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**COMPARATIVE ASSESSMENT OF THE EFFECTIVENESS OF PICS AND
POLYTHENE BAGS IN REDUCING POST-HARVEST LOSSES OF GREEN GRAM**

CASE STUDY: MAGORO SUBCOUNTY, KATAKWI DISTRICT

A dissertation presented to

FACULTY OF AGRICULTURE

in partial fulfillment of the requirements for the award of the degree

Master of Science in Agro-ecology

UGANDA MARTYRS UNIVERSITY

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August, 2025

DEDICATION

This dissertation is dedicated to the loving memory of my late parents, Papa Opio Mark Anthony and Toto Conslanta Acidong, whose unwavering guidance and support laid the foundation of my journey. To my devoted wife, Mary Immaculate Atukei, whose constant encouragement has been my anchor through every challenge. And to my cherished children, whose love and inspiration continue to propel me forward in all that I do.

ACKNOWLEDGEMENTS

First and foremost, I give my deepest thanks to God Almighty, whose boundless grace and strength have guided me through this journey. As it is written, "I can do all things through Christ who strengthens me" (Philippians 4:13). His unwavering presence and wisdom have sustained me in times of challenge and doubt.

I would also like to express my sincere gratitude to my supervisor, Dr. John Bosco Bwambale, for his invaluable guidance, patience, and encouragement throughout the process of completing this dissertation. His insight and constructive feedback have greatly enriched this work and contributed to my growth as a researcher.

My heartfelt appreciation extends to the dedicated staff at Uganda Martyrs University, whose support and resources have been instrumental in my academic journey. I am also deeply grateful to my colleagues, whose collaboration, camaraderie, and shared commitment have made this journey fulfilling. Special thanks go to my friends for their encouragement, understanding, and belief in me, which have fueled my motivation and drive.

To each and every one who has supported me in this endeavor, I am profoundly grateful. May God bless you abundantly.

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LIST OF ABBREVIATIONS

ANOVA	:	Analysis of Variance
CVI	:	Content Validity Index
DV	:	Dependent Variable
FAO	:	Food and Agriculture Organization
HDPE	:	High-Density Polyethylene Independent
IV	:	Independent Variable
Km	:	Kilometer
MAAIF	:	Ministry of Agriculture, Animal Industry and Fisheries
NARO	:	National Agricultural Research Organization
NGOs	:	Non-Government Organizations
OPM	:	Office of the Prime Minister
PHL	:	Postharvest loss
PICS	:	Purdue Improved Crop Storage
RCT	:	Rational Choice Theory
SPSS	:	Statistical Package for the Social Science
SSA	:	Sub Saharan Africa
UBOS	:	Uganda Bureau of Statistics
UMU	:	Uganda Martyrs University
UN FAO	:	United Nations Food and Agriculture Organization
UN	:	United Nations
USAID	:	United Statement Agency for International Development

USD : United States Dollar

WFP : World Food Program

ABSTRACT

In rural Uganda, post-harvest losses remain a major challenge, especially in Magoro Subcounty, Katakwi District, where improper storage, poor handling, and pests reduce crop quality and quantity. Green gram, a key crop in the region, is particularly susceptible to these losses. Effective storage methods are essential for minimizing losses and improving farmers' livelihoods. Purdue Improved Crop storage (PICS) technology and polythene bags have been proposed as potential solutions, but their effectiveness and factors influencing adoption are not well understood. This study aimed to assess farmers' perceptions, the extent of post-harvest losses, and the factors affecting these storage methods, with data collected from 171 farmers and analyzed using SPSS version 20.

Results show that, PICS bags were rated significantly higher than polythene bags across several parameters. Farmers rated PIC bags' effectiveness in reducing spoilage with a mean score of 4.3, compared to 2.9 for polythene bags ($p < 0.001$). Despite this, accessibility and affordability were rated similarly for both types of bags, with no significant difference between the two ($p = 0.367$). On ease of use, PICS bags were also rated significantly more user-friendly, with a mean score of 4.0 compared to 2.2 for polythene bags ($p < 0.001$). However, convenience remained a key factor for some farmers, with a preference for polythene bags due to their lighter weight and ease of transport ($p < 0.001$). Lastly, farmers expressed higher satisfaction with the performance of PIC bags, reporting a mean score of 4.5 compared to 3.2 for polythene bags ($p < 0.001$).

Post-harvest losses in green gram stored in PICS bags were significantly lower than those stored in polythene bags. Storage duration did not show significant differences ($p = 0.921$), but moisture content was significantly lower in PIC bags (14.5%) compared to polythene bags (16.2%, $p < 0.001$). Post-storage weight retention was significantly higher in PICS bags (105.6 kg) than in polythene bags (67.9 kg, $p < 0.001$). No damaged grains were recorded in PIC bags, while significant damage occurred in polythene (32.1 kg, $p < 0.001$) and combined storage methods (28.3 kg, $p < 0.001$).

Regression analysis explained 51.4% of the variance in post-harvest losses (adjusted R-squared = 0.514). Storage conditions showed a marginally significant positive effect on effectiveness (coefficient = 5.329, $p = 0.093$), while the duration of storage exhibited a marginally negative relationship with losses (coefficient = -7.197, $p = 0.079$). However, bag material properties (coefficient = 0.311, $p = 0.932$) and user practices (coefficient = 1.489, $p = 0.682$) did not significantly influence post-harvest losses.

The findings indicate that PICS bags outperform polythene bags in reducing post-harvest losses, preserving grain weight, and maintaining grain quality. It is recommended that farmers in Katakwi District and similar regions adopt PICS bags for more efficient storage of green gram and other legumes. Agricultural extension services should focus on optimizing storage conditions to enhance the effectiveness of storage technologies. Further research is needed to assess the performance of PIC bags across different agroecological zones to identify best practices for reducing post-harvest losses in varying climatic conditions.

Key words: Post-harvest loss, storage, handling, processing and distribution

CHAPTER ONE:

GENERAL INTRODUCTION

1.1 Background

Globally, post-harvest loss (PHL) of food crops remains a significant challenge that impacts food security, nutrition, and incomes for smallholder farmers, particularly in low-income countries. More than one-third of all food produced for human consumption is either lost or wasted, primarily during post-harvest handling, processing, and storage stages, amounting to about 1.3 billion tons per year (Kumar & Kalita, 2017; FAO, 2019). This loss represents a major barrier to achieving global food security goals, especially under growing population pressures and climate-related stresses that heighten the demand for resilient food systems. Consequently, reducing these losses is essential to advancing global development targets such as Sustainable Development Goal (SDG) 2, which aims to end hunger and ensure access to safe and nutritious food by 2030 (Affognon *et al.*, 2015). The financial cost of food loss is vast, estimated at around USD 680 billion in developed countries and USD 310 billion in developing regions (FAO, 2011). Given these figures, enhancing post-harvest management and storage practices is critical for strengthening global food systems and reducing the economic burden on vulnerable regions (World Bank, 2017; WFP, 2019 and FAO, 2020).

In Sub-Saharan Africa (SSA), post-harvest losses are especially high, where roughly 37% of produced food is lost due to inefficiencies in storage, handling, and processing (FAO, 2011). For staple crops such as grains, the economic loss due to these inefficiencies is estimated at nearly USD 4 billion annually, a cost that surpasses the cumulative food aid provided to SSA in the last decade (World Bank *et al.*, 2011; Shee *et al.*, 2019). For smallholder farmers, these losses directly diminish household incomes and food availability, threatening both food security and economic stability in the region (Kaminski & Christiaensen, 2014). Existing storage methods, including traditional granaries, metal drums, and chemical treatments, often fall short in efficacy due to high costs, limited scalability, or health risks posed by chemical residues (Njoroge *et al.*, 2014). As a result, there is an urgent need for sustainable, accessible storage solutions that address both pest control and long-term food preservation (FAO, 2020).

In East Africa, grain crops such as green gram (*Vigna radiata*), which is rich in protein and essential amino acids, are particularly vulnerable to post-harvest losses due to pest infestations (Belitz, Grosch, & Schieberle, 2009; Tadele & Million, 2019). Green gram, alongside other pulses such as pigeon pea, chickpea, and black gram, plays a vital role in food security, contributes to soil health, and supports the sustainability of agricultural systems in the region (Ronner & Giller, 2013). However, in East African countries, effective storage is essential for preserving these grains, which serve as critical dietary components that supplement cereal-based diets and enhance nutritional quality. Due to the lack of reliable storage practices, farmers are often forced to sell their harvests prematurely, reducing their profit margins and limiting the availability of nutritious food sources during the lean seasons (Abass et al., 2014; Shiferaw et al., 2011).

