture, and microbial infestation. The extent to which these factors of PHL can be controlled is determined by the socioeconomic characteristics of the value chain actors such as the age of the value chain actor,

education level, distance to market, quantity harvested/purchased, farming and trading experience, storage facilities, type of packaging material, hygienic conditions, duration of selling the produce, access to credit, access to market and type of marketing system, access to transport facilities, and lack of proper postharvest handling knowledge and skills (Kereth *et al*., 2013; Kulwijila, 2021).

Poor technological capacity across different stages along the value chain such as harvesting, storage, and transportation is one of the most critical factors attributing to post-harvest losses in developing countries. In middle and high-income countries the losses are mainly associated with consumer behavior and the existence of strict safety policies and marketing standards (Porat *et al.*, 2018). In developing countries, food chains are characterized by inadequate and inefficient cold facilities and other related problems particularly improper storage. For instance, Elik *et al.* (2019) reported that approximately 23 % of perishable agricultural produce gets spoiled due to cold storage-related challenges. The type of packaging material used greatly affects the shelf life of agricultural produce as it directly influences the variability in temperature and relative humidity in storage or during transportation of that product (Kader & Rosa, 2004). In most developing countries inappropriate packaging materials such as wooden crates, bamboo baskets, and sacks are widely used to pack vegetables due to their cost-effectiveness and availability and they result in massive post-harvest losses (Kereth *et al.*,2013; Apolot *et a*l., 2020). In Uganda, a study carried out on post-harvest handling practices of leafy vegetables revealed that most farmers did not use any form of packaging for leafy vegetables due to economic reasons. They simply tied the vegetables into bundles for easy loading and off-loading (Apolot *et al.*, 2020).

Some losses occur during transportation; these are usually caused by poor physical infrastructure, poor packaging, and inappropriate methods of loading and arrangement of products in the vehicle (Mtui, 2017). Mechanical injuries during loading, off-loading, stacking of products, and

transportation exacerbate the losses due to increased susceptibility to microbial infestation (Prussia & Mosqueda, 2006; Yahaya & Mardiyya, 2019).

From the above review, it is evident that the drivers of postharvest losses vary across geographical spaces. Therefore, those from one area cannot be imposed or generalized on other areas. Hence those specific to Gulu city and district need to be established.

2.5 Factors influencing the choice of postharvest handling techniques

Since the adoption of post-harvest handling techniques involves diverting economic resources from other productive activities, the value chain actors are always trying to decide carefully to ensure the most effective and efficient utilization of such resources. The choices of post-harvest handling techniques are influenced by many factors ranging from demographic to socio-economic. Using a multivariate probit model, a study on factors influencing the choice of storage techniques used by maize farmers in Gatsibi district-Rwanda, found out that the quantity of maize produced, access to training, access to credit, membership in a farmer group, and the season at which maize was sold significantly influenced the choice of storage techniques (Benimana *et al.*, 2021). In another study conducted by Abate *et al*. (2019) in the Dera district of Ethiopia to determine the factors that influenced the choice of a market channel by teff farmers, a multivariate probit regression revealed that age, household head, the quantity of teff produced, land size, price of teff, family size, membership of cooperative society and distance to the nearest market were the main determinants of the farmers' decisions on the choice of the market channel.

Okoruwa *et al.* (2009) conducted a study in South-West Nigeria to examine factors influencing the choice of storage techniques for grain farmers and found that the gender of the farmers, education status, the quantity of grain stored, price of grains, and capital invested significantly

influenced the farmers' choice of the storage techniques. A probit regression model was employed in a study that aimed at determining the factors that influenced the choice of storage techniques for potatoes in the eastern and southern highlands of Uganda and the findings showed that the level of income obtained from activities other than potato farming, access to credit and access to storage management advice were the most important determinants of the choice of storage techniques (Akello *et al*., 2022). Improved postharvest handling techniques such as the use of cold chain for perishable foods product during harvest, collection, packaging, processing, storage, transport, and marketing is very common and highly effective in developed countries (Kitinoja, 2013). Such techniques are not widely used in developing countries due to the high costs associated with their adoption and problems related to access to power. A study conducted by Mwebaze &Mugisha, (2011) in Uganda found that farmers prefer local postharvest reduction methods instead of government-improved postharvest technologies because they do not know whether the benefits of the latter will surpass the costs. From these studies it is evident that factors influencing choice of postharvest handling techniques vary greatly along the geographical locations and hence those specific to Gulu must be established.

2.6 Theoretical Framework of the Study

2.6.1 Rational Choice Theory

The rational choice theory assumes that human beings are rational and thus tend to act in ways that would benefit them more; every individual tends to take actions that they believe will offer them maximum advantage (Hechter & Kanazawa, 1997). In addition to the food security and nutritional motive, vegetable value chain actors have an economic motive to engage in the vegetable enterprise. As economic agents, vegetable value chain actors are faced with the decision of whether to invest in post-harvest handling techniques. Being rational individuals, their decisions will be

determined by comparing the perceived benefits accrued from the use of post-harvest handling techniques to the overall costs of their acquisition. The magnitude and economic value of post-harvest losses experienced by vegetable value chain actors could therefore be the most important determinants of their decision to adopt post-harvest management techniques or not. Rational choice theory was used by Ahmad Rizal *et al.* (2021) in a study that sought to determine the factors that influenced small holder farmers' decision to obtain a sustainable palm oil production certification. The results showed that perceived benefits significantly affected farmers' decisions.

CHAPTER THREE: METHODOLOGY

3.1 Study Area

The study was conducted in Gulu district and Gulu city which are situated in the Acholi sub-region of Northern Uganda. Gulu district is located between 2°51'21.7"N and 32°25'48.0"E (Figure 2), while Gulu city is located between 2°46'54.0"N and 32°17'57.0"E. Gulu district is bordered by Omoro in the East, Amuru, and Nwoya in the West, and Kitgum in the north (UBOS, 2017). According to the 2014 National Census, the study area has a total population of 443,733 (UBOS, 2020). Agriculture is the most dominant economic activity in Gulu with some of the most important crops being vegetables, maize, soybeans, sorghum, groundnuts, millet, beans, cassava, sweet potatoes, and cowpeas (Dalipagic & Elepu, 2014). The study area was selected because it is one of those with the highest potential for fruits and vegetable production in the country (Gasser, 2020). In addition to their high potential for vegetable production, the study was carried out in the two districts to ensure enough sample size.

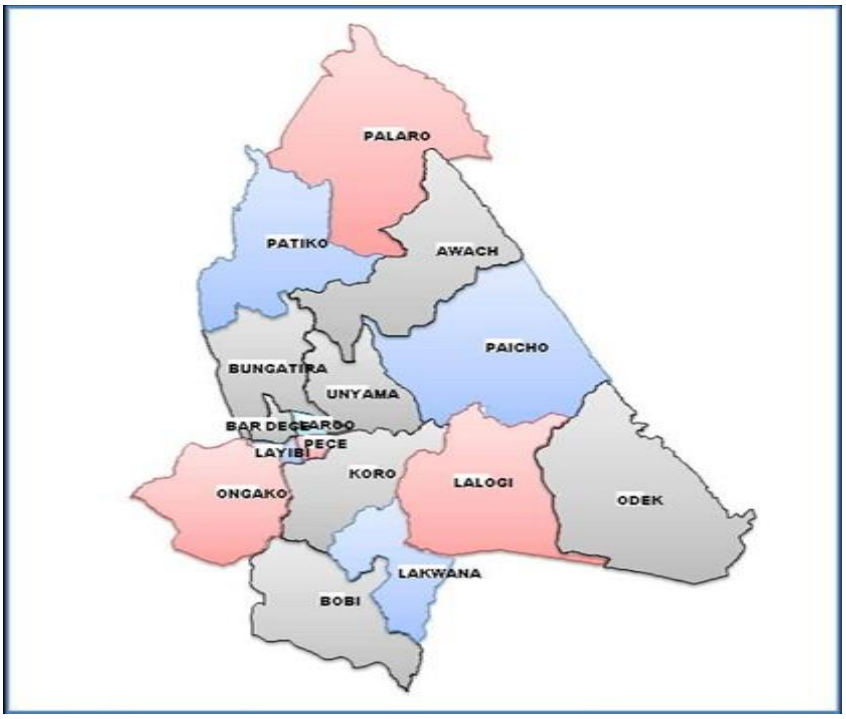


Figure 2. The map of Gulu district

3.2 Research design

A cross-sectional research design was used in the study to collect both qualitative and quantitative data from farmers, wholesalers, and retailers using a researcher-administered questionnaire. This method was adopted because it allows collection of data at one point in time and thus, easy, inexpensive and time saving (Wang & Cheng, 2020). In addition Loree & Tuckman (1999) indicated that in cross section surveys, the study sample represents a cross section of the target population.

3.3 Sample size determination and sampling technique

3.3. 1 Sampling procedure

A multistage sampling approach was used to select all the respondents for the study. In the first stage, Gulu District and Gulu City were selected due to their high potential for vegetable

production. Secondly, five urban markets; Gulu main market, Cereleno market, Layibi market, Olailong market, and Lacor market were selected purposively. These markets were selected because they are among the biggest in the study area and thus have the largest proportion of vegetable traders nearby. In the third stage, stratification was used to identify farmers, wholesalers, and retailers. A farmer qualified to participate in the study if they produced at least 20 Kg of tomatoes, 5Kg of kale, and 10 Kg of carrots per season. For wholesalers, a weekly purchase of at least 200 Kg of tomatoes, 15 Kg of carrots, and 10 Kg of kale per week was considered. Retailers who qualified were those that purchased at least 10kg of tomatoes, 5Kg of carrots, and 2Kg of kale per week. A total of 115 farmers, 55 wholesalers, and 70 retailers were selected through simple random sampling. The farmers were selected from nearby sub-counties of Unyama, Paicho and Bungatira. Farmers, wholesalers, and retailers who had at least one of the vegetables of interest were included as study participants while farmers, wholesalers, and retailers who had none of the vegetables of interest were excluded from the study.

3.3.2. Sample size determination

The sample size (n) for the study was determined using the equation described by Cochran (1977).

$n = \frac{Z^2 Pq}{e^2}$ …… (1)

Where n is the required sample size, Z is the confidence level at 95% (standard value of 1.96), P= the variability in the proportion of the population (estimated proportion of vegetable farmers, wholesalers, and retailers in Gulu district and Gulu city by the district's agricultural production officer) = 14%, e = Margin of error at 5% (standard value of 0.05).

Using the formula in (equation 1),

$$n = \frac{(1.96)^2 * 0.86(0.14)}{(0.05^2)} = 185$$

To compensate for farmers' wholesalers, and retailers absence and non-response, an addition of 30 % was required following the suggestion of Bujang, (2021) which was equivalent to 55 respondents, this resulted in a total sample size of 240. A total of 115 farmers, 55 wholesalers, and 70 retailers were interviewed during the study.

3.4 Data collection

3.4.1 Data collection instrument

For all objectives, primary data were collected using pretested structured questionnaires. To enhance the validity and reliability of the data instruments, pre-testing was done before data collection. A total of 30 respondents; 10 farmers, 10 wholesalers, and 10 retailers were interviewed from Nwoya district. Afterwards, data were cleaned, coded, and analyzed. Anomalies that emerged in the form of redundancies and omissions were corrected by restructuring the items of the tools affected.