A major factor contributing to these losses is the infestation by storage pests, which can cause substantial damage to stored grains. The cowpea weevil (*Callosobruchus maculatus*) is particularly damaging to pulses, leading to as much as 100% loss within a few months in untreated storage conditions (Moussa et al., 2011; Baoua et al., 2014). Other pests such as the larger grain borer (*Prostephanus truncatus*) and the lesser grain borer (*Rhyzopertha dominica*) also contribute to storage losses in grains, further compromising food security in affected communities (Njoroge et al., 2014; Ngamo et al., 2007). Without adequate pest management, these infestations lead to substantial grain quality deterioration, creating health risks for consumers and decreasing market value for farmers (Niyukuri et al., 2021). Thus, finding effective storage solutions that mitigate pest infestations without chemical treatment has become essential for protecting food stocks (FAO, 2017).

Hermetic storage technologies, such as Purdue Improved Crop Storage (PICS) bags, offer a promising solution to post-harvest losses faced by smallholder farmers in SSA. Developed by Purdue University, PICS bags are made of triple-layered plastic films that form a gas-tight barrier, creating an environment that impedes pest survival (Baributsa et al., 2010). This technology has gained wide acceptance for being chemical-free, cost-effective, and accessible to rural farming communities. Originally developed for cowpeas, PICS bags have since proven effective for a range of grains, including green gram, by reducing oxygen levels to inhibit pest activity (Murdock et al., 2012). This hermetic technology has been widely adopted in SSA and Southeast Asia, where it supports farmers by preserving food quality and quantity through

extended storage periods, thereby improving income and food availability (Baoua et al., 2014; Affognon et al., 2015).

In Uganda, post-harvest losses due to inadequate storage and pest infestation result in an estimated 30-40% reduction in agricultural output annually, translating into considerable financial, nutritional, and food security losses (Ariong et al., 2023; Sheahan & Barrett, 2017). This high level of loss, particularly for staple crops, highlights the need for enhanced storage and handling practices that are accessible to smallholder farmers. Among these technologies, hermetic storage solutions such as PICS bags are increasingly recognized as viable options, as they enable farmers to store grains for longer periods without the need for chemical inputs. Despite this potential, however, the use of PICS bags remains limited due to insufficient awareness and a lack of training in post-harvest management practices. Addressing these gaps through educational initiatives and policy support continues to be an important process for ensuring that farmers can effectively use these technologies (Kaminski & Christiaensen, 2014).

In Katakwi District, Uganda, where green gram cultivation is widespread, farmers face severe challenges in preserving their harvests due to pest infestations and the absence of effective storage solutions. Traditional storage methods, such as the use of ash, sand, and botanical treatments, are common but often unreliable and labor-intensive. Although PICS bags have been introduced, their adoption remains limited, often due to a lack of awareness and training in how to use this technology effectively. Investigating the comparative effectiveness of PICS and conventional polythene bags for green gram storage could offer valuable insights into practical and affordable solutions that can improve food security and farmer incomes in among smallholder farmers (Mompremier et al., 2022; Affognon et al., 2015).

1.2 Problem Statement

Uganda experiences substantial postharvest losses, estimated at Ugx 72 billion per season, due largely to limited investment in effective food loss management (EPRC & Mpuuga, 2023). The introduction of PICS (Purdue Improved Crop Storage) bags, which create an airtight environment to prevent pest infestations, offers a promising, chemical-free alternative to traditional storage methods commonly used by smallholder farmers. These traditional methods frequently rely on polythene or polypropylene bags, which

are affordable but generally ineffective at preventing insect damage and spoilage over time (Baributsa et al., 2010; Moussa et al., 2014). While PICS bags have gained support from local government and development organizations such as SOCADIDO and Uganda Red Cross for distribution in Katakwi District, systematic research comparing the effectiveness of PICS bags to these conventional polythene bags remains limited. Additionally, farmers' knowledge of proper PICS bag use has not been thoroughly assessed, potentially affecting their efficacy. This study seeks to address these gaps by evaluating the performance of PICS bags relative to polythene bags in reducing postharvest losses of green grams, while also assessing smallholder farmers' knowledge of PICS technology in Magoro Sub-County.

1.3 Objectives

1.3.1 Major Objective

The major objective of this study was to assess the effectiveness of PICS bags compared to conventional polythene bags in reducing postharvest losses of green grams in Magoro Sub County. Additionally, the study aimed to evaluate the level of knowledge among smallholder farmers regarding the proper use of PICS bags to ensure optimal storage outcomes.

1.3.2 Specific Objectives

- i. To analyze farmers' perceptions PICS bags versus polythene bags for green gram storage in Katakwi District.
- ii. To assess post-harvest losses of green grams in PICS bags compared to polythene bags in Katakwi District.
- iii. To determine the factors influencing the effectiveness of PICS and polythene bags in reducing green gram post-harvest losses in Katakwi District.

1.4 Research Questions/Hypotheses

1.4.1 Research Questions

- i. What are farmers' perceptions of PICS bags compared to polythene bags for green gram storage in Katakwi District?

- ii. What is the extent of postharvest losses of green grams when stored in PICS bags versus polythene bags in Katakwi District?
- iii. Which factors influence the effectiveness of PICS bags and polythene bags in reducing postharvest losses of green grams in Katakwi District?

1.4.2 Hypotheses

- i. **H₀:** There is no significant difference in farmers' perceptions of PICS bags compared to polythene bags for green gram storage.
- ii. **H₀:** There is no significant difference in postharvest losses of green grams when stored in PICS bags compared to polythene bags.
- iii. **H₀:** No specific factors significantly influence the effectiveness of PICS and polythene bags in reducing postharvest losses of green grams.

1.5 Scope

1.5.1 Subject Scope

The scope of this study centered on evaluating three key aspects of green gram storage in Katakwi District. First, it examined farmers' perceptions of PICS bags versus polythene bags, focusing on their preferences, perceived benefits, and drawbacks of each storage method. Second, it assessed the actual postharvest losses of green grams stored in each bag type, providing a comparative analysis of their effectiveness in minimizing spoilage and pest damage. Finally, the study investigated factors that influence the effectiveness of these storage methods, including storage conditions, usage practices, and farmers' knowledge of proper bag handling to determine their effect on postharvest preservation.

1.5.2 Geographical Scope

The geographical scope of this study was limited to Magoro Sub-County in Katakwi District, located in Uganda's Eastern Region. Katakwi District shares borders with several other districts: Napak to the north, Nakapiripirit to the east, Kumi to the south, Ngora and Soroti to the southwest, and Amuria to the west. The district's central administrative town, Katakwi, lies approximately 55 kilometers (34 miles) north of Soroti, which is the largest urban center in the sub-region (Uganda Bureau of Statistics,

2016). Positioned at coordinates 1.54°N, 34.00°E, Katakwi District is characterized by a predominantly rural population engaged in small-scale agriculture, making it a representative area for examining green gram storage practices among smallholder farmers. This study's focus on Magoro Sub-County reflects the need to assess postharvest losses and storage technologies in a region where farming is a primary livelihood and effective storage solutions could directly impact food security and income stability (EPRC & Mpuuga, 2023).

1.5.3 Time Scope

The time scope of this study spanned from April to October 2024, encompassing the harvest and storage period for green gram farmers in Magoro Sub-County from April to August 2024. This timeframe allowed for data collection during the critical postharvest phase when farmers actively managed their crops. Following the harvest and storage period, September and October were dedicated to data entry, cleaning, analysis, and report writing. This structured timeline facilitated a thorough examination of the effectiveness of different storage methods, particularly PICS and polythene bags, in reducing postharvest losses during this vital period.

1.6 Significance

This study will provide practical benefits to various stakeholders, including smallholder farmers, agricultural policymakers, development agencies, and the academic community.

Smallholder farmers will gain valuable information about the effectiveness of PICS bags compared to traditional polythene bags for storing green grams. Access to details regarding the best storage method for reducing postharvest losses will empower farmers to enhance their crop management practices. Improved storage technology can lead to better quality produce and increased market prices. Additionally, educational workshops based on the study's findings will equip farmers with the knowledge needed to use and maintain PICS bags effectively.

Agricultural policymakers will benefit from data-driven information that informs the development of policies aimed at enhancing food security and agricultural sustainability. The results will advocate for investments in farmer education and technology dissemination programs. Creating regulations or incentives that promote the adoption

of improved storage technologies can significantly reduce postharvest losses at both community and national levels.

Development agencies will find this study useful for designing targeted interventions that address specific challenges faced by farmers in postharvest management. Knowledge gained from the study can guide organizations in offering subsidized PICS bags or facilitating workshops on postharvest loss prevention strategies. Aligning initiatives with the study's findings will enhance the impact of support programs, ensuring efficient resource allocation to assist local farmers.

The academic community will benefit from empirical evidence contributing to the understanding of postharvest management practices in Uganda. Findings from this research can stimulate further studies, encouraging collaboration among researchers, practitioners, and policymakers to develop innovative solutions for agricultural storage challenges. Integrating results into academic curricula will equip future agricultural professionals with the necessary knowledge to tackle postharvest loss issues.

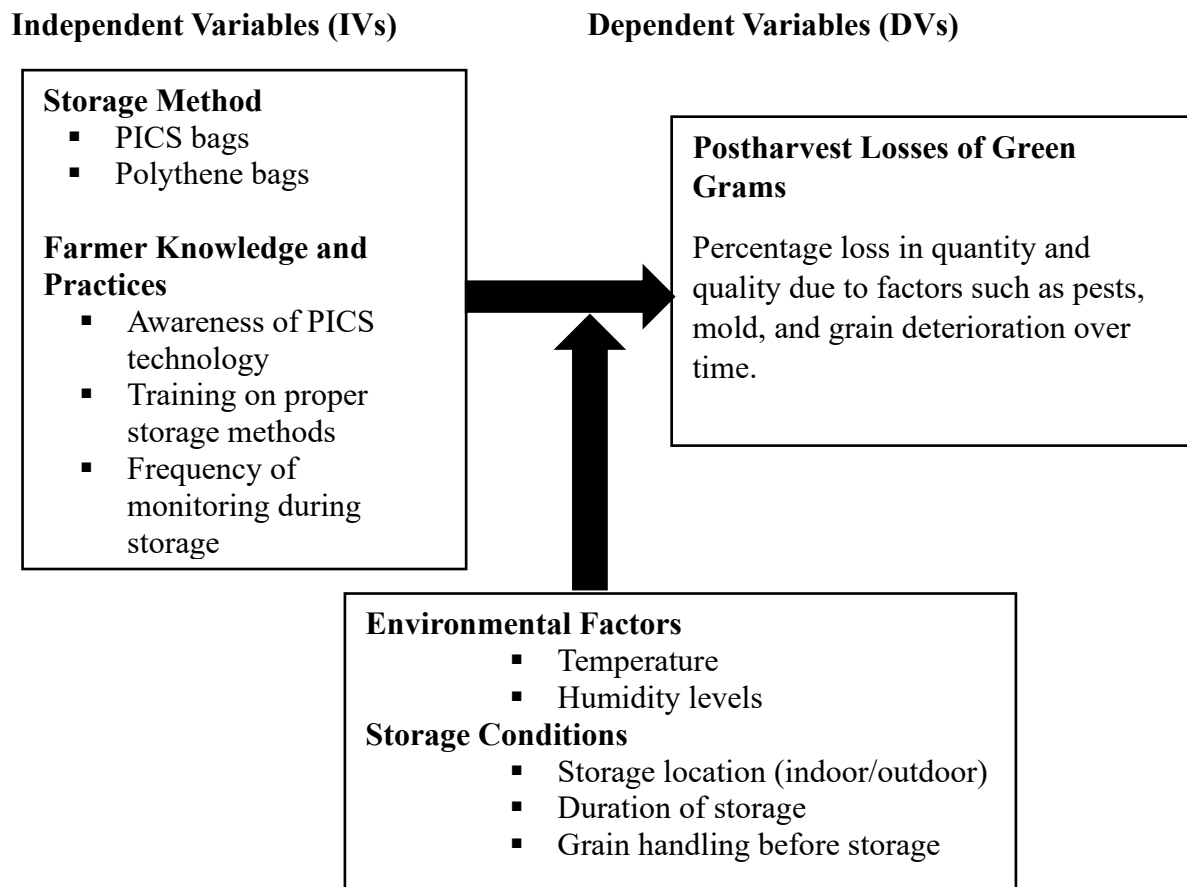
1.7 Justification

This study is justified as it directly aligns with national priorities and the Sustainable Development Goals (SDGs), particularly Goal 2, which focuses on ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture (United Nations, 2015). In Uganda, postharvest losses are alarmingly estimated at 30-40%, significantly hindering food availability and the livelihoods of smallholder farmers (EPRC & Mpuuga, 2023). Addressing these losses is essential for enhancing food security, and the research specifically evaluates the effectiveness of PICS technology in preserving grain quality and reducing pest infestations (Mompremier et al., 2022). Increased interest in PICS technology reflects a shift towards innovative agricultural practices that build resilience against food insecurity, in line with the Ugandan government's strategic objectives outlined in the National Development Plan (Government of Uganda, 2020). This plan stresses the importance of adopting modern storage solutions that minimize waste and optimize resource use. The comparative analysis of PICS bags and traditional polythene bags aims to provide empirical evidence that informs policymakers and guides the development of strategies to enhance food storage practices and reduce postharvest losses (Baoua et al., 2014). Ultimately, the research seeks to empower smallholder farmers through improved

technology adoption, which is vital for achieving both national development goals and global sustainability objectives, thus fostering a more secure and sustainable food system in Uganda (FAO, 2020).

1.8 Conceptual Framework

Figure 1: Conceptual Framework of the Study



Source: Researcher’s construct (2024)

The conceptual framework (figure 1) of this study presents a structured approach to understanding how different factors contribute to the effectiveness of PICS (Purdue Improved Crop Storage) bags and polythene bags in reducing postharvest losses in green gram storage among farmers in Katakwi District. The framework outlines the interaction between three primary variables: independent, dependent, and intervening, each influencing the outcomes of green gram storage in distinct but interconnected ways.

The independent variables include the type of storage method (PICS vs. polythene bags) and farmer knowledge and practices. These variables directly impact the quality and

quantity of stored green grams. PICS bags are designed to maintain an airtight seal, which helps reduce the need for chemical insecticides and minimizes pest-related damage during storage. Polythene bags, in contrast, are more prone to pest infiltration and spoilage due to their non-airtight nature. Farmer knowledge and practices are equally essential, as farmers' understanding of proper storage techniques, pest monitoring, and grain handling significantly affects storage outcomes. Well-informed farmers who are trained in the use of PICS bags and who regularly inspect their stored produce are likely to see improved storage results.

The dependent variable is the extent of postharvest losses of green grams, reflected in the quality and quantity of grain that remains intact during storage. Effective storage methods and good management practices result in lower levels of postharvest losses, characterized by less pest damage, reduced spoilage, and the retention of grain nutritional value. Higher postharvest losses indicate that the storage method or practices may be insufficient, leading to degradation in quality and loss in quantity. Therefore, the study measures the effectiveness of PICS and polythene bags based on how well they preserve the green grams over the storage period.

Intervening variables such as environmental factors (temperature, humidity) and storage conditions (location, duration, and handling) serve as moderating influences that can amplify or mitigate the impact of storage methods and practices on postharvest losses. For instance, high humidity and temperature can accelerate spoilage and pest proliferation, particularly in storage bags that are not airtight. Proper storage conditions, such as keeping the bags in shaded, cool areas, can enhance the effectiveness of the storage method, while poor conditions may negate the benefits of even the best storage techniques. These environmental and situational factors thus play a role in determining the overall success of grain storage.

1.9 Definition of Key Terms

Post-Harvest Loss (PHL)

Post-harvest loss refers to the reduction in quantity or quality of agricultural produce between harvest and consumption. It includes losses during storage, handling, processing, and distribution stages, often due to inadequate storage methods, pest infestations, and unfavorable environmental conditions (Kumar & Kalita, 2017).

Green Gram (*Vigna radiata*)

Green gram, scientifically known as *Vigna radiata*, is a leguminous crop commonly grown in tropical and subtropical regions. It is rich in protein, vitamins, and minerals, making it a valuable food source that supports food and nutritional security (Belitz, Grosch, & Schieberle, 2009).

PICS Bags (Purdue Improved Crop Storage Bags)

PICS bags are hermetic storage bags developed by Purdue University, designed to protect stored grains from pests by creating an airtight environment. This technology minimizes the need for chemical insecticides and is widely adopted in Sub-Saharan Africa due to its affordability, reusability, and efficacy (Baoua et al., 2014).

Polythene Bags

In agricultural contexts, polythene bags are standard plastic bags used for storing grains. Unlike PICS bags, they lack hermetic properties and are often less effective in preventing pest infestations and moisture exchange, which can lead to significant post-harvest losses (Moussa et al., 2011).

Hermetic Storage Technology

Hermetic storage technology involves airtight storage methods that limit oxygen exchange, effectively controlling pests by creating an environment unsuitable for their survival. This technology is crucial for maintaining grain quality and reducing reliance on chemical treatments (Shee et al., 2019).