The questionnaire comprised of both close-ended and open-ended questions to collect data. To get data for post-harvest loss estimates, the study employed a commodity assessment methodology. The first part of the questionnaire captured the socio-demographic characteristics of the respondents. The second part captured the level of vegetable production and sales per season for farmers and the quantity of vegetables purchased and sold by wholesalers and retailers per week. In addition to that, the quantities consumed and/or used for other purposes by the actors were noted. The third part collected information about different post-harvest handling techniques that the vegetable value chain actors were implementing (See appendix b).

3.4.2 Data collection procedure

Data were collected with the help of five research assistants. They were well-trained in the content of the questionnaire and the interviewing process but did not assist the respondents to answer them. The research assistants were fluent in both the local language (Acholi) and English and had previous exposure to conducting surveys. Acholi was the language used for interviews with responses recorded in English. This was so because most respondents speak and understand the local language best.

3.5 Data quality control

3.5.1 Data reliability and validity

To ensure the reliability and validity of data, questionnaire items were formulated to meet the research objectives being investigated with guidance from the supervisors. A pre-test of the translated questionnaire was conducted on 30 respondents in Nwoya district. After the pre-test, modifications were made to the questionnaire to improve the reliability of the content.

3.6 Limitations of the study

Limitation could arise from the translation of the data collection instrument since it was designed in English and administered in the local language (Acholi). This could have an adverse effect on the quality of responses; however, this was checked by using educated and well-trained research assistants with excellent knowledge of both English and Acholi.

3.7 Data analysis

3.7.1 Determining economic postharvest losses in selected vegetables

Descriptive statistics (such as averages, frequencies, percentages, mean and standard deviations) were used to describe the socio-demographic characteristics of the study respondents and to determine the level of economic post-harvest losses of tomatoes, carrots, and kale. Post-harvest losses for farmers, wholesalers, and retailers were quantified by adding up all the losses from the main operations such as harvesting, loading/offloading, transportation, packaging, and storage. To estimate the value of post-harvest losses of vegetables, the average quantity of post-harvest losses obtained was multiplied by the average price at each key node. Analysis of variance (ANOVA) was used to ascertain if the losses were statistically different across the vegetable value chain actors, farmers, wholesalers, and retailers. The economic quantification of vegetable losses was computed using equation (1) below.

Quantity of vegetables lost (kg) = (Quantity of vegetables harvested or purchased – Quantity of vegetables sold)/ Quantity of vegetables harvested or purchased * Average price…. (2)

3.7.2 Ascertaining the drivers of postharvest losses in selected vegetables

Regression analysis was used to ascertain the drivers of post-harvest losses in the selected vegetable value chains. The multiple linear regression model was used to ascertain the drivers of PHL at the farm, wholesale and retail levels using the Ordinary Least squares (OLS) technique. This model was chosen because the dependent variable is continuous (Vásquez *et al.*, 2020).

The general model depicting the relationship is shown in equation 3.

$$Yi = \beta 0 + \beta 1 Mar.Stat + \beta 2 Prd.Sytm + \beta 3 M.Ass/Corp + \beta 4 QtyHarv/Purch + \beta 5 FultimFarm/Trad + \beta 6 D.Harv/Sale + \beta 7 LossLoad/Offload + \beta 8 Dist.Mkt + \beta 9 N.roads + \beta 10 M.Transpt + B11 Pests\&Diseases + \beta 12 Packaging + ei \ldots\ldots\ldots (3)$$

Yi = Quantity of postharvest loss at the farm, wholesale, or retail level (kg)

$\beta 0$ = Regression coefficient

$\beta 1 + \beta 2 + \beta 3 + \cdots$ = Coefficient of the explanatory variables

ei= error term

The independent variables specified in the model include marital status, production system, membership to a farming or trading association or cooperative for farmers, and wholesalers, and retailers respectively, the quantity of vegetable harvested per season for farmers and quantity purchased per week for wholesalers and retailers, full-time, farming/trading, delay in harvest/sale, loading/offloading, distance to the nearest market, nature of roads, mode of transport, pests and diseases, and packaging (Table 1).

Two (2) functional forms of the model including linear and semi-log, functions were fitted for the regression analysis. This was done to select the best functional form of the model that best fits the data. Variance Inflation Factor (VIF) was conducted to test for multicollinearity and the results (appendix e) of VIF less than 2 demonstrated the absence of multicollinearity in the model.

Table 1. Variables used in the linear regression model for the drivers of post-harvest losses in vegetables

Variables	Description (Unit of measurement)	Expected sign	Citation
Dependent Variables			

Quantity of vegetable post-harvest losses at farm level, wholesale, and retail (Y)	Kilogram		Tadesse *et al.* (2018**);** Maziku (2017)
Independent Variables			
Gender	1 = Male 0 = Female	+/-	Mebratie *et al.* (2015)
Age	Number of years	+/-	Ansah & Tetteh (2016)
Education Level	Number of years	+	Shee *et al.* (2019);Maziku (2017) **);** Ahmed (2015)
Farm Size	Acre	+/-	Kikulwe *et al.* (2018)
Fulltime Farming/Trading	1= Yes 2= No	+/-	Obayelu *et al.* (2021)
Farmer experience	Number in years	+/-	Bantayehu *et al.* (2018); ; Doki *et al.* (2019)
Quantity of vegetables harvested/Purchased	Kilograms	+/-	Santos *et al*. (2020); Alidu *et al*. (2016)
Delay in harvest/Sale	1=Yes 2= No	+/-	Ramjan *et al.* (2017)**;** Addo *et al.* (2015)
Distance to market	Kilometers	+/-	Khatun & Rahman (2019)**;** Tadesse *et al.* (2018)
Loading/Offloading	Kilograms	+/-	Alhassan & Kumah (2018)
Pest and diseases	Kilograms	+/-	Kasso & Bekele (2018)**;**
Memb.Ass/Corp	1=yes 2=no	+/-	Aidoo *et al.*(2014)**;** Si *et al.* (2018)
Access to credit	1=yes 2=no	+/-	Kitinoja (2013)
Access to extension	1=yes 2=no	+/-	Nymand-Grarup *et al.* (2015)
Storage Conditions	1=controlled 2=normal temperature	+/-	Brasil & Siddiqui (2018)**;** Deoraj *et al*. (2015)**;** Ziv & Fallik (2021)
Packaging materials	1=plastic bag 2=bamboo basket 3=wooden crate 4=plastic crate 5=Sack 6=others	+/-	Elik *et al.* (2019)**;** Kitinoja (2013)**;** Mibulo *et al.* (2020)
Transport mode	1=head 2=bicycle 3=motorcycle 4=ox cart	+/-	Malekian *et al.* (2015)**;** (Ndirangu *et al*. (2017)

Nature and type of the road	1=murram 2=tarmac 3=ungraded 4=other	+/-	Debebe (2022)

3.7.3 Assessing the determinants of the choice of postharvest handling techniques

A multivariate Probit model was used to analyze the factors that influenced farmers' choice of post-harvest handling techniques. This is because in a single statistical model, information on farmers' choice of post-harvest handling technique does not alter the likelihood of a farmer's choice of another post-harvest handling technique. The use of postharvest handling techniques is choice-based, in that a household could opt to use a combination of techniques based on the perceived benefit that can be derived from them. Farmers can also use more than two post-harvest handling techniques. Therefore, the multivariate Probit model was the best model for this objective because it allows possible concomitant correlations in the choice to use the combination of post-harvest handling techniques simultaneously. The variables used in the multivariate probit are described along with the *a priori* expected signs in (Table 2).

Table 2. Variables used in the multivariate Probit model for the determinants of the choice of post-harvest handling techniques

Variables	**Description (Unit of measurement)**	**Expected sign**	**Citation**
Dependent Variables			

Maturity indices Shade Sorting/grading Washing/hygiene Improved containers Solar drying Cooling	 1 = yes, 0 = no 1 = yes, 0 = no 1 = yes, 0 = no 1 = yes, 0 = no 1 = yes, 0 = no	 +/- +/- +/- +/- +/-	Arah *et al*. (2016)**;** Cherono *et al*.(2018)**;** Msogoya & Kimaro, (2011)**;** Abdelfattah *et al*. (2020)
Independent Variables			
Gender	1 = Male 2 = Female	+/-	Amaza *et al*. (2016)
Age	Number of years	+/-	Ngowi & Selejio (2019)
Education Level	Number of years	+	Kariyasa & Dewi (2013)
Household Size	Number of persons	+	Nkurunzinza & Habimana (2021)
Farming experience	Number in years	+/-	Mukarumbwa *et al.* (2017)
Distance to market	Kilometers	+/-	Akello *et al*. (2022)
Vegetable quantity	Kilograms	+/-	Mukarumbwa (2017)
Household income	Ugandan shilling	+/-	Balana *et al*. (2022)
Association/Cooperative	1 = yes 0= no	+/-	Nwabuogo (2019)**;** Ajibesin *et al.*(2019*)*
Access to credit	1 = yes 0= no	+/-	Kattel *et al.* (2020)

3.8 Ethical considerations of the study

This study observed all legal and ethical expectations governing research as defined within the context of the Republic of Uganda. Before starting the study, ethical clearance was obtained from Gulu University Research and Ethics Committee (GUREC-2022-195). An approval letter was obtained from the Chief Administrative Officers to carry out the research in the district (appendix f). During data collection, respondents had to consent by signing the consent form and this was done voluntarily. The researcher ensured that human rights were fully respected and that all respondents and research assistants were participating under healthy and favorable conditions. Proper referencing was ensured to avoid all forms of plagiarism and academic fraud.

CHAPTER FOUR: RESULTS

4.1 Socio-economic characteristics of selected vegetable farmers

Results in Table 3 show that majority of vegetable value chain actors (75.8 %) were females and they dominated 100 % of vegetable wholesale and retail. Many farmers were married (73.9%) compared to wholesalers (69.1%) and retailers (54.3). A big proportion of wholesalers worked full-time (98.2%) compared to farmers (76.5%) and retailers (87.5 %). The results further revealed that the largest proportion of wholesalers (36.4 %) earned more than Ugx 500,000 per week from vegetables whereas only 23.5 % and 10 % of the farmers and retailers respectively earned the same amount per week. Most of the farmers (81.7 %) had access to extension services followed by wholesalers (49.1 %) and retailers (21.4 %). All the farmers who had access to extension services (81.7 %) also had access to credit. 85.5 % and 57.1 % of wholesalers and retailers had access to credit respectively. In addition, the largest proportion of wholesalers were members of trading associations/co-operatives compared to farmers and retailers (Table 3).

Most of the farmers grew their vegetables under rain-fed conditions; (78.6 %) tomatoes, (66.7 %) carrots, and (51.7 %) kale. On average, farmers dedicated more land to tomato farming 0.53 acres compared to 0.09 acres for kale and 0.08 acres for carrots. The largest proportion of the farmers grew vegetables on their land (87.0 %), while (9.6 %) rented and (3.5 %) borrowed. All the farmers purchased vegetable seeds from seed dealers located mainly around Gulu city.