Smallholder Farmers

Smallholder farmers are individuals or families who operate small-scale farms primarily for subsistence or limited commercial sale. They often face resource constraints, including limited access to advanced storage technologies and practices, which impacts their ability to minimize post-harvest losses (FAO, 2011).

CHAPTER TWO:

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the relevant theoretical framework and literature on key aspects of this study. The chapter is organized around three major areas: (1) farmers' perceptions of PICS bags compared to polythene bags for green gram storage, (2) the extent of post-harvest losses in green gram storage using PICS bags relative to polythene bags, and (3) factors that influence the effectiveness of PICS and polythene bags in reducing post-harvest losses of green grams.

2.1 Theoretical Framework

The Theory of Planned Behavior (TPB), developed by Ajzen (1991), serves as a foundational framework for understanding the factors that influence smallholder farmers' choices regarding the use of PICS (Purdue Improved Crop Storage) bags versus polythene bags for green gram storage. This theory posits that an individual's intention to engage in a behavior is shaped by three primary components: attitudes toward the behavior, subjective norms, and perceived behavioral control. In the context of this study, farmers' attitudes toward PICS bags can be influenced by their beliefs about the effectiveness of these bags in reducing pest damage and spoilage compared to polythene bags. For instance, if farmers perceive PICS bags as superior in preserving grain quality and preventing post-harvest losses, their positive attitude will likely lead to a higher intention to adopt this technology (Ajzen, 1991; Fishbein & Ajzen, 2010).

Subjective norms also play a key role in this decision-making process. Farmers are often influenced by the views and behaviors of peers, family members, and community leaders. If respected individuals within a farmer's social network endorse the use of PICS bags, it can create a sense of social pressure to adopt this storage method (Kelley & Thibaut, 1978). Additionally, perceived behavioral control is essential; it reflects farmers' confidence in their ability to use PICS bags effectively. This confidence can stem from previous experiences with similar technologies, training received on the use of PICS bags, or access to support from agricultural extension services. When farmers feel they possess the skills and knowledge necessary to utilize PICS bags, they are more likely to adopt this storage method, thus demonstrating the relationship between

attitudes, social influences, and self-efficacy as outlined by TPB (Ajzen, 1991; Fishbein & Ajzen, 2010; Krauss et al., 2019).

Complementing the observation provided by TPB, the Diffusion of Innovation Theory proposed by Rogers (2003) offers a broader understanding of how new technologies such as PICS bags are disseminated within agricultural communities. This theory identifies five critical factors that influence the adoption of innovations: relative advantage, compatibility, complexity, trialability, and observability. In the context of this study, PICS bags demonstrate a clear relative advantage over polythene bags. They provide an effective, chemical-free solution for pest control, significantly extending the shelf life of stored green grams (Baoua et al., 2014). Furthermore, these bags align well with the sustainable practices favored by smallholder farmers, which enhances their compatibility with existing agricultural methods and values (Abdallah et al., 2022).

The complexity of using PICS bags is relatively low, as they are designed to be user-friendly, but some initial training may still be required to maximize their effectiveness (Baoua et al., 2014). The concept of trialability is significant; farmers who are able to test PICS bags in a limited capacity or observe their neighbors successfully using them are more inclined to adopt the technology (Rogers, 2003). This observation ties into the final factor of observability: when farmers witness the positive results that their peers achieve with PICS bags, such as reduced spoilage rates, they are more likely to view these bags as a viable option for their own storage needs (Moussa et al., 2011; Murdock et al., 2012).

While the TPB provides valuable knowledge into individual decision-making processes regarding the use of PICS bags, the Diffusion of Innovation Theory emphasizes the broader community dynamics that facilitate or hinder the adoption of new technologies. However, a limitation of TPB lies in its focus on individual perceptions and intentions, which may not fully capture the collective behaviors and cultural influences that also impact farmers' decisions. Conversely, the Diffusion of Innovation Theory may overlook personal factors, such as individual skills, resources, and motivations, which play a significant role in the adoption process. Together, these theories offer a clear framework for understanding the factors influencing the adoption of PICS bags, but their role requires further exploration to provide a holistic understanding of the adoption process in agricultural settings (Krauss et al., 2019; Abdallah et al., 2022).

2.2 Farmers' Perceptions PIC Bags Versus Polythene Bags for Green Gram Storage

Perception, as defined by Robinson (2019), involves the mental processes through which individuals interpret sensory information, leading to an understanding of their surroundings. It is a complex construct shaped by cognitive frameworks that help individuals make sense of new experiences and information. Farmers' perceptions of agricultural practices, for instance, are deeply influenced by personal beliefs, cultural backgrounds, and social contexts (Bourguignon & Ghanem, 2017; (Mekonen & Wubetie, 2021). These factors play a key role in how farmers evaluate and adopt post-harvest management technologies, with their attitudes toward innovations significantly impacting their decision-making processes (Mutungi, *et al.*, 2023)

When examining the perception of PICS (Purdue Improved Crop Storage) bags, studies show that positive attitudes among farmers are often associated with the bags' proven effectiveness in reducing spoilage and managing pest infestations (Baoua et al., 2014; Baributsa & Njoroge, 2020). The hermetic sealing properties of PICS bags prevent oxygen entry, which helps in maintaining grain quality and reducing spoilage compared to traditional storage methods (Okori et al., 2022). Despite these benefits, negative perceptions do persist among some farmers, particularly regarding concerns about usability and initial costs, which may deter broader adoption of the technology (Murtala et al., 2021; Ogema et al., 2018).

Accessibility and cost-effectiveness are other critical indicators that shape farmers' perceptions of PICS bags compared to polythene bags. Although PICS bags are recognized for their durability and long-term value, their higher initial cost relative to polythene bags is often perceived as a barrier by economically constrained farmers (Murtala et al., 2021). Studies find that despite awareness of the long-term benefits, many farmers still opt for cheaper, single-use polythene bags due to immediate financial limitations (Rwebangira et al., 2022). However, programs offering subsidies or installment payments have proven effective in some regions, as they lower the entry barrier for low-income farmers, allowing them to experience the cost-benefit ratio of PICS bags firsthand (Rabé et al., 2022).

Ease of handling is a further aspect influencing the choice between PICS and polythene bags for storage. Research indicates that farmers often find PICS bags more robust and

secure but slightly more cumbersome to handle compared to lightweight polythene bags (Murtala, 2021). PICS bags, being designed for durability, require careful sealing to maintain hermetic conditions, which some farmers perceive as time-consuming (Baoua et al., 2014). However, others appreciate the sturdiness and design of PICS bags, which reduces spillage and allows for easier stacking during transport (Ogema et al., 2018). Training programs that demonstrate effective handling of PICS bags are shown to improve farmers' ease of use perceptions, making the bags a preferred choice over polythene bags (Baributsa & Njoroge, 2020).

Preferences for polythene bags often stem from their convenience and familiarity, especially among farmers with limited exposure to new technologies. It is also revealed that farmers accustomed to polythene bags prefer them for their lighter weight and wide availability, making them a convenient option for short-term storage needs (Aker et al., 2023). Polythene bags also appeal to farmers due to their lower initial costs, even though they lack the long-term durability of PICS bags (Rwebangira et al., 2022). Despite these advantages, it has been shown that the convenience of polythene bags comes at the expense of storage effectiveness, as their permeability allows for moisture accumulation and pest entry (Baoua et al., 2014; Ogema et al., 2018). This contrast highlights that there is still limited awareness about the hidden costs of using polythene bags, especially the losses incurred through spoilage and pest damage (Akrel et al., 2018).

The perception of PICS bags as effective in reducing post-harvest losses is supported by empirical evidence showing a decrease in spoilage rates among users. According to Rabé et al. (2022), farmers report that switching to PICS bags from polythene significantly decreases post-harvest losses, allowing them to store grains longer without the need for chemical treatments. This has a direct effect on household food security and economic stability, as farmers can sell stored grains at optimal prices during off-season months (Heve et al., 2023). This perceived benefit enhances farmers' trust in PICS bags, with some studies suggesting that positive experiences with spoilage reduction lead farmers to endorse the technology within their communities (Okori et al., 2022). Consequently, the perception of improved storage efficiency aligns closely with farmers' actual outcomes, reinforcing the credibility and appeal of PICS bags.

Polythene bags are often perceived as inadequate in protecting grains, an opinion shaped by firsthand experiences of spoilage and pest damage. Farmers in Sub-Saharan

Africa have observed that polythene bags lack the air-tight seal essential for protecting stored grains, a feature that PICS bags provide through hermetic sealing (Baoua et al., 2014). This comparative disadvantage is particularly apparent in humid climates, where polythene bags are prone to moisture accumulation, exacerbating spoilage risks (Baributsa & Njoroge, 2020). In one study, it was observed that, farmers who switch to PICS bags notice an immediate improvement in grain preservation, reinforcing their preference for hermetically sealed bags over traditional options (Murtala, 2021). This indicates a widespread perception that polythene bags are insufficient for long-term storage, prompting a shift toward PICS bags for more effective protection against environmental and pest-related spoilage.

Satisfaction with PICS bags as a storage solution is consistently high among farmers who adopt the technology, with many expressing contentment with the preservation outcomes. Ogema et al., (2018) demonstrated that satisfaction correlates with reduced post-harvest losses and the elimination of chemical preservatives, which aligns with health and safety concerns prevalent in many farming communities (Mekonen & Wubetie, 2021). Farmers also value the cost savings achieved through prolonged grain storage, enabling them to mitigate price fluctuations in the market (Heve et al., 2023). This sense of satisfaction influences farmers' loyalty to PICS bags, leading to positive word-of-mouth recommendations within agricultural communities (Rabé et al., 2022).

Farmers' willingness to recommend PICS bags over polythene bags to their peers reflects a broader community acceptance that is essential for widespread adoption. Studies have found that farmer-to-farmer recommendations are among the most effective means of promoting PICS bags, as trust in peer experiences significantly influences adoption decisions (Baoua et al., 2014). This social endorsement is critical in communities where formal extension services are limited, with farmers often relying on trusted voices to guide their technology choices (Baributsa & Njoroge, 2020). The role of community endorsements highlights the importance of collaborative learning approaches, where early adopters share their experiences and encourage others to transition from polythene to PICS bags. This community-driven model of knowledge dissemination plays an essential role in sustaining the adoption of PICS bags across farming communities (Aker et al., 2023).

Despite the growing body of literature on farmers' perceptions of PICS bags versus polythene bags, a significant research gap exists in understanding how these perceptions vary across different socio-economic and environmental contexts. Existing studies, such as those by Baoua *et al.* (2014) and Baributsa and Njoroge (2020), largely focus on the technical effectiveness of PICS bags and general farmer attitudes, but they do not adequately address how factors like regional climate conditions, economic constraints, and cultural beliefs may shape individual and community perceptions differently. For instance, while some studies highlight positive perceptions tied to reduced spoilage and pest control (Ogema *et al.*, 2018), others show hesitations due to cost and usability concerns, yet these analyses remain fragmented without examining the nuances of these factors in diverse settings (Murtala, 2021). Additionally, most research focuses on Sub-Saharan Africa broadly without considering specific variations within regions, which could provide knowledge into localized barriers or motivators for adopting PICS bags. This gap demonstrates the need for a more granular approach to studying farmers' perceptions, emphasizing the socio-economic diversity that influences adoption decisions. Addressing these gaps could reveal strategies to enhance the accessibility, awareness, and adoption of PICS bags, particularly among farmers in varied economic conditions and cultural contexts who might still rely on traditional storage solutions.

2.3 Post-Harvest Losses of Green Grams in PIC Bags Compared to Polythene Bags

Post-harvest losses (PHL) refer to the reduction in quantity and quality of food crops from the time of harvest until they reach the consumer, often caused by factors such as improper handling, inadequate storage, and suboptimal transportation (Kumar & Kalita, 2017). These losses affect the economic value of crops and reduce food availability, particularly in developing countries where storage infrastructure and preservation methods are limited (Parfitt *et al.*, 2010). The Food and Agriculture Organization (FAO) highlights that PHL can occur at any stage of the post-harvest chain, including during drying, milling, storage, and packaging, especially under conditions that expose produce to moisture, pests, and microbial contamination (FAO, 2013). Crop losses in suboptimal storage environments, such as those with fluctuating temperatures and humidity levels, often lead to accelerated spoilage, mold growth, and loss of nutritional quality (Affognon *et al.*, 2015). These conditions impact staple grains, vegetables, and

pulses like green grams, with estimates indicating that up to 30% of total production is lost post-harvest in some regions due to inadequate storage practices (Gustavsson et al., 2011).

The occurrence of post-harvest losses is attributed to a complex interplay of environmental, biological, and infrastructural factors. Biological agents, such as pests and microorganisms, play a significant role in reducing the quality of stored grains, which may occur when crops are inadequately dried or improperly packaged (Affognon et al., 2015). Further, poor post-harvest handling techniques, like rough loading and unloading, can physically damage crops, leading to increased vulnerability to microbial attacks and subsequent spoilage (Kitinoja et al., 2011). In many low-income countries, limited access to modern storage solutions, such as airtight containers and temperature-controlled environments, exacerbates PHL (Kader, 2005). Additionally, climatic conditions, such as excessive rainfall and high humidity, encourage mold growth and grain discoloration, ultimately reducing both market value and nutritional integrity (Sheahan & Barrett, 2017).

Cowpeas, closely related to green grams and widely cultivated in Africa and Asia, show significant post-harvest advantages when stored in PIC bags rather than polythene bags. A study in Nigeria by Okwu *et al.* (2020) found that cowpeas stored in PIC bags experienced a 75% reduction in losses caused by weevils, which are prevalent in traditional storage methods. This preservation was attributed to the oxygen-restricted environment of PIC bags, which disrupts insect development, effectively extending the shelf life of cowpeas for up to a year (Ogunbayo *et al.*, 2019). Another study in Burkina Faso highlighted that, compared to polythene bags, PIC bags prevented over 85% of moisture ingress, significantly reducing fungal contamination and maintaining cowpea quality (Bambara *et al.*, 2019). Additionally, in Uganda, farmers reported that cowpeas stored in PIC bags retained more nutritional content and quality after several months compared to those stored in polythene, which saw greater pest and mold damage (Adesina *et al.*, 2018). This evidence illustrates the reliability of PIC bags in protecting cowpea grains, especially in humid conditions that often accelerate spoilage in traditional storage options.

Pigeon peas, another legume similar to green grams, benefit from PIC bags' ability to prevent pest infestation and moisture retention compared to polythene bags. In a study

conducted in India, one of the largest pigeon pea producers, PIC bags were found to reduce insect damage by 68%, while polythene bags had little effect on pest control (Panghal et al., 2017). This is due to PIC bags' hermetic design, which creates a low-oxygen environment that hinders pest proliferation (Fana *et al.*, 2020). Furthermore, research in Tanzania revealed that pigeon peas stored in PIC bags retained a higher quality and weight over six months than those stored in polythene bags, which allowed for rapid pest infestation and microbial growth (Mohammed *et al.*, 2018). Another study from Kenya showed that pigeon peas stored in PIC bags had lower moisture content, reducing mold growth and enhancing shelf life compared to conventional storage methods (Ng'ang'a et al., 2017).

Lentils, a close relative of green grams and widely grown in countries like India and Canada, have shown improved preservation in PIC bags compared to polythene bags. In Canada, where lentil quality is a significant market factor, PIC bags were observed to maintain higher nutritional value and reduced pest damage over a year-long storage period (Morrison *et al.*, 2021). A study in Ethiopia demonstrated that lentils stored in PIC bags experienced a 42% decrease in spoilage due to pests compared to polythene-stored lentils, primarily due to the hermetic sealing effect (Fentahun *et al.*, 2020). Additionally, in South Asia, lentils stored in PIC bags were found to resist fungal contamination and retained a more consistent moisture level than those in polythene bags, which are more permeable to moisture (Sultana *et al.*, 2019). Research by Gebretsadik et al. (2018) also supported that PIC bags reduce storage-related nutritional degradation, ensuring the quality of lentils for both export and local markets. These outcomes highlight the efficacy of PIC bags in maintaining lentil quality across diverse climatic conditions.

Mung beans, which are botanically similar to green grams, exhibit significant storage benefits in PIC bags over polythene alternatives. In Bangladesh, where mung beans are a dietary staple, studies have shown that PIC bags reduce storage-related losses by 62%, mainly by preventing pest access and moisture-induced spoilage (Hossain *et al.*, 2020). Another study in Myanmar found that mung beans stored in PIC bags experienced far less mold growth than those in polythene bags, which allowed air and moisture infiltration (Nayak *et al.*, 2019). In Thailand, researchers reported that PIC bags extended the shelf life of mung beans by nearly double compared to polythene, retaining better flavor and appearance over six months (Nampak *et al.*, 2018). Moreso,

a study from Kenya found that PIC bags reduced insect damage in mung beans by 53%, highlighting the effectiveness of hermetic storage in pest-prone regions (Ochieng et al., 2018).