Table 3: Comparisons of categorical variables for characteristics of selected vegetables value chain actors

Variables	Farmers (n = 115) Freq (%)	Wholesalers (n = 55) Freq (%)	Retailers n = 70) Freq (%)	Total (240)	χ	Sig.
Gender					13.120***	0.001
Male	58 (50.4)	-	-	58 (24.17)		
Female	57 (49.6)	55 (100)	70 (100)	182(75.83)		
Marital status					11.380*	0.077
Married	85 (73.9)	38 (69.1)	38 (54.3)	161 (67.1)		
Unmarried	30 (26.1)	17 (30.9)	32 (45.7)	79 (32.9)		
Full-time farming/trading					24.361***	0.000
Yes	88 (76.5)	54 (98.18)	68 (97.1)	210 (87.5)		
No	27(23.5)	1 (0.02)	2 (2.9)	30 (12.5)		
Income						
0-100,000	19 (16.5)	-	13 (18.6)	32 (13.3)	41.491***	0.000
100,000-200,000	19 (16.5)	3 (5.5)	22 (31.4)	44 (18.3)		
200,000-300,000	20 (17.4)	11 (20.0)	12 (17.1)	43 (17.9)		
300,000-400,000	17 (14.8)	6 (10.9)	11 (15.7)	34 (14.2)		
400,000-500,000	13 (11.3)	15 (27.3)	5 (7.1)	33 (13.8)		
>500,000	27 (23.5)	20 (36.4)	7 (10)	54 (22.5)		
Membership in Assoc./Corp					1.333	0.513
Yes	86 (74.8)	50 (90.9)	53 (75.7)	189 (78.8)		
No	29 (25.2)	5 (9.1)	7 (24.3)	41 (21.2)		
Access to Extension					13.494***	0.001
Yes	94 (81.7)	27 (49.1)	15 (21.4)	136 (56.7)		
No	21 (18.3)	28 (50.9)	55 (78.6)	104 (43.3)		
Access to Credit					1.227	0.541
Yes	94 (81.7)	47 (85.5)	40 (57.1)	181 (75.4)		
No	21 (18.3)	8 (14.5)	30 (42.9)	59 (24.6)		
Production System Tomatoes						
Rainfed	81 (78.6)	-	-			
Irrigation	22 (21.4)	-	-			
Production System Kale						
Rainfed	17 (53.1)	-	-			

Irrigation	15 (46.9)	-	-
Production System Carrots			
Rainfed	20 (69.0)	-	-
Irrigation	9 (31.0)	-	-
Farmsize Tomatoes.	0.53	-	
Farm size Kale	0.09	-	
Farm size Carrots	0.08	-	
Land ownership			
Owned	100 (87)	-	-
Rented	11 (9.6)	-	-
Borrowed	4 (3.5)	-	-
Source of seeds			
Purchased	115 (100)	-	-
From previous harvests	0(0)		

*****, **, *:** Significance level at 1%, 5% and 10%, respectively.

The mean age of the vegetable value chain actors was 37 years with farmers being older compared to wholesalers, and retailers with the mean age of 40 years and 34 years respectively. On average, the value chain actors had 8 years of education and work experience although farmers had slightly fewer years of experience (7 years) compared to wholesalers and retailers (Table 4)

Table 4: Comparisons of continuous variables for characteristics of selected vegetables farmers, wholesalers, and retailers

Variable	Value chain actors				F	Sig.
	Farmers	wholesalers	Retailers	Pooled mean		
Age	40.05	34.16	34.87	37.15	3.585*	0.029
Education	7.51	8.33	7.50	7.72	0.366	0.694
Years of experience	6.97	7.82	8.17	7.51	1.525	0. 220

4.2. Economic quantification of postharvest losses in tomatoes, kale, and carrots

The results in Table 5 revealed that post-harvest losses were more severe in tomatoes compared to carrots and kale. An average of 164.96 Kg of tomatoes was lost per acre per season per farmer which was equivalent to Ugx 311,444. Additionally, it was found that an average of 19.52 and 9.57 Kgs was lost by wholesalers and retailers per capita per week, the losses were equivalent to Ugx 59,357and Ugx 29,852 at wholesale and at retail levels respectively.

Table 5: The average amount (Kilograms) of tomatoes lost last season 2020/21 and their causing factors

	Farmers			**Wholesalers**			**Retailers**		
	Quantity (Kg)	**%**	**Value (Ugx)**	**Quantity (Kg)**	**%**	**Value (Ugx)**	**Quantity (Kg)**	**%**	**Value (Ugx)**
Harvesting	4.55	5.2	8592	-	-		-	-	-
Late harvest	16.39	18.75	30,950	-	-		-	-	-
Load/Offload	8.16	9.33	15,409	2.30	11.78	6,994	0.89	9.30	2,776
Dist to Mkt	6.24	7.14	11,783	0.18	0.92	547	0	0	0
Transport	7.45	8.52	14,068	0.44	2.25	1,338	0.23	2.40	717
Contamination	17.73	20.28	33,480	3.85	19.72	11,707	2.43	25.40	7,580
Storage	19.77	22.61	37,333	12.71	65.11	38,649	5.89	61.5	18,373
Packaging	7.14	8.17	13,483	0.04	0.20	122	0.13	1.34	406
Total	**87.43**	**100**	**165,098**	**19.52**	**100**	**59,357**	**9.57**	**100**	**29,852**
Farm size (Acres)	**0.53**								
Loss/Acre	**164.96**		**311,444**						

Note: (i) Number of respondents = 103 farmers, 51 wholesalers, and 67 retailers, (ii) Average price: 1888 farmers, 3041 Ugx wholesalers, and 3119 Ugx retailers;(iii) Farmers' losses reported per season, wholesalers', and retailers' losses reported per week

On average, 116.71 Kg of carrots were lost per acre per season per farmer which was equivalent to Ugx 320,953. Additionally, it was found that 4.42 and 2.23 Kgs of carrots were lost by

wholesalers and retailers per capita per week, the losses were equivalent to Ugx 16,678 and Ugx 9,681 at wholesale and at retail levels respectively (Table 6).

Table 6: The average amount (Kilograms) of carrots lost last season 2020/21 and their causing factors

	Farmers			**Wholesalers**			**Retailers**		
	Quantity (Kg)	**%**	**Value (Ugx)**	**Quantity (Kg)**	**%**	**Value (Ugx)**	**Quantity (Kg)**	**%**	**Value (Ugx)**
Harvesting	2.13	26.0	5,921	-	-	-	-	-	
Late harvest	0.38	4.65	1,056	-	-	-	-	-	
Load/Offload	0.98	12.0	2,724	0.27	6.1	1,019	0	0	0
Dist to Mkt	0.57	6.98	1,585	0	0	0	0	0	0
Transport	0.98	12.0	2,724	0.54	12.22	2,038	0.14	6.2	608
Contamination	0.49	6.0	1,362	0.48	10.86	1,811	0.31	13.	1,346
Storage	1.97	24.1	5477	3.13	70.81	11,810	1.76	87.	7,640.0
Packaging	0.67	8.20	1,863	0	0	0	0.02	0.9	87
Total	**8.17**	**100**	**22,712**	**4.42**	**100**	**16,678**	**2.23**	**100**	**9,681**
Avg farm	**0.07**								
Loss/Acre	**116.71**		**320,953**						

Note:(i) Number of respondents =29 farmers, 28 wholesalers, and 21 retailers

(ii)Average price =2750 Ugx farmers, 3,773 Ugx wholesalers, and 4,340 Ugx retailers,

(iii)Farmers' losses reported per season, wholesalers', and retailers' losses reported per week

An average of 92.11 Kg of kale was lost per acre per season per farmer which was equivalent to Ugx 448,668. Moreover, it was found that an average of 11.64 and 2.51 Kgs was lost by wholesalers and retailers per capita per week, the losses were worth Ugx 75,045 and Ugx 62,038 at wholesale and at retail levels respectively (Table7).

Table 7: The average amount (Kilograms) of kale lost last season 2020/21 and their causing factors

	Farmers			**Wholesalers**			**Retailers**		
	Quantity (Kg)	%	Value (Ugx)	Quantity (Kg)	%	Value (Ugx)	Quantity (Kg)	%	Value (Ugx)
Harvesting method	0.14	1.69	682	-			-	-	
Late harvest	1.54	18.60	7,501	-			-	-	
Load/offload	0.61	7.4	2,971	0.53	4.55	3,417	0.08	3.19	700
Dist to Mkt	0.19	2.29	925	0.11	0.95	709	0.12	4.78	41,825
Transport	0.41	4.95	1997	0	0	0	0.02	0.80	175
Contamination	1.30	15.7	6,332	3.0	25.77	19,342	0.36	14.34	3,150
Storage	2.97	35.87	14,466	8.0	68.3	51,579	1.85	0.74	16,188
Packaging	1.12	13.53	5455	0	0	0	0.08	3.19	700
Total	**8.28**	**100**	**40,329**	**11.64**	**100**	**75,047**	**2.51**	**100**	**62,038**
Avg farm size (Acres)	**0.09**								
Loss/Acre	**92.11**		**448,668**						

Note: Number of respondents = 32 farmers, 19 wholesalers, and 26 retailers

Average price =4871 Ugx farmers, 6447 Ugx wholesalers, and 8,750 Ugx retailers

Farmers' losses reported per season, wholesalers', and retailers' losses reported per week

One-way analysis of variance (ANOVA) was used to determine the mean differences (average) post-harvest losses for farmers, wholesalers, and retailers of tomatoes (Table 8). The P-value was significant at 1% (p=0.000) which implies that the differences in postharvest losses for tomatoes were statistically different for the three tomato value chain actors. Further, the ANOVA 5% (p=0.033) showed that postharvest losses in carrots were statistically different for the three value chain actors (farmers, wholesalers, and retailers).

Table 8: Comparisons of mean tomato, carrot, and kale losses for farmers, wholesalers and retailers

	Tomato	Carrot	Kale
Chain actors	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Farmers	74.517±118.322[a]	1.954±4.356[a]	2.139±6.69
Wholesalers	15.818±10.569[b]	1.836±2.665[b]	1.418±2.405
Retailers	9.061±9.991[c]	0.661±1.496[c]	0.892±2.255

The mean value with different subscripts indicates a significant difference at 1% (p-value ≤ 0.05)

The results of One-way analysis of variance (ANOVA) (Table 9) revealed variations in the postharvest losses for the three vegetables (tomatoes, carrots and kale). Comparison of the mean post-harvest losses for the three vegetables at 1% (p=0.000) showed that these losses were statistically different across the vegetables.

Table 9: Comparisons of mean losses across the selected vegetables' value chains

Vegetable categories	**Mean ± SD**
Tomatoes	47.970±92.384[a]
Carrots	5.026±4.51[b]
Kale	5.367±7.857[c]

Mean values with different subscripts indicate a significant difference at 1% (p-value ≤ 0.01)

4.3 Drivers of postharvest losses in selected vegetables

4.3.1 Drivers of postharvest losses in tomatoes, kale, and carrots

The model explained the drivers for tomato post-harvest losses was significant at 1 % (Prob>F=0.000) across all the value chain actors. The adjusted R^2 was 0.678 for farmers, 0.504 for wholesalers, and 0.774 for retailers. This means that in this model, 67.8%, 50.4%, and 77.4% of the variation in total tomato post-harvest losses experienced by farmers, wholesalers, and retailers respectively, was explained by the independent variables. The results in Table 10 further, indicated that tomato losses for farmers were influenced positively by the tomato production system used (p<0.1), quantity of tomatoes harvested (p<0.01), distance to the nearest market

(p<0.01), loading/off-loading (p<0.1), and mode of transport (p<0.1). The quantity of tomatoes purchased (p<0.01) had a significant and positive effect of PHL for wholesalers. In addition, distance to the nearest market, loading/or offloading, mode of transport, and pests and diseases also affected PHL for wholesalers (p<0.1). For retailers, quantity purchased (p<0.01), loading/or offloading (p<0.01), and pests and diseases (p<0.1) positively affected PHL in tomatoes.