Black gram, another legume closely related to green grams, benefits from the improved pest and moisture protection provided by PIC bags compared to polythene bags. Research in India, a major black gram producer, found that PIC bags reduced insect infestations by nearly 72%, while polythene bags allowed for greater pest access (Kumar et al., 2018). This reduction is attributed to the hermetic environment in PIC bags, which inhibits pest reproduction and thereby extends storage periods without spoilage (Singh et al., 2019). Studies in Nepal highlighted that black gram stored in PIC bags maintained higher moisture stability, reducing mold growth and aflatoxin risk compared to traditional bags (Khanal et al., 2020). Research from Uganda also indicated that black gram stored in PIC bags had better quality retention, with less discoloration and odor compared to polythene-stored grains (Ademola et al., 2017).

Chickpeas, widely grown in regions such as India and the Middle East, show improved post-harvest outcomes in PIC bags compared to polythene. Studies in Egypt indicated that chickpeas stored in PIC bags had reduced moisture uptake, retaining a higher quality over a nine-month period compared to polythene-stored chickpeas, which experienced rapid spoilage and pest infestation (Abdel-Aziz et al., 2020). In Morocco, chickpeas stored in PIC bags displayed less insect activity and mold development, with polythene-stored chickpeas showing up to 28% more spoilage (Mellah et al., 2019). Research in India further demonstrated that chickpeas retained nutritional value and flavor better in PIC bags, which prevented both moisture ingress and pest activity (Sethi et al., 2019). Additionally, studies by Soltani et al. (2018) in Tunisia showed that PIC bags extended chickpea shelf life significantly compared to polythene, highlighting the potential for reducing losses in local markets.

Field peas, another legume cultivated in temperate regions, benefit from PIC bags' hermetic protection, especially in comparison to polythene storage. In Canada, a leading producer of field peas, studies have shown that PIC bags minimize spoilage and pest infestation, leading to a 37% reduction in storage losses compared to polythene bags, which lack airtight sealing (Aldrich et al., 2021). In Australia, field peas stored in PIC bags maintained their nutritional profile and exhibited minimal fungal

contamination over six months, whereas polythene-stored peas faced significant spoilage (Grain Research and Development Corporation, 2018). A study in Ethiopia further demonstrated that field peas in PIC bags had a lower incidence of insect damage and retained better physical quality than those stored in polythene bags (Suleiman et al., 2019). Another study in China found that PIC bags enhanced field pea quality by limiting moisture ingress and protecting against aflatoxin-producing molds (Li *et al.*, 2020). These outcomes confirm that PIC bags are highly effective in extending the shelf life and quality of field peas across different production regions.

Despite the growing body of research on post-harvest losses in pulses, including green grams, significant gaps remain in understanding the localized effects of various storage methods on nutritional quality and economic viability in smallholder farming contexts, particularly in Uganda. While numerous studies have evaluated the efficacy of hermetic storage systems and their impact on reducing pest infestations, fewer investigations focus on the long-term implications of these methods on the nutritional retention of pulses over extended storage periods. Additionally, the socio-economic factors influencing the adoption of improved storage technologies among smallholder farmers in Uganda remain underexplored. Addressing these gaps is essential for developing strategies that enhance food security and livelihoods in the region, ultimately contributing to the sustainability of agricultural practices in the face of increasing climate variability.

2.4 Factors Influencing the Effectiveness of PIC and Polythene Bags in Reducing Green Gram Post-Harvest Losses

The effectiveness of PICS and polythene bags in reducing post-harvest losses is heavily influenced by storage conditions, which include temperature, humidity, and ventilation. According to a study conducted in India, farmers reported that storing legumes in cool, dry places significantly decreased the incidence of pest infestations, thereby enhancing the longevity of their harvests (Kumar *et al.*, 2019). Similarly, research in Kenya demonstrated that farmers utilizing controlled storage environments experienced up to a 40% reduction in post-harvest losses compared to those with poor storage practices (Mokaya et al., 2020). The study emphasized the need for training on ideal storage conditions, as many farmers lacked awareness of how ambient conditions could affect legume quality. Furthermore, a survey of smallholder farmers in Bangladesh revealed that those who received education on moisture management were able to maintain

higher seed quality over time (Rahman et al., 2021). This correlation between knowledge and storage practices illustrates the vital role of education in improving post-harvest outcomes. The findings suggest that increased awareness of proper storage conditions is essential for maximizing the effectiveness of both PICS and polythene bags.

On another note, the properties of bag materials used for storage directly has been associated with the quality and safety of legumes. A study conducted in Ethiopia found that farmers using PICS bags, designed with multiple layers to minimize oxygen and moisture, reported lower levels of insect damage compared to those using traditional jute bags (Abebe et al., 2020). The study noted that the physical characteristics of the bags, including permeability and durability, were critical factors influencing farmers' decisions. A comparative analysis in Nigeria highlighted that farmers were increasingly aware of the advantages of polythene over other materials, which offered better resistance to moisture and pests (Adesina et al., 2021). In this study, it was observed that farmers who understood the importance of bag material properties were more likely to invest in high-quality storage solutions. This knowledge was linked to a 30% decrease in post-harvest losses among those who prioritized appropriate materials for storage. Additionally, training initiatives focused on material properties were associated with enhanced farmer confidence in managing post-harvest challenges effectively. Thus, educating farmers about the unique benefits of different bag types could lead to more informed choices that enhance storage efficacy.

Furthermore, user practices significantly influence the effectiveness of PICS and polythene bags in reducing post-harvest losses. A study in Ghana revealed that improper handling and inadequate sealing of storage bags led to increased losses from pests and moisture ingress (Mensah et al., 2020). Farmers who received training on best practices for sealing and handling storage bags reported a marked improvement in their ability to protect stored legumes. This study highlighted that user practices, including cleanliness and bag maintenance, were key areas where farmers needed more education. Furthermore, a qualitative assessment in Uganda showed that awareness of the importance of periodic inspections of stored legumes was associated with lower pest incidences and better overall quality (Obua *et al.*, 2021). Farmers who actively engaged in regular monitoring were able to address issues promptly, thereby minimizing losses. Thus, fostering good user practices through targeted training significantly enhances the

effectiveness of storage technologies, consequently, farmers reencouraged to regularly inspect and maintain the storage devices to extend the shelf life of the storage grain and reduce post-harvest losses in legumes.

The duration for which legumes are stored before consumption or sale is another factor in managing post-harvest losses. A study conducted in Tanzania highlighted that farmers who were aware of the optimal storage duration for legumes experienced less quality degradation and fewer pest infestations (Kihara *et al.*, 2022). This study indicated that a significant number of farmers were unaware of the negative impacts prolonged storage could have on legume viability and marketability. Specifically, a study in Mozambique revealed that many farmers stored legumes for extended periods without understanding the risks involved, leading to increased losses over time (Machava *et al.*, 2021). This lack of knowledge about duration was linked to insufficient training on post-harvest handling and storage practices. The study suggested that providing farmers with clear guidelines on storage timelines could enhance their management practices and reduce losses. A focus on educating farmers about the ideal storage duration tailored to specific legumes could foster better market outcomes and food security.

On another note, the cost and accessibility of storage technologies play a pivotal role in farmers' adoption and effective utilization. A survey in India revealed that while PICS bags were more effective at reducing post-harvest losses, the initial cost was a barrier for many smallholder farmers (Patel *et al.*, 2020). The study found that farmers who had access to subsidized storage options reported significantly better outcomes than those without financial support. Additionally, a comparative study in Brazil indicated that the availability of affordable storage solutions was critical for widespread adoption among smallholder farmers (Santos *et al.*, 2021). This research highlighted that when farmers were aware of cost-effective options, they were more likely to invest in improved storage technologies. Furthermore, farmers who participated in community-based training programs were able to share resources, which further enhanced their access to effective storage solutions. Thus, creating awareness around affordable storage technologies was found to be essential in promoting their use among resource-limited farmers hence ensuring that farmers understand the long-term economic benefits of investing in high-quality storage.

Farmer education and training are fundamental in enhancing the knowledge necessary for effective post-harvest management. A study in Malawi indicated that farmers who participated in training programs on PICS and polythene bag usage demonstrated a marked improvement in their post-harvest practices (Phiri et al., 2020). This study showed that education increased awareness about the long-term benefits of using improved storage technologies, leading to better adoption rates. Furthermore, research in Pakistan highlighted that farmers with formal education were more likely to seek out and apply new storage techniques, resulting in lower losses (Khan et al., 2021). A comparative analysis in South Africa revealed that continuous education and peer-to-peer learning significantly impacted farmers' ability to manage post-harvest losses effectively (Van der Merwe et al., 2022). Such initiatives fostered a culture of knowledge sharing that empowers farmers to adopt best practices confidently. The evidence clearly indicates that enhancing farmers' education and training is a strategic approach to improving post-harvest management and reducing losses in legume production.

Despite the growing body of research on the effectiveness of PICS and polythene bags in reducing post-harvest losses of legumes, there remains a significant gap in understanding the specific mechanisms through which farmer education influences storage practices across diverse socio-economic contexts. Most studies have highlighted the benefits of improved storage technologies and the importance of monitoring and maintenance; however, few have explored how varying levels of education and training impact farmers' ability to implement these practices effectively. Additionally, there is limited research examining the long-term effects of targeted training programs on the sustainability of storage solutions and their influence on post-harvest loss reduction over time.

2.5 Conclusion

This chapter has systematically reviewed the relevant theoretical framework and literature concerning the study's key areas: farmers' perceptions of PICS bags compared to polythene bags for green gram storage, the extent of post-harvest losses associated with these methods, and the factors influencing their effectiveness in reducing such losses. Observations indicate that while farmers generally recognize the benefits of PICS bags, particularly in reducing pest incidence and improving seed quality, there is

variability in their adoption rates influenced by socio-economic factors and access to training. Additionally, the analysis of post-harvest losses highlights that PICS bags tend to perform better in maintaining grain quality; however, the extent of loss reduction is often contingent upon user practices and storage conditions. Despite these outcomes, a significant research gap remains in understanding how specific socio-cultural and economic contexts shape farmers' perceptions and practices regarding the use of PICS and polythene bags. There is a need for deeper exploration into the relationship between farmer education, community dynamics, and the sustained effectiveness of these storage technologies over time. Addressing this gap could lead to more tailored educational programs and interventions that enhance the practical application of storage solutions, ultimately contributing to improved post-harvest management and reduced losses in green gram production.

CHAPTER THREE:

RESEARCH METHODOLOGY

3.0 Introduction

This chapter outlines the study's design, methods, and techniques for data collection and analysis. It covers essential elements such as the research design, study area, target population, sampling procedures, including sample size and sampling techniques, data collection methods and instruments, quality control measures, data management and processing, and data analysis strategies. Additionally, it addresses ethical considerations, as well as the study's limitations and delimitations.

3.1 Research Design

A cross-sectional research design was selected for this study to evaluate the effectiveness of PICS bags versus conventional polythene bags in reducing post-harvest losses of green grams in Katakwi District. This design is particularly suited for studies aiming to compare groups at a single point in time, without the need for extended follow-up periods. A cross-sectional approach allows researchers to capture specific variables simultaneously, providing a snapshot that is ideal for comparing the performance of storage methods in this case (Creswell & Creswell, 2018).

A cross-sectional design is advantageous in agricultural studies where rapid assessments of intervention efficacy are required. It is often utilized when researchers need to assess differences across groups with distinct characteristics or conditions (Bhattacharjee, 2012). For this study, the design enabled the analysis of storage effectiveness and factors influencing storage outcomes without being influenced by temporal changes, making it practical for assessing immediate storage outcomes under the specific conditions faced by smallholder farmers in Katakwi District. Additionally, the cross-sectional approach supports the use of quantitative data collection, which strengthened the objectivity and reliability of comparisons (Bryman, 2016).

The choice of this design also aligns with the study's aim to evaluate farmers' perceptions and knowledge regarding PICS bag use compared to polythene bags. This focus on comparative perceptions required a design that could capture data from multiple groups concurrently, thus making cross-sectional analysis essential. Furthermore, this approach allowed for hypothesis testing within the framework of the

study, enabling a statistical examination of the significance of differences between storage methods (Mertens, 2014).

3.2 Area of Study

The study was conducted in Magoro Sub-County, situated in Katakwi District within Uganda's Teso subregion in Eastern Region. This area experiences a semi-arid climate, with bimodal rainfall patterns typically occurring between March and May, and September and November. The annual rainfall averages between 750 to 1,000 millimeters, which is suitable for drought-resistant crops like green grams. Temperatures in Teso are generally warm, averaging between 22°C and 30°C, offering an ideal environment for green gram cultivation. However, rainfall variability sometimes poses challenges for farmers, impacting crop growth and requiring careful management of planting times to maximize yield potential (Uganda National Meteorological Authority, 2019).

The soils in Magoro are primarily sandy loams, characterized by good drainage and moderate nutrient levels, creating favorable conditions for green gram cultivation. These soils support root growth and reduce risks associated with waterlogging, which can otherwise lead to root and stem diseases. Sandy loam soils are also less prone to compaction, which is beneficial for legumes that rely on nitrogen fixation for growth. However, limited soil fertility remains a challenge, as it necessitates careful nutrient management practices to maintain productivity levels (Tumuhairwe et al., 2020).

Pests and diseases pose significant challenges to green gram production in this region. Common pests include aphids (*Aphis craccivora*) and pod borers (*Helicoverpa armigera*), which lead to substantial yield losses if not effectively managed. Post-harvest storage pests, particularly the cowpea bruchid (*Callosobruchus maculatus*), are also prevalent, infesting stored green gram grains and causing extensive damage. Warm and humid storage conditions in the region often facilitate pest proliferation, worsening the losses. The high temperatures typical in Teso Subregion exacerbate these conditions, making pest management critical for preserving stored produce. Given these challenges, promoting improved storage technologies, such as PICS bags, became essential for reducing post-harvest losses, minimizing pest damage, and safeguarding the livelihoods of smallholder farmers by ensuring they retain more of their harvest for sale or consumption (Nduku et al., 2013; Murdock et al., 2012).

3.3 Study Population

The study population consisted of 300 farmers who were trained in the use of PICS bags by the Community Development Office in partnership with the Agricultural Extension Service in 2020. These farmers used PICS bags, polythene bags, or both for storing their green gram harvests. The selection of this population was based on their direct involvement in post-harvest storage practices, specifically those using different storage methods to preserve their crops.

3.4 Sampling Procedure

This involves sample size determination and sample size selection across the different parishes (strata) in the study area (Magoro subcounty).

3.4.1 Sample Size

Sample size refers to the number of participants or units selected from the total population to be included in a study (Cochran, 1977). In this study, the total population of Green Gram farmers who attended the training on the use of PICS bags is known ($N = 300$). To determine the appropriate sample size, a margin of error (e) of 5% was used. The sample size was calculated using **Yamane's (1967) formula** for a finite population, which is:

$$n = \frac{N}{1 + N(e)^2}$$

Where, N = Total population (300 farmers) and e = is the desired Margin of error set at (0.05), which is typical for studies aiming for a 95% confidence level. Thus, substituting,

$$n = \frac{300}{1 + 300(0.05)^2} \approx 171$$

Therefore, with a population of 300 farmers and a 5% margin of error, a sample of 171 green gram farmers was sufficient to achieve reliable results while maintaining the desired precision.

3.4.2 Sampling Strategy

Stratified Random Sampling was used to ensure that each subgroup within the population was adequately represented in the sample. Stratified sampling is considered an effective method when the population is heterogeneous, as it allows for a more accurate representation of the diverse characteristics within the population (Cochran,

1977). This technique improves the precision of the estimates by ensuring that every subgroup is represented proportionally, reducing the possibility of bias and increasing the reliability of the results (Kumar, 2011).

In this study, stratified random sampling was applied to select 171 Green Gram farmers from the total population of 300. The sample size for each of the five parishes; Kamenu, Omasia, Oriau, Magoro, and Opeta, was determined through proportional allocation. This approach involved calculating the percentage of the total population in each parish and applying it to the total sample size. The sample for each parish was then drawn based on these proportions, ensuring that each parish contributed a representative share of the total sample (Bryman, 2016). For instance, Kamenu parish, which had 79 farmers, contributed 45 participants, reflecting 26.3% of the total sample size, and so on for the other parishes.

Table 1: Stratified Random Sampling

Parish	Population (N)	Sample Size (n)	Percentage of Total Sample (%)
Kamenu	79	45	26.3%
Omasia	65	37	21.6%
Oriau	74	42	24.6%
Magoro	42	24	14.0%
Opeta	41	23	13.5%

After determining the proportional sample sizes for each parish, random selection of participants was conducted to ensure that the sample accurately represented the broader population of Green Gram farmers. A random number generator was employed to select individual farmers from a list of those registered in each parish. The list was compiled from the records provided by the Community Development Office and the Agricultural Extension Service. The random number generator was used to assign numbers to the farmers, and a specified number of individuals was selected from each parish based on the proportional allocation established earlier (Fowler, 2014).