Table 10: Determinants of postharvest losses in tomatoes for farmers, wholesalers, and retailers

	Farmers(N=103)		**Wholesalers (N=51)**		**Retailers (N=67)**	
Variables	**Coef.**	**Std.Err.**	**Coef.**	**Std.Err**	**Coef.**	**Std.Er**
Marital status	0.273	0.167	0.018	1.908	0.136	0.311
1=married 0= unmarried						
Prod. System	0.328*	0.173	N/A	N/A	N/A	N/A
1=rain fed 0 =irrigation						
Membership in Ass/Corp.	-0.100	0.167	0.039	3.771	-0.015	0.120
1=yes, 0 =No						
Qty harvested/purchased	0.045***	0.062	0.054***	0.004	0.050***	0.064
Full-time farming/Trading	0.103	0.168	0.024	6.769	0.102	0.311
1=yes 0 =No						
Loading/ offloading	0.045*	0.230	0.045*	1.812	0.099***	0.147
1=yes 0 =No						
Distance to Market	0.049***	0.075	0.039*	0.590	-0.009	0.047
1=Yes 0 =No						
Nature of roads	0.222	0.147	0.063	3.215	-0.293	0.249
1=Yes, 0 = No						
Mode of Transport	0.297*	0.171	0.051*	2.344	-0.021	0.116
1=yes, 0 = No						
Pests and Diseases	0.527	0.369	0.021*	2.605	0.038*	0.198
1=yes, 0 =No						
Cons	-0.971	0.684	13.443	10.097	0.171	0.501
Adjusted R^2	0.678		0.504		0.774	
F-ratio	22.55		6.65		26.14	

Prob>F	0.000	0.000	0.000

*****, **, *:** Significance level at 1%, 5% and 10%, respectively.

4.3.2 Drivers of postharvest losses in kale

Table 11 shows the determinants of PHL in kale for farmers, wholesalers, and retailers. The model for kale losses was significant at 10 % across all the value chain actors; Prob>F=0.056 for farmers, Prob>F=0.073 for wholesalers, and Prob>F=0.008 for retailers. Based on the adjusted R^2, the independent variables in the MLR models used to determine the factors that influenced PHL among farmers, wholesalers, and retailers explained 51, 45.9, and 65.2 % of the variation in kale losses respectively. Results showed that membership to a farming association or cooperative society ($p<0.1$), and distance to the nearest market ($p<0.05$) positively affected PHL in kale for farmers while fulltime farming and mode of transport negatively affected the losses ($p<0.1$). The results further indicated that membership to a trading association/or cooperative negatively affected PHL for retailers while the quantity of vegetables purchased ($p<0.05$) positively affected kale losses for both wholesalers and retailers (Table11).

Table 11: Determinants of postharvest losses in kale for farmers, wholesalers, and retailers

	Farmers (N=32)		**Wholesalers (N=19)**		**Retailers (N=26)**	
Variables	**Coef.**	**Std.Err.**	**Coef.**	**Std.Err**	**Coef.**	**Std.Err**
Marital status	0.344	0.258	-0.172	0.340	-0.025	0.239
1=married, 0 = Unmarried						
Production system	0.374	0.274	N/A	N/A	N/A	N/A
1=rain fed, 0 = Irrigation						
Member of Ass/Corp.	0.073*	0.333	-0.176	0.432	-0.043*	0.234
1=yes, 0 = No						
Qty harvested/purchased	0.217	0.135	0.051**	0.135	0.062**	0.136

Full-time farming/Trading	-0.080*	0.285	-0.086	0.613	-0.023	0.522
1=yes, 0 = No						
Loading/ offloading	0.539	0.451	0.002	0.225	-0.406	0.263
1=yes, 0 = No						
Distance to Nearest Market	0.052**	0.015	0.122	0.158	0.109	0.092
1=Yes, 0 = No						
Nature of roads	0.442	0.254	0.196	0.544	-0.469	0.419
1=yes, 0 = No						
Mode of Transport	-0.075*	0.297	0.294	0.467	-0.076	0.278
1=yes, 0 = No						
Pests and Diseases	0.319	0.322	-0.247	0.626	-0.397	0.346
1=yes, 0 = No						
Cons	0.807	0.755	-0.349	1.001	0.550	0.999
Adjusted R^2	0.510		0.459		0.652	
F-ratio	3.69		2.70		6.19	
Prob>F	0.0056		0.073		0.008	

*****, **, *:** Significance level at 1%, 5% and 10%, respectively.

4.3.3 Drivers of postharvest losses in carrots

Multiple linear regression was estimated to assess the factors that influence post-harvest losses in carrots among farmers, wholesalers, and retailers. The model was significant at 1 % for farmers and retailers (0.000) and 5 % (0.001) for wholesalers. The R^2 was 0.834 for farmers, 0.728 for wholesalers, and 0.870 for retailers. These results show that the independent variables explained 83.4 %, 72.8%, and 87.0% of the variation in carrots losses experienced by farmers, wholesalers, and retailers respectively. The quantity of carrots harvested per season ($p<0.01$), and the nature of roads ($p<0.1$) positively affected PHL for farmers. In addition, the quantity of carrots purchased ($p<0.05$) positively affected PHL for wholesalers while the mode of transport ($p<0.1$) negatively affected the losses. Furthermore, membership to a trading association/or cooperative ($p<0.1$),

quantity of carrots purchased ($p<0.01$), and distance to the nearest market ($p<0.1$) affected carrots losses for retailers (Table 12).

Table 12: Determinants of postharvest losses in Carrots for farmers, wholesalers and retailers

	Farmers (N=30)		Wholesalers		Retailers (N=21)	
Variables	**Coef.**	**Std.Err.**	**Coef.**	**Std.Err**	**Coef.**	**Std.Err**
Marital status	0.088	0.999	0.224	0.226	-0.188	0.125
1=married, 0 = unmarried						
Member of Ass/Corp.	0.194	0.469	-0.351	0.408	0.026*	0.137
1=yes, 0 = No						
Qty Of Carrots Harvested/Purchased	0.040***	0.588	0.014**	0.004	0.056***	0.085
Delay in harvest/Selling	0.576	0.938	0.423	0.520	0.189	0.170
1=yes, 0 = No						
Loading /offloading	0.222	0.64	0.103	0.202	0.049	0.188
1=yes, 0 = No						
Distance to Nearest Market	0.260	0.602	-0.000	0.001	0.056*	0.035
1=yes, 0 = No						
Nature of roads	0.059*	0.001	-0.369	0.338	-0.051	0.276
1=yes, 0 = No						
Mode of Transport	0.332	0.142	-0.067*	0.331	-0.025	0.127
1=yes, 0 = No						
Pests and Diseases	0.650	0.650	-0.205	0.371	0.237	0.201
1=yes						
Cons	-7.219	2.712	0.015	0.729	0.116	0.398
Adj R^2	0.834		0.728		0.870	
F-ratio	12.84		5.35		16.32	
Prob>F	0.000		0.001		0.000	

*****, **, *:** Significance level at 1%, 5% and 10%, respectively

4.4 Factors influencing farmers' choice of postharvest handling techniques for tomatoes, carrots, and kale

Table 13 shows the factors influencing farmers' choice of post-harvest handling techniques and practices for tomatoes, kale, and carrots (Table 13). The Wald Chi-square value of 82.51 (Prob>chi2 = 0.000 and Prob>chi = 0.007) showed that the likelihood ratio statistics are significant suggesting that predictor variables included in the model were capable of jointly predicting and explaining the choice of post-harvest handling techniques. The results revealed that access to credit influenced the choice of maturity indices (p=0.097) and sorting or grading (p=0.029) methods of postharvest handling. Furthermore, membership to an association or cooperative society (p=0.040 and p=0.080) and average income from vegetable production (p=0.055 and p=0.097) influenced the choice of shade and sorting or grading as methods of postharvest handling respectively. The quantity of tomatoes and carrots harvested (p=0.002 and p=0.000) influenced the choice of maturity index and shade methods of postharvest handling respectively while the quantity of kale harvested (p=0.000) influenced the choice of maturity index. In addition to that, age (p=0.050) and the distance to the nearest market (p=0.000) influenced the choice of shade. Age increased the vegetables' value chain actors' likelihood to adopt shade by 1.6 % while access to credit reduced the likelihood to adopt maturity index and sorting/or grading by 4.7 % and 9.6 % respectively. Membership to an association/cooperative increased the likelihood to adopt shade and sorting/ or grading by 9.5 % and 15.2 % respectively. Income from vegetables increased the likelihood to adopt shade by 17.1 % but reduced the likelihood to adopt sorting/or grading by 14.8 %. Distance to the market increased the likelihood to adopt shade by 10.6 % but reduced the likelihood to adopt sorting/or grading by 19.1 %. The quantity of tomatoes harvested increased the actors' likelihood to adopt maturity index and shade by 25.5 % and 20.3 % respectively. The quantity of kale

harvested reduced the likelihood to adopt the maturity index by 34 % while the quantity of carrots harvested reduced the likelihood to adopt the maturity index and shade by 19.2 % and 8.8 % respectively.

Table 13. Factors influencing farmers' choice of postharvest handling techniques and practices for tomatoes, kale wiki, and carrots

	Maturity Indices		**Shade**		**Sorting/Grading**	
	Coef.	**Std. Err**	**Coef.**	**Std. Err**	**Coef.**	**Std. Err**
Age	-0.287	0.533	0.016*	0.594	-0.155	0.575
Access to credit	-0.047*	0.088	0.291	0.484	-0.096*	0.684
Association/Corp	-0.203	0.485	0.095*	0.484	0.152*	0.397
Income	0.290	0.587	0.171*	0.477	-0.148*	0.451
Distance to Mkt	-0.239	0.183	0.106***	0.276	-0.191***	0.167
Qty harvested Tomatoes	0.255**	0.843	0.203***	0.139	0.381	0.091
Qty harvested Kale	-0.340***	0.088	0.085	0.111	-0.089	0.089
Qty harvested Carrots	-0.192*	0.230	-0.088***	0.219	-0.011	0.235
Constant	3.366	2.323	-0.930**	2.776	1.090	2.383

*Note: ***, **, *; significance level at 1%, 5 % and 10 % respectively.*

Multivariate probit (SML, # draws =2); Number of respondents =115; wald chi2 (24) =82.51.

Log likelihood = -92.444; Prob >chi2 =0.000; Prob>chi2=0.006

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 Socio-demographic characteristics of the vegetable value chain actors

The observed participation of more female actors (75.8 %) in the vegetable value chain could be because the enterprise entails a lot of menial tasks which females are most likely to endure compared to males. Furthermore, the marketing (wholesale and retail) of vegetables was done exclusively by females although the percentage of male farmers was slightly higher (50.4 %) compared to women (49.6%) (Table 3). The chi-square results revealed a significant association ($p=0.001$) in gender between the categories of value chain actors, indicating females' dominance of the vegetable enterprise. These results complement the findings of Dias (2011) who reported that women contribute 58 % of total labor hours in the vegetable production sub-sector in India and they occupy at least 50 % of employment positions in the vegetable export industries in Kenya, Zimbabwe, South Africa and in some of the Latin American countries. The mean age of the respondents is 40 and 34 years for farmers, and traders (wholesalers, and retailers) respectively implying that in the study area, a good number of youths are engaging actively in vegetable trading. According to the East African community definition, a youth is someone aged between 15-35 years of age (Barishansky, 2016). The Analysis of Variance (ANOVA) revealed that age was statistically different ($p=0.029$) across the categories of the value chain actors indicating an association in the age of the value chain actors. Many farmers were married (73.9%) compared to wholesalers (69.1%) and retailers (54.3 %). Moreover, the chi-square results revealed a significant association ($p=0.077$) between marital status and the categories of value chain actors. There were many wholesalers who worked full time (98.2%) compared to farmers (76.5%) and retailers (87.5 %), and in addition to that, there was a significant association between fulltime farming/or trading and the categories of value chain actors ($p=0.000$) indicating that there were more wholesalers who

worked fulltime compared to retailers and farmers. The largest proportion of wholesalers (36.4 %) earned more than Ugx 500,000 per week from vegetables whereas only 23.5 % and 10 % of the farmers and retailers respectively earned the same amount per week. The chi square results revealed a significant difference (p=0.000) between the level of income obtained from vegetables farming/or trading and the categories of the value chain actors. This implies that the income levels from vegetable farming/or trading were different across the three value chain actors.

The fact that all value chain actors had attained on average 8 years of education indicates that actors involved in vegetable farming and trading in Gulu had attained primary-level education and as such can comprehend messages relating to PHH. The results of this study are consistent with the findings of Mtui (2017) which showed an average of 7 years of education for vegetable farmers and retailers respectively, and 8 years for wholesalers. Education is such an important attribute as it enables the value chain actors to process information relating to their farming and trading activities. The average of 7 and 8 years of work experience for farmers, wholesalers and retailers respectively imply that all the value chain actors have enough knowledge and skills to properly manage their enterprises. Muhammad *et al.* (2012) reported that vegetable farmers in Kano, Nigeria had more than 10 years of farming experience which afforded them the managerial skills needed to maximize output.

5.2 The economic quantification of postharvest losses for tomatoes, carrots, and kale

The results revealed that PHL were more severe in tomatoes compared to carrots and kale possibly due to their higher susceptibility to mechanical damages especially bruises and breaks especially during transportation, loading and off-loading. The major causes of economic losses in tomatoes included delays in harvest for farmers, followed by storage conditions with uncontrolled temperature and contamination which affected the losses for wholesalers and retailers as well.

According to Tilahun *et al.* (2019), tomatoes can be harvested at the mature green, breaker, light red, and full ripe stages, and harvesting decisions depend on the target markets and their availability. Due to market challenges, most farmers harvest their tomatoes when they are ripe, a stage at which they are very susceptible to physical damage which leads to their losses. These findings are consistent with those of a study conducted by Gardas *et al*. (2018) which showed that poor storage conditions are one of the principal causing factors of PHL in tomatoes.

For carrots, the harvesting method used, and the storage conditions were the major causes of post-harvest losses. Uprooting was the only method used to harvest carrots in the study area and it caused breaking which made the carrots very susceptible to microbial infections and moisture losses. The results concur with those of Bond (2016) who noted that harvesting methods, injury to carrots, and environmental conditions were the most important factors that caused post-harvest losses in carrots.

The finding that delay in harvesting and contamination were the main causes of PHL in kale mirror the findings of a study conducted by Rahiel *et al.* (2018) which showed that post-harvest losses in leafy vegetables were attributed to a wide range of factors particularly improper storage conditions, mechanical damage, and microbial infections. Kiringia (2018) argued that inappropriate storage conditions above 10°C cause yellowing and excessive moisture losses in leafy vegetables which contribute to both their physical and economic losses.

5.3 Drivers of postharvest losses in tomatoes, carrots, and kale

5.3.1 Drivers of Postharvest losses in tomatoes

The significant relationship between volume of tomatoes harvested and purchased by farmers and traders (wholesalers, and retailers) respectively and postharvest losses in tomatoes implies that

post-harvest losses in tomatoes increased with an increase in the quantity of tomatoes harvested/purchased. These findings could be attributed to the fact that an increase in the volume of tomatoes would require a longer marketing period which would result in losses due to the inaccessibility of proper storage facilities among the value chain actors. The findings of this study concur with those of a study conducted by Santos *et al.* (2020) which revealed that the volume of fruits and vegetables purchased by the value chain actors was one of the principal factors that affected post-harvest losses. Alidu *et al*. (2016) reported similar findings showing that an increase in the quantity of tomatoes harvested by farmers was significantly and negatively related to post-harvest losses in tomatoes. It is important to note that until they are processed or consumed, fresh fruits and vegetables continue to carry out their metabolic activities, particularly respiration, ripening, and senescence which can significantly reduce their shelf-life if they are not stored under optimal conditions (Ziv & Fallik, 2021). The positive association of loading and offloading of tomatoes with increased post-harvest losses in tomatoes indicate that there was rough handling of vegetables during these processes that caused mechanical damages such as bruises, breaking, and softening, these further exacerbate the losses as they increase vegetables' susceptibility to microbial infestations. This concurs with Alhassan & Kumah (2018) who indicated that loading and offloading are one of the most critical stages in the post-harvest chain where most losses occur.

Pests and diseases are among the biggest contributing factors to PHL as they attack crops at both pre-and post-harvest stages (Kiaya, 2014). The findings of this study revealed a significant and positive relationship between pests and diseases, and postharvest losses in tomatoes for wholesalers and retailers. A higher incidence of pests and diseases in tomatoes led to an increase in losses. In most markets, rats were reported as the most common type of pest that affected tomatoes. All tomatoes that were eaten by rats were either discarded or used as animal feed. These

findings complement Kasso & Bekele (2018) who revealed that pests and diseases increased post-harvest losses in horticultural crops, reported that microbial infestations and other pests such as insects, rodents, and birds were among the most critical factors of post-harvest losses in developing countries. Distance to the nearest market was another factor that affected post-harvest losses in tomatoes for farmers and wholesalers. The longer the distance to the market the more losses experienced by the value chain actors. This could have resulted from the fact that tomatoes spend many hours in transit before they reach the market yet respiration which contributes to deterioration continues to occur. This situation is exacerbated by poor and inappropriate packaging materials used coupled with lack of cold storage during transportation. The results of this study complement the findings of Khatun & Rahman, (2019) who found that long distance to the market was one of the factors that contributed the largest share of post-harvest losses in brinjal. Poor packaging materials and sub-optimal temperature conditions during transportation expose produce to physical damage and accelerate spoilage (Elik *et al.,* 2019).

Regarding transportation, the use of motorcycles tomatoes led to an increase in tomato losses for farmers and wholesalers respectively. This could be attributed to the fact that most farmers and wholesalers stay far from the market and therefore have to transport their tomatoes over longer distances and in most cases on poor roads. These results contradict the findings of Ndirangu *et al.* (2017) who found that farmers who used motorcycles to transport their vegetables experienced minimal post-harvest losses compared to those who used vehicles, bicycles, and head. The mode of transport used is an important determinant of physical damage and microbial contamination in fresh produce (Malekian *et al.*, 2015). In addition, the positive and significant relationship between the production system used with postharvest losses in tomatoes implied that the production of tomatoes under rainfed conditions influenced postharvest losses. This could be due to the

undesirable moisture levels during rainy seasons which favor the breeding of diseases and pests causing microorganisms that contribute to postharvest losses in tomatoes.

5.3.2 Drivers of postharvest losses in kale

For kale the significant and positive effect of the volume of kale purchased by wholesalers and retailers on post-harvest losses. implied that an increase in the quantity of kale purchased by wholesalers and retailers led to an increase in the losses. This could be attributed to the small market size resulting in delayed vegetable sales. Rajapaksha *et al.* (2021) reported that small-size markets are caused by poor marketing and awareness channels to connect vegetable value chain actors with buyers. Vegetables have a high moisture content and therefore, a delay in sales would require an extension of their shelf life which can only be achieved under optimal temperature conditions. According to Deoraj *et al.* (2015), high temperature and low relative humidity lead to increased respiration rate, transpiration, and ethylene production in vegetables which are responsible for the deterioration of their quality. Membership to an association/or cooperative was significantly and positively related to post-harvest losses in kale for farmers but negatively related to the losses for retailers. The observation where membership to a trading association/or cooperative led to an increase and decrease of postharvest losses in kale for farmers and retailers respectively could be that membership to a farming cooperatives/or associations entails financial obligations such as mandatory saving, and fee payment. This could have resulted in inadequate financial resources for farmers to properly manage their farms due to the seasonal nature of their farming activities. On the other hand, the vegetable trade is not seasonal and thus, retailers were not adversely affected by their financial obligations in their respective cooperatives/or associations. Moreover, they benefit from low-interest credit which they use to properly manage their activities and consequently reduce losses. These findings contradict the findings of Aidoo *et*

al. (2014) who posited that membership in farmer-based organizations contributes to a reduction in PHL for farmers as they link the farmers with buyers who buy their tomatoes on time and consequently reduce the losses. It was further observed that full-time kale farming was negatively related to post-harvest losses. This could be attributed to the fact that full-time farmers tend to allocate enough time to manage their farm activities. For example, full-time farmers are most likely to effectively manage pests and diseases on the farm which enhances the post-harvest quality of their vegetables leading to reduced losses. Distance to the nearest market was another significant driver of post-harvest losses in kale for farmers. The positive coefficient implied that the longer the distance to the market the more the losses experienced by the farmers; this could have resulted from the long time that kale takes in transit before it reaches the market coupled with inappropriate transport facilities with uncontrolled temperature conditions and poor packaging materials. Brasil & Siddiqui (2018) suggested that optimal temperature in vegetable transportation and storage slows down aging, softening, moisture loss, and microbial infections and hence minimizes losses. The results of this study further revealed a significant and negative relationship between the mode of transport and post-harvest losses experienced by kale farmers. This means that the mode of transport used was associated with lower levels of losses in kale. The use of motorcycles to transport kale reduced post-harvest losses for farmers. This could be explained by the easy access to and affordability of this mode of transport in the study area which enables farmers to take their fresh produce to the market immediately after harvest minimizing moisture losses and physical damage. These findings concur with Gogo *et al.* (2018) who showed that modes of transport are an important driver of post-harvest losses in vegetables and their choice by farmers is determined by the distance to the market.

5.3.3 Drivers of postharvest losses in carrots

For carrots, the observation that postharvest losses in carrots were associated with large volumes of carrots harvested and purchased by farmers and traders (wholesalers, and retailers) respectively, could be because the marketing of a large volume of carrots requires an extension of their shelf life which can only be possible under optimal temperature conditions. It is important to note that all the value chain actors in the study area stored their carrots under normal temperatures and mixed them with other types of vegetables such as tomatoes, green peppers, and onions. According to Ziv & Fallik (2021), high temperature causes excessive moisture loss and favors the growth of microorganisms in vegetables which accelerate their deterioration. The findings of this study concur with Santos *et al.* (2020) which revealed that the volume of fruits and vegetables purchased by the value chain actors was one of the most critical factors that affected post-harvest losses. Membership to an association/cooperative was found to increase carrots post-harvest losses for retailers. This could be caused by high costs associated with the retailer's membership in their respective associations/cooperatives in terms of membership fees, mandatory savings, and related expenses. The longer the distance to the market the more carrots losses experienced by retailers. The long time that carrots took in transit, coupled with other challenges especially poor packaging materials resulted in the breaking of the carrots which leads to losses. This concurs with the findings of Tadesse *et al. (2018)* which indicated a negative relationship between the distance to the market and the post-harvest losses experienced by farmers in potatoes. There was a significant and positive relationship between the mode of transport used and post-harvest losses in carrots experienced by wholesalers. This implies that the mode of transport used decreased postharvest losses in carrots. As was the case for tomatoes and kale, the most common mode of transport used by carrots wholesalers in the study area was by motorcycle. The high accessibility and affordability

of this means of transport encourages many wholesalers to use it which enables wholesalers to take their carrots to the market on time and avoid losses. These findings concur those of Gogo *et al.* (2018) where it was revealed that the mode of transport used was an important determinant of post-harvest losses in vegetables. The nature of roads was found to affect carrot post-harvest losses negatively for farmers. This could be because most roads where farmers grow their carrots are in bad condition. Poor roads characterized by potholes cause breaking and bruising of carrots during transportation which results in post-harvest losses. These results complement the findings of Debebe (2022) which indicated that farmers who stayed far from all weathered roads experienced more post-harvest losses in grains than those who stayed closer to such roads.

5.4 Factors influencing farmers' choice of postharvest handling techniques for tomatoes, carrots, and kale

Objective three of this study was to evaluate the factors influencing farmers' choice of postharvest handling techniques for tomatoes, carrots, and kale. Several socio-demographic factors affected the choice of PHH techniques for tomatoes, kale, and carrots. It is important to highlight that the PHH techniques of the vegetables is very key in reducing PHL. In this study, an increase in age was associated with the adoption of shade to manage postharvest losses in vegetables. This could be due to the fact that the use of shade does not involve a lot of activities like other postharvest handling techniques for example sorting or grading and thus less tedious. These findings are in line with those of Ngowi & Selejio (2019) which indicated a significant and positive relationship between age and the adoption of modern postharvest handling techniques.

Access to credit was negatively associated with farmers' adoption of maturity indices and sorting or grading to manage postharvest losses in vegetables. This implies that the more access to credit farmers have the less likely they are to adopt maturity indices and sorting or grading postharvest

handling techniques. This could be due to the fact that with more financial resources, farmers tend to shift from local and less effective postharvest handling techniques and practices to modernized and more effective ones. These results concur with the findings of Kattel *et al.* (2020) who indicated that access to credit was associated with the adoption of improved postharvest practices for large cardamom. Membership to a farming association or cooperative group was also found to significantly influence the choice of postharvest handling techniques and practices. Farmers who belonged to a farming association or cooperative group were more likely to adopt shade and sorting or grading to manage vegetable losses than their counterparts who did not belong to such entities. This implies that farmers require capacity building to adopt postharvest handling practices, a role that is played by farming associations and cooperatives. These findings are consistent with Akyoo & Sitima (2017) who reported that farmer training on postharvest handling practices was a significant influencing factor in farmers' adoption of improved storage bags for maize. In a similar study, (Allbritton *et al.*, 2017) found that membership in a marketing group or association had a significant and positive influence on tomato farmers' adoption of returnable plastic crates to minimize postharvest losses in tomatoes.

Average income from vegetable farming increased farmers' likelihood to use shade but reduced the likelihood to use sorting or grading to manage postharvest losses in vegetables. This could be due to the fact that grading or sorting is labor intensive and thus more costly; even with higher incomes, farmers preferred shade to sort or grade. The findings of this study are consistent with Balana *et al.* (2022) who argued that income level is one of the most important determinants of the adoption of postharvest techniques and practices for perishable value chains. The results further revealed that distance to the market had a significant and positive influence on the farmers' choice of shade but negatively influenced the choice of sorting or grading. This implies that long distances

to the market increased the farmers' likelihood to adopt shade to minimize the losses but reduced their likelihood to adopt sorting or grading. This could be explained by the high costs associated with sorting and grading. Akello *et al*. (2022) argued that long distances to the market are associated with low motivation to commercialize agricultural produce among farmers; this could be a possible explanation for their minimal efforts in managing postharvest losses.

The quantity of vegetables harvested is also another important determinant of the choice of postharvest handling techniques. High volumes of tomatoes harvested increased farmers' probability of adopting maturity indices and shade to manage postharvest losses. This implies that with more harvest farmers are willing to use several postharvest handling techniques to minimize the risks associated with postharvest losses. This could be explained by the fact that increased farm outputs result from bigger investments and therefore farmers are willing to adopt several postharvest handling techniques to reduce the risks of losing their capital. These findings are in line with those of Mukarumbwa *et al.* (2017)which indicated a significant and positive relationship between the quantity of vegetables harvested and the adoption of postharvest handling techniques. Musasa *et al.* (2015) argued that large farm outputs create a surplus which influences farmers to adopt postharvest handling techniques to minimize the losses and take advantage of new market opportunities.

Large volumes of kale and carrots harvested were negatively associated with farmers' adoption of maturity indices and shade to manage postharvest losses. This implies that the more the volume of kale and carrots harvested the less likely were the farmers to use maturity indices to manage postharvest losses. A possible explanation for this could be that having a lot of vegetables on the farm, farmers would not observe the maturity indices of the vegetables but rather decide to harvest based on market availability. The results further indicated a negative relationship between the

quantity of carrots harvested and farmers' likelihood to adopt shade as a postharvest handling technique. This might be due to the fact that with a large harvest a farmer would want to invest more in advanced postharvest handling techniques and practices and thus the shift from local and less effective ones. These findings concur with Okeke *et al.* (2017), who mentioned that farmers with increased farm outputs tend to invest in improved postharvest handling techniques due to their high-income levels.

CHAPTER SIX: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary

The study focused on quantifying postharvest losses in three important vegetables (tomatoes, carrots, and kale) in Gulu district and Gulu city of northern Uganda, while also evaluating factors influencing postharvest handling techniques and practices among different value chain actors.

The vegetable enterprise in the study area was predominantly led by females, with an average age of 37 years and approximately 8 years of schooling and working experience. A significant association was observed between gender, marital status, full-time farming/trading, income, and access to extension services among the value chain actors.

Tomatoes emerged as the most cultivated and traded vegetable in the study area, and they also exhibited the highest postharvest losses. Postharvest losses were measured as kilograms per capita per season and per week for different actors in the value chain.

For tomatoes, losses were substantial, with 164.96 kg per capita per season for farmers, 19.52 kg per capita per week for wholesalers, and 9.57 kg per capita per week for retailers. Kale losses were significant as well, with 92.11 kg per capita per season for farmers, 11.64 kg per capita per week for wholesalers, and 2.51 kg per capita per week for retailers. Carrots exhibited losses of 116.71 kg per capita per season for farmers, 4.42 kg per capita per week for wholesalers, and 2.23 kg per capita per week for retailers. The study identified various factors driving postharvest losses, including the system of production, quantity harvested or purchased, loading/offloading, distance to the market, mode of transport, pests and diseases, membership in an association or cooperative, and the nature of roads.

The relative importance of these factors varied depending on the vegetable and the category of value chain actor (farmers, wholesalers, retailers). Several determinants influenced the choice of postharvest handling techniques and practices, including age, access to credit, income from vegetables, distance to the market, and the quantity of vegetables harvested.

The study's findings have significant implications for improving postharvest management of vegetables in the study area. Strategies to address losses should be tailored to the specific factors driving those losses. The study emphasizes the need for targeted interventions to reduce postharvest losses, promote food security, and increase income for farmers and other actors along the value chain.

6.2 Conclusion

By identifying the drivers of these losses and the determinants of postharvest handling techniques, this research provides valuable insights for policymakers and agricultural stakeholders seeking to enhance food security, reduce waste, and promote economic sustainability in the region. Addressing postharvest losses in vegetable production is an essential step towards achieving both nutritional and economic goals, benefiting both the farming community and the broader society.

6.3 Recommendations

6.3.1 Policy recommendations

Based on the findings of this study the following recommendations are suggested:

1. Adequate training and capacity-building programs on postharvest losses to help the actors realize the implication of poor postharvest handling of tomatoes, carrots and kale and improve incomes, food, and nutrition security for vegetable value chain actors.

2. Simple and cost-effective postharvest handling technologies should be promoted by the government and other stakeholders to enhance adoption among small-scale farmers, wholesalers, and retailers.

6.3.2 Recommendations for further research

1. This study focused on the quantitative losses of tomatoes, carrots, and kale; future studies may focus on the qualitative losses of these vegetables.
2. This study quantified PHL losses in tomatoes, carrots, and kale for farmers, wholesalers, and retailers. Future studies may focus on quantifying losses for the entire value chain.
3. Future studies may further consider the cost-benefit analysis of existing postharvest technologies and the effects of the adoption of such technologies on the reduction of losses.

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APPENDICES

a) INFORMED CONSENT FORM

Title of the study: ECONOMIC ANALYSIS OF POST-HARVEST LOSSES OF SELECTED VEGETABLES IN NOTHERN UGANDA

Investigator(s): JOHN NEEMA Institution(s) GULU UNIVERSITY **Introduction**

Hello, my name is John Neema, a master's student /researcher from the Department of Rural Development and Agribusiness, Faculty of Agriculture and Environment, Gulu University, Uganda. I am collecting data on the topic: **"Economic Analysis of Post-harvest Losses of Selected Vegetables in Gulu district of Uganda."** This study is purely academic and purposely intended to help researchers understand the economic loss resulting from post-harvest losses of selected vegetables in the Gulu district. You have been selected randomly to participate in this survey. please note that the information provided by you will be treated confidential and there will be no way to identify you as the one who gave specific information. I would be glad if you could spare some time (approximately 30 minutes) to answer our questions.

Thank you

A brief description of the sponsors of the research project

This study is funded by Mastercard RUFORUM in Collaboration with Tagdev Gulu University.

Purpose:

The study seeks to analyze the economic loss resulting from post-harvest losses of selected vegetables in the Gulu district. The study will serve as a suitable tool for agricultural researchers, planners, and policy-makers. It will also avail the farmers with information on the extent of postharvest losses of the selected vegetables as well as their drivers which is key for determining appropriate strategies for reducing such losses. Combating the losses will in return lead to

improved food security and nutrition, and income levels of all the value chain actors. The discoveries of the study will attract the attention of researchers, and promote awareness among scientists, policymakers, consumers, and producers.

Procedures:

Your participation in this study will involve answering the questions while filling in the questionnaires as requested.

Who will participate in the study?

The participants in this study are farmers and traders of tomatoes, carrots, and kale in Gulu district and Gulu city.

Risks/discomforts:

The research team will observe all covid SOPs during the entire period of data collection to mitigate the risk of Covid-19 spread.

Benefits:

The potential benefits of this study are improved food and nutrition, and income levels for vegetable value chain actors, particularly farmers, retailers, and wholesalers. The reduction of post-harvest losses will also improve food availability which in return will result in more affordable and stable food prices thus improving the nutrition and health of consumers. The study will help to determine the drivers of post-harvest losses in vegetables, a key step in designing effective strategies for their reduction. Research participants will also get feedback on the findings and progress of the study, and any new information that affects the study participants (including incidental findings) will be made available to the research participant.

Confidentiality:

Your identity will not be revealed to anyone as we shall only use codes to identify participants. Information obtained will only be accessible to the research team. Soft copies of the data will be protected by password and hard copy files will be kept under lock and key. Confidential information will only be accessed by the principal investigator.

Alternatives:

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.

Cost:

There will not be any additional cost incurred as a result of participating in this study.

Questions:

If you have any questions related to the study or your rights as a research participant, you can contact the principal investigator, JOHN NEEMA on telephone 0788088623 or via email at neyjohn30@gmail.com

Statement of voluntariness:

Participation in the research study is voluntary and you may join of your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any issues with your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, Dr. Gerald Obai Tel: No., 0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; or the Uganda National Council for Science and

Technology, on plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

……has described to me what is going to be done, the risks, the benefits involved, and my rights as a participant in this study. I understand that my decision to participate in this study will not affect me in any way. In the use of this information, my identity will be concealed. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name of participant……Signature/Thumbprint……...Date……. Name of witness……Signature……Date……

Name of interviewer…… Signature……Date……

b) QUESTIONNAIRES

GULU UNIVERSITY

FACULTY OF AGRICULTURE AND ENVIRONMENT DEPARTMENT OF RURAL DEVELOPMENT AND AGRIBUSINESS INTERVIEW SCHEDULE

ON

ECONOMIC ANALYSIS OF SELECTED VEGETABLES POSTHARVEST LOSSES IN NORTHERN UGANDA.

(Farmers)

Dear Respondent,

Request for Response to Questionnaire

I am a master's student of the above-named Department and University and you have been selected as one of the respondents to supply the needed information to address the specific objectives of the study. I, therefore solicit your candid response as objectively as possible to the questions/items in the questionnaire. It is purely academic work therefore all information supplied by you will be strictly treated as confidential and for the research purpose only. Thanks, John, Neema Kasilo

Date: **…….**

District **……**

Sub-County **…….**

SECTION A: SOCIO-ECONOMIC AND SOCIO-DEMOGRAPHIC DATA. PLEASE INDICATE AND TICK WHERE APPLICABLE.

Qn.	**Question**	**Responses**
1	Gender of the respondent	1 = Male 2 = Female
2	Age ***(in completed years)***	
3	Educational Status	1 = Primary 2 = Secondary 3 = Tertiary
4	Marital Status	1 = Married 2 = Single 3 = Widowed 4 = Widower 5 = Separated
6	Farming Experience in Veg. Production (years)	
7	Are you a full-time farmer?	1 = Yes 2 = No
8	If not, what is your other occupation?	
9	What is the estimate of the amount of money realized from the other occupation monthly? (in UGX)	
10	Do you have access to credit?	1 = Yes 2 = No
11	Do you have access to extension services?	1 = Yes 2 = No
12	Are you a member of a farming association/cooperative society?	1 = Yes 2 = No
13	What is the household's average income from vegetable production per month	

SECTION B: VEGETABLE PRODUCTION AND FARMING DECISION

14	What is your major objective in vegetable production?	1= Making Profits 2 = Support the family 3 = Reduce the risk of hunger; 4 = As a way of life; 5 = Have no other option (could abandon farming) 6 = Others (specify
15	What farm size is allocated to vegetable cultivation? In acres	
16	Type of land ownership?	1 = Owned 2= Rented 3=Borrowed
17	What type of seed did you plant in the last season? Tomatoes: Kale (Sukuma) Carrots	1 = Improved 2 = Not improved
18 18 18 18	How much (on average) do you harvest per season? Tomatoes; _____kg Kale (Sukuma);_____kg Carrots;_____Kg	

19	How much do you sell per season? Tomatoes; _____kg Kale (Sukuma);_____kg Carrots;_____Kg	
20	How many (Kg) of vegetable produce are used as food per season? Tomatoes:_____Kg Kale (Sukuma): _____kg Carrots:_____Kg	

21	How many Kgs of vegetable produce were used for other purposes? Tomatoes:_____Kg Kale (Sukuma): _____ Kg Carrots: _____Kg	
22	How do you harvest your produce? Tomatoes; _____ Kale (Sukuma): _____ Carrots; _____	1 = Harvested manually 2 = Harvested with scissors 3= Harvested with a Knife
23	How many Kgs of tomatoes are lost due to the following reason? Harvesting method:_____Kg Time of harvesting _____Kg Loading/Off-loading: Kg Distance to the market: _____Kg Mode of transport: _____Kg Contamination: _____Kg Storage condition: _____Kg Packaging materials: _____Kg	Value of the loss in Ugx

24	How much Kale (Sukuma) is lost due to the following reason? Harvesting method_____Kg Time of harvesting_____Kg Loading/Off-loading:_____Kg Distance to the market_____Kg Mode of transportation: _____Kg Contamination:_____Kg Storage condition:_____Kg	Value of the loss in Ugx
25	How many Kgs of carrots are lost due to the following reason? Harvesting method:_____Kg Time of harvesting:_____Kg Loading/Off-loading: _____Kg Distance to the market: ____ _kg Mode of transport:_____Kg Contamination: _____Kg Storage condition: _____ _____Kg Packaging materials: _____Kg	Value of the loss in Ugx

SECTION C: DRIVERS OF VEGETABLES' POSTHARVEST LOSSES

26	Do you experience a delay in the selling of Tomatoes?	1 = Yes 2 = No
27	Do you experience a delay in the selling of Kale (Sukuma)?	1 = Yes 2 = No
28	Do you experience a delay in harvesting and selling Carrots?	1 = Yes 2 = No
29	Do you experience postharvest losses during loading/offloading?	1 = Yes 2 = No
30	How far is the nearest market where you sell your Vegetables? In Km	

31	What is the nature of the roads for transport?	1 =Murram 2 = Tarmac 3 = Ungraded 4 = Other

32	What is the mode of transportation?	1 = Head 2 = Bicycle 3 = Motorbike 4 = Ox cart 5 = Car 6 = Truck
33	Do you have pest and disease infestation on your vegetable farm?	1 = Yes 2 = No
34	Do you store your farm produce?	1 = Yes 2 = No
33	If yes, what is the storage condition	1= Normal temp 2 = controlled temp
34	Do you pack your produce during transportation?	1 = Yes 2 = No
35	If YES, what are the packaging materials	1 = Plastic bag 2 = Bamboo basket 3 = Wooden crate 4 = Plastic crate;

SECTION D: DETERMINANTS OF THE CHOICE OF POSTHARVEST HANDLING PRACTICES AND TECHNIQUES

36	Do you use any post-harvest handling practices and techniques?	1 = Yes 2 = No
37	If yes, what post-harvest handling practices and techniques do you use in Tomatoes?	
	Maturity indices: Shade: _____ Sorting/grading: _____ Use of improved containers: _____ Washing/hygiene: _____ Solar drying: _____ Cooling: Others (specify): _____	1 = Yes 2 =No
38	If yes; What post-harvest handling practices and techniques do you use in Kale (Sukuma)?	
	Maturity indices: _____ Shade:_____ Sorting/grading: _____	1 = Yes 2 =No

	Use of improved containers: _____ _ Washing/hygiene: _____ Solar drying: _____ Cooling: _____	
39	If yes; What post-harvest handling practices and techniques do you use in Carrots?	
	Maturity indices: _____ Shade: _____ Sorting/grading: _____ Use of improved containers: _____ Washing/hygiene: _____ Solar drying: _____ Cooling: _____ Others: _____	1 = Yes 2 =No

Thank you for your participation.

GULU UNIVERSITY

FACULTY OF AGRICULTURE AND ENVIRONMENT DEPARTMENT OF RURAL DEVELOPMENT AND AGRIBUSINESS INTERVIEW SCHEDULE

ON

ECONOMIC ANALYSIS OF SELECTED VEGETABLES POSTHARVEST LOSSES IN NORTHERN UGANDA

(Wholesalers and retailers)

Dear Respondent,

Request for Response to Questionnaire

I am a master's student of the above-named Department and University and you have been selected as one of the respondents to supply the needed information to address

the specific objectives of the study. I, therefore solicit your candid response as objectively as possible to the questions/items in the questionnaire. It is purely academic work therefore all information supplied by you will be strictly treated as confidential and for the purpose of the research only. Thanks

John, Neema Kasilo

Date: **…….**

District **……**

Sub-County **…….**

Category of the respondent (wholesaler or retailer) **……..**

SECTION A: SOCIO-ECONOMIC AND SOCIO-DEMOGRAPHIC DATA. PLEASE INDICATE AND TICK WHERE APPLICABLE.

Qn.	**Question**	**Responses**
1	Gender of the respondent	1 = Male 2 = Female
2	Age ***(in completed years)***	
3	Educational Status	1 = Primary 2 = Secondary 3 = Tertiary
4	Marital Status	1 = Married 2 = Single 3 = Widowed 4 = Widower 5 = Separated
6	Experience in Veg. selling (years)	
7	Are you a full-time vegetable trader?	1 = Yes 2 = No
8	If not, what is your other occupation?	
9	What is the estimate of the amount of money realized from the other occupation monthly? (in UGX)	
10	Do you have access to credit?	1 = Yes 2 = No
11	Do you have access to extension services?	1 = Yes 2 = No
12	Are you a member of a farming association/cooperative society?	1 = Yes 2 = No
13	What is the household's average income from vegetable sales per month?	

14	What is your major objective in vegetable selling?	1= Making Profits 2 = Support the family 3 = Reduce the risk of hunger; 4 = As a way of life; 5 = Have no other option (could abandon farming) 6 = Others (specify
15	How many vegetables do you purchase per week? A. Tomatoes_____kg B. Curly Kale (Sukuma);_____kg C. Carrots;_____Kg	
16	How many kg of vegetables do you sell per week? A. Tomatoes; _____kg B. Kale (Sukuma);_____kg C. Carrots;_____Kg	
17	How many (Kg) of vegetable produce were used as food? A Tomatoes:_____Kg B. Kale (Sukuma): _____Kg C. Carrots:_____Kg	
18	How many Kg of vegetable produce were used for other purposes? A. Tomatoes: _____kg B. Kale (Sukuma): _____kg C. Carrots:_____kg	

19	How many kgs of tomatoes are lost due to the following reasons Loading/Off-loading: _____ Kg Distance to the market: _____Kg Nature of the road_____Kg Mode of transport: _____Kg Contamination: _____Kg Storage condition: _____Kg Sales delay_____Kg Packaging materials _____ Kg	Value of the loss in Ugx
20	How much Curly Kale (Sukuma) is lost due to the following reasons? Loading/Off-loading: _____ Kg Distance to the market: _____kg Mode of transport: _____Kg Contamination: _____Kg Storage condition: _____Kg Sales delay_____Kg Packaging materials _____ Kg	Value of the loss in Ugx
21	How many Kgs of carrots are lost due to the following reason? Loading/Off-loading: _Kg Distance to the market: _____Kg Nature of the road_____Kg Mode of transport: _____ Kg Contamination: _____Kg Storage condition:_____Kg H. Sales delay _____Kg Packaging materials: _____Kg	Value of the loss in Ugx

SECTION C: DRIVERS OF VEGETABLES' POSTHARVEST LOSSES

22	Do you experience a delay in the selling of Tomatoes?	1 = Yes 2 = No
23	Do you experience a delay in the selling of Kale (Sukuma)?	1 = Yes
		2 = No
24	Do you experience a delay in the selling of Carrots?	1 = Yes 2 = No
25	Do you experience postharvest losses during loading/offloading?	1 = Yes 2 = No
26	Do you have access to extension services?	1=Yes 2=No
27	How far is the nearest market where you sell your Vegetables? In Km	
28	What is the nature of the roads for transport?	1 = Murram 2 = Tarmac 3 = Ungraded 4 = Other
29	What is the mode of transportation?	1 = Head 2 = Bicycle 3 = Motorbike 4 = Ox cart 5 = Car 6 = Truck
30	Do you have pests and disease infestation on your vegetables?	1 = Yes 2 = No
31	Do you store your farm produce?	1 = Yes 2 = No
32	If yes, what is the storage condition	1= Normal temp 2 = controlled temp
33	Do you pack your produce during transportation?	1 = Yes 2 = No

34	If YES, what are the packaging materials	1 = Plastic bag 2 = Bamboo basket 3 = Wooden crate 4 = Plastic crate;
35	How long do you store your vegetable before selling them? A. Tomatoes:_____days Kale (Sukuma)_____days Carrots_____days	
36	On average, how long does it take to sell all your vegetables? Tomatoes_____days Curly Kale: _____days Carrots_____days	
37	Do you sort/grade vegetables? Tomatoes: _____ Kale:__ C. Carrots:	1 = Yes 2 = No

SECTION D: DETERMINANTS OF THE CHOICE OF POSTHARVEST HANDLING PRACTICES AND TECHNIQUES

38	Do you use any post-harvest handling practices and techniques?	1 = Yes 2 = No
39	If yes, what post-harvest handling practices and techniques do you use in Tomatoes?	
	Maturity indices: _____ Shade: _____ Sorting/grading: _____ Use of improved containers: _____ Washing/hygiene: _____ Solar drying: _____ Cooling: _____ Others: _____	1= Yes 2= No
40	If yes; What post-harvest handling practices and techniques do you use in Kale (Sukuma)?	
	Maturity indices: _____ Shade: _____ Sorting/grading: _____ Use of improved containers: _____ Washing/hygiene: _____ Solar drying: _____ Cooling: _____	1= Yes 2= No
41	If yes; What post-harvest handling practices and techniques do you use in Carrots?	

	Maturity indices: _____ Shade: _____ __ _____ Sorting/grading: _____ Use of improved containers: _____ Washing/hygiene: _____ ____ _____ Solar drying: _____ Cooling: _____ Others: _____	1= Yes 2= No

Thank you for your participation.

c) WORK PLAN & TIME FRAME

Task	Responsible Party	November, 2021 – August, 2022									
		Nov – Jan 2022	Jan - Feb	Jan – Feb	Jan – Feb	Feb	Mar	Apr	May - Jun	Jul-Aug	Sep-Nov
Preparation Phase											
Proposal Development and Finalization	PI& S										
Design and Review of survey Instruments	PI & S										
Selection and Training of Enumerators	PI & S										
Pilot of survey Instruments (Test-retest)	PI& E										
Sampling of Study Area	PI & E										
Data Collection Phase											
Field data collection + Back checking	PI & E										
Re-visitation (Attrition)	PI & E										
Data Entry											
Data Entry and Sorting	PI										
Data Analysis											
Statistical analysis (Round 1 and 2)	PI										
Results and Discussions	PI										
Report Writing											
Draft Findings Presentation	PI										
Comments on draft Reports	Supervisors										
Incorporation of Comments	PI										
Final Report	PI & S										

NB: PI-, Principal investigator, S- Supervisors, E - Enumerator

d) POST ESTIMATIONS TESTS

i) Drivers of tomato losses for farmers, wholesalers, and retailers

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    Variable |       VIF       1/VIF
-------------+----------------------
NewQtyHarv~o |      1.64    0.608887
 NewDistance |      1.55    0.643919
LossLoadin~y |      1.39    0.721402
ModeOfTran~y |      1.37    0.731943
MemberOfAs~y |      1.18    0.850896
FulltimeFa~y |      1.16    0.865272
Produ~odummy |      1.15    0.866446
NatureOfRo~y |      1.14    0.879475
Pests_Dise~y |      1.13    0.881096
Maritalsta~y |      1.08    0.924875
-------------+----------------------
    Mean VIF |      1.28

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    Variable |       VIF       1/VIF
-------------+----------------------
ModeOfTran~y |      1.81    0.553580
 Newdistance |      1.75    0.572239
MemberOfAs~y |      1.63    0.614284
Pests_Dise~y |      1.42    0.703393
Fulltimeve~g |      1.40    0.716801
Qty_TomatoP~ |      1.39    0.720036
LossLoadin~y |      1.24    0.806424
Maritalsta~y |      1.20    0.834816
NatureOfRo~y |      1.18    0.845066
-------------+----------------------
    Mean VIF |      1.45
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Variable	VIF	1/VIF
Qty_TomatoP~	1.92	0.520196
Newdistance	1.50	0.665569
Maritalsta~y	1.31	0.761179
ModeOfTran~y	1.30	0.767961
LossLoadin~y	1.28	0.784088
Fulltimeve~g	1.15	0.871633
Pests_Dise~y	1.13	0.885365
MemberOfAs~y	1.13	0.888193
NatureOfRo~y	1.11	0.900952
Mean VIF	1.31	

ii) Drivers of kale losses for farmers, wholesalers, and retailers

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. vif
```

Variable	VIF	1/VIF
NewQtyHarv~a	2.36	0.422863
DistanceTo~t	1.91	0.524660
MemberOfAs~y	1.54	0.651253
Pests_Dise~y	1.51	0.660638
Produ~adummy	1.50	0.666872
NatureOfRo~y	1.40	0.714373
ModeOfTran~y	1.39	0.719274
FulltimeFa~y	1.30	0.768353
LossLoadin~y	1.23	0.810929
Maritalsta~y	1.23	0.814473
Mean VIF	1.54	

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. vif
```

Variable	VIF	1/VIF
ModeOfTran~y	5.87	0.170399
DistanceTo~t	5.55	0.180336
Pests_Dise~y	5.23	0.191189
MemberOfAs~y	3.15	0.317427
NatureOfRo~y	2.93	0.341387
Fulltimeve~g	2.65	0.378061
Maritalsta~y	2.43	0.411472
NewQtySuku~k	1.88	0.532582
LossLoadin~y	1.76	0.566991
Mean VIF	3.49	

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. vif
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Variable	VIF	1/VIF
NewQtySuku~k	3.00	0.333725
ModeOfTran~y	2.15	0.464940
Maritalsta~y	2.01	0.496625
LossLoadin~y	1.94	0.516362
NatureOfRo~y	1.77	0.563922
Pests_Dise~y	1.73	0.578122
MemberOfAs~y	1.53	0.652085
Fulltimeve~g	1.43	0.700473
Newdistance	1.41	0.707048
Mean VIF	1.89	

iii) Drivers of carrots losses for farmers, wholesalers, and retailers

```
. vif
```

Variable	VIF	1/VIF
ModeOfTran~y	1.87	0.536183
LossLoadin~y	1.66	0.600818
Pests_Dise~y	1.60	0.626699
Delay~sdummy	1.44	0.694770
NewDistance	1.38	0.726673
NatureOfRo~y	1.34	0.747766
Maritalsta~y	1.33	0.751471
MemberOfAs~y	1.32	0.755346
inNewQtyCa~t	1.32	0.756721
Mean VIF	1.47	

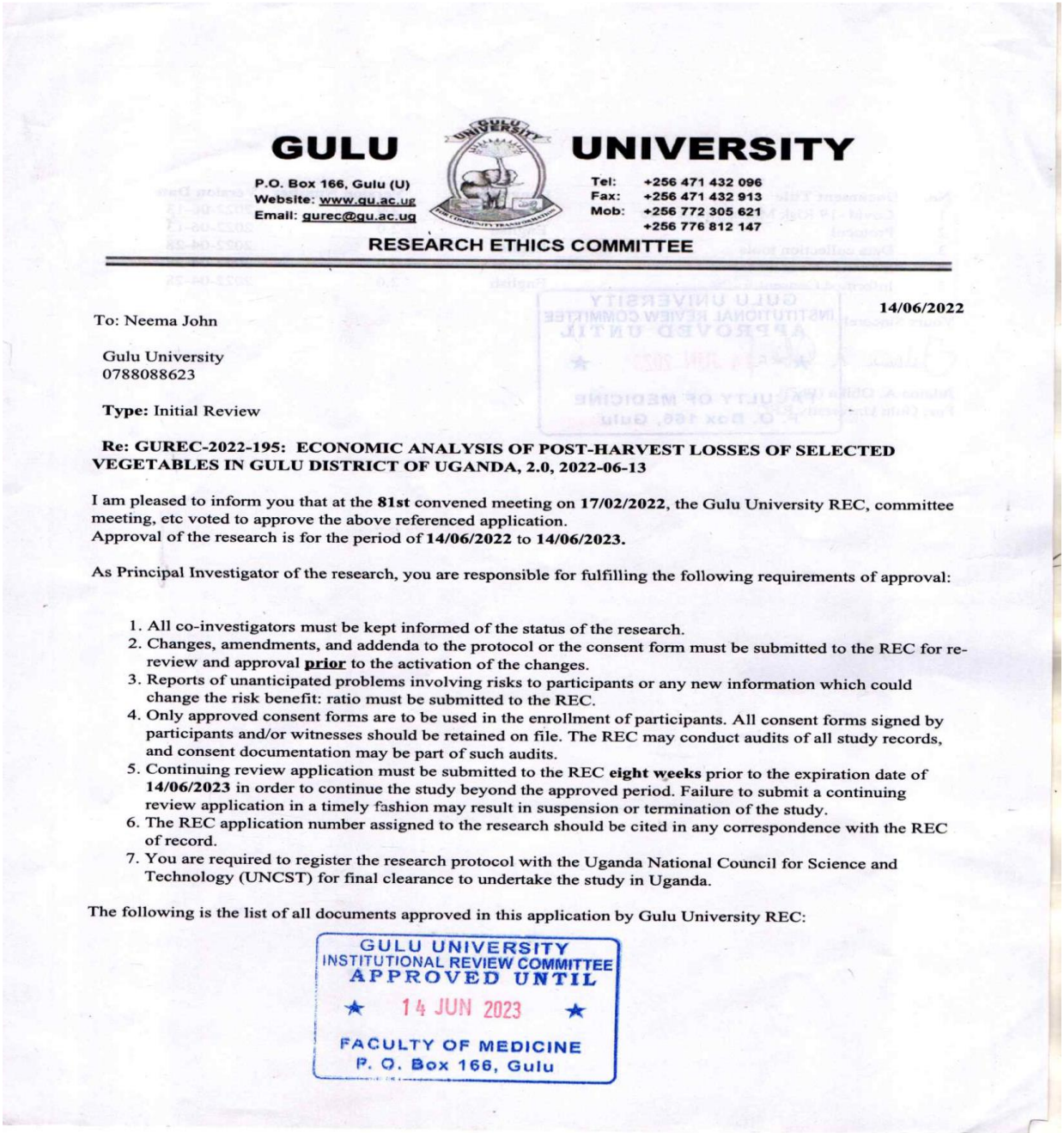
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Variable	VIF	1/VIF
Qty_Carrot..	2.99	0.334459
Pests_Dise~y	2.28	0.438627
MemberOfAs~y	1.88	0.531176
Maritalsta~y	1.87	0.534981
ModeOfTran~y	1.85	0.541557
NatureOfRo~y	1.63	0.614575
DistanceTo~t	1.52	0.657049
DelayInSel~s	1.39	0.720880
LossLoadin~y	1.38	0.724683
Mean VIF	1.86	

. vif

Variable	VIF	1/VIF
DistanceTo~t	2.70	0.371045
ModeOfTran~y	2.64	0.379402
Pests_Dise~y	1.82	0.548462
Maritalsta~y	1.70	0.587033
MemberOfAs~y	1.52	0.657743
DelayInSel~s	1.52	0.658870
Qty_Carrot..	1.43	0.700735
NatureOfRo~y	1.41	0.709944
LossLoadin~y	1.39	0.718143
Mean VIF	1.79	

e). APPROVAL LETTER



GULU UNIVERSITY

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RESEARCH ETHICS COMMITTEE

14/06/2022

To: Neema John

Gulu University
0788088623

Type: Initial Review

Re: GUREC-2022-195: ECONOMIC ANALYSIS OF POST-HARVEST LOSSES OF SELECTED VEGETABLES IN GULU DISTRICT OF UGANDA, 2.0, 2022-06-13

I am pleased to inform you that at the **81st** convened meeting on **17/02/2022**, the Gulu University REC, committee meeting, etc voted to approve the above referenced application.
Approval of the research is for the period of **14/06/2022** to **14/06/2023.**

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **14/06/2023** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of all documents approved in this application by Gulu University REC:

GULU UNIVERSITY
INSTITUTIONAL REVIEW COMMITTEE
APPROVED UNTIL
★ 14 JUN 2023 ★
FACULTY OF MEDICINE
P. O. Box 166, Gulu