To carry out the selection, a list of farmers in each parish was arranged in random order, ensuring no systematic bias. The number of selected participants from each parish was predetermined by the proportional allocation. For instance, in Kamenu, which had a

sample size of 45, the random number generator was used to select 45 farmers from the 79 registered farmers (1 3 5 6 9 10 11 13 15 16 17 18 20 22 23 25 26 27 28 29 30 32 33 34 35 40 41 42 43 45 46 47 50 54 57 58 60 63 65 66 68 69 71 74 75). This process was repeated for each parish, including Omasia, Oriau, Magoro, and Opeta, ensuring that the correct number of farmers was selected for each group based on the predetermined proportions. The use of a random number generator helped eliminate any potential biases in the selection process and gave every farmer within a parish an equal chance of being selected.

The use of random selection was essential for ensuring that the sample was representative of the entire population, as it reduced the risk of bias in the selection process and enhances the reliability of the findings (Cochran, 1977). This methodology ensured that the study's results could be generalized to the broader population of Green Gram farmers in Magoro Sub-County, providing more accurate findings into the effectiveness of PICS bags and polythene bags in reducing postharvest losses.

3.5 Data Collection Methods and Tools

The survey method in this study was employed to systematically gather data on the post-harvest storage practices of Green Gram farmers across five parishes in Magoro Sub-County. This approach involved designing and implementing a structured process to reach a sample of 171 farmers, representing the broader population of 300 farmers trained on PICS bag usage. The survey format allowed the researcher to capture essential information regarding farmers' experiences with PICS bags and polythene bags, and provided a basis for statistical analysis to assess the effectiveness of these storage methods. After determining the sample size and selecting respondents using stratified random sampling, trained enumerators administered the survey to ensure that data was collected consistently across all parishes. Enumerators followed a standardized protocol, asking each participant the same questions to reduce bias and enhance data comparability. The survey was conducted in a face-to-face manner, allowing the enumerators to provide necessary explanations and capture reliable data directly from the participants, ensuring each farmer's responses were accurately recorded and aligned with the study's objectives.

To support the data collection within the survey method, a semi-structured questionnaire (Appendix 1) was developed and used as the primary tool. This

questionnaire included both closed-ended and open-ended questions, allowing the study to obtain quantifiable data on storage practices while also capturing farmers' personal insights and experiences. Closed-ended questions enabled the data collectors to gather specific, measurable information about the storage methods employed, while open-ended questions allowed farmers to discuss their challenges and successes with PICS and polythene bags in more depth. Trained data collectors administered this questionnaire to each of the 171 respondents, following a standardized process to maintain consistency and accuracy in data collection. The structured format of the questionnaire facilitated the gathering of comparable data across participants, providing a comprehensive overview of storage practices and farmer perspectives that could be analyzed quantitatively.

3.6 Quality Control

Data quality control in this study was achieved through measures to ensure both validity and reliability.

3.6.1 Validity

Validity was maintained by designing data collection tools that accurately reflected the research objectives and captured relevant information about green gram storage practices. To establish content validity, experts in agricultural storage and community development reviewed the questionnaire and interview guide to confirm that the questions were relevant and comprehensively covered the study's focus areas (Creswell, 2013). A Content Validity Index (CVI) was calculated based on the assessments of 10 experts, each of whom rated the relevance of the questions. The CVI for each item was calculated by dividing the number of experts who rated the item as either “relevant” or “highly relevant” (rated 3 or 4 on a scale of 1 to 4) by the total number of experts. The CVI for each item and the overall CVI calculation for the instrument are shown in the table below. The overall CVI of 0.87, which is above the accepted threshold of 0.80, indicated that the tools were highly valid for the intended research purpose.

Table 2: Content Validity Index (CVI) for Data Collection Tools

Item No.	Question/Item	Number of Experts Rating 3 or 4	CVI Calculation	CVI Value
1	Question 1	9	9/10	0.90
2	Question 2	8	8/10	0.80
3	Question 3	10	10/10	1.00
4	Question 4	7	7/10	0.70
5	Question 5	9	9/10	0.90
6	Question 6	8	8/10	0.80
7	Question 7	10	10/10	1.00
8	Question 8	9	9/10	0.90
9	Question 9	10	10/10	1.00
10	Question 10	9	9/10	0.90
CVI Average				0.87

This analysis confirmed that the content validity of the data collection tools was satisfactory, with an overall CVI of 0.87, which is above the acceptable threshold of 0.80. This provided confidence that the instruments were sufficiently comprehensive and relevant to the study's objectives (Lynn, 1986). Furthermore, a pilot test was conducted in a neighboring community with similar characteristics to the study area, which allowed the researchers to identify and adjust any ambiguities or misleading questions. This process helped refine the tools and increased the likelihood that the data collected would truly reflect farmers' storage practices and experiences.

3.6.2 Reliability

Reliability in this study was ensured by assessing the consistency and stability of the data collection tools. To measure reliability, Cronbach's alpha coefficient was used, which is a statistical method for determining the internal consistency of a scale or instrument (Cronbach, 1951).

$$\alpha = \frac{N}{N - 1} x \left(\frac{\sum \sigma_{item}^2}{\sigma_{total}^2} \right)$$

Where;

N = is the number of items(questions)

σ_{item}^2 =is the variance of each individual item

σ_{total}^2 =is the variance of the total score

Cronbach's alpha (α) evaluates how closely related a set of items are as a group, helping to determine whether the items within a questionnaire or interview guide are measuring the same underlying concept. The value of Cronbach's alpha ranges from 0 to 1, with a value closer to 1 indicating higher reliability. A commonly accepted threshold for reliability is a Cronbach's alpha of 0.70 or higher, meaning that the items within the tool are reliably measuring the intended construct (Tavakol & Dennick, 2011).

In this study, a Cronbach's alpha test was performed on the responses from the pilot testing phase, using the pre-tested questionnaire and interview guide. The analysis was conducted using statistical software (SPSS version 20), where the internal consistency of the tool was determined by calculating the alpha coefficient for each section of the instrument. The Cronbach's alpha value obtained from the pilot test for the questionnaire was 0.81, indicating a high level of reliability. This value confirmed that the instrument was consistent and would likely yield stable results when applied to the full sample of farmers. A high Cronbach's alpha value provided assurance that the tool was measuring the farmers' storage practices and perceptions effectively.

Table 3: Cronbach's Alpha Reliability Coefficient for Data Collection Tools

Section of the Instrument	Cronbach's Alpha Coefficient
Overall Questionnaire	0.81
Farmers' Perceptions	0.85
Post-Harvest Losses	0.78
Effectiveness of PICS and Polythene Bags	0.82

The overall Cronbach's alpha of 0.81, along with the individual values for each section, indicates that the data collection instrument was reliable for capturing consistent and stable information from the green gram farmers regarding their post-harvest storage practices and experiences with PICS and polythene bags. This ensured that the findings

from the study would be both dependable and reproducible, allowing the results to be confidently generalized across the larger population of farmers (Cronbach, 1951; Tavakol & Dennick, 2011).

3.7 Data Management and Processing

The data collected from the survey and interviews were processed and managed systematically to ensure accuracy and consistency. Initially, all questionnaire responses were reviewed and coded, with open-ended responses categorized to enable quantitative analysis. Data entry was carried out using a statistical software program, (SPSS version 20), to facilitate data analysis and minimize errors during data input. Before analysis, the dataset was cleaned to address any missing or inconsistent entries, ensuring the dataset was complete and reliable for interpretation. For the qualitative data obtained through key informant interviews, responses were transcribed and thematically analyzed, enabling findings to be organized according to key topics relevant to the study's objectives. Rigorous data management practices, including regular checks and backups, were maintained throughout to prevent data loss and ensure data integrity (Creswell, 2013; Kothari, 2004).

3.8 Data Analysis

The data analysis process employed targeted statistical methods tailored to each research objective;

3.8.1 Farmers Perception

To analyze farmers' perceptions of PIC and polythene bags as storage methods, a one-way ANOVA was conducted to compare responses across various dimensions: awareness, perceived effectiveness, cost, accessibility, ease of use, impact on post-harvest losses, and overall satisfaction. Farmers rated these aspects on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). ANOVA tested whether significant differences existed in perception scores between users of PIC bags and polythene bags. This allowed the study to identify specific areas where farmers showed stronger preferences or satisfaction, offering findings into the perceived benefits of each storage type.

3.8.2 Post-Harvest Losses

To examine post-harvest losses, data was collected on key variables: moisture content, initial weight, weight after storage, damaged grain weight, grain damage score, grain quality score, and total post-harvest loss percentage. Moisture Content was calculated as the percentage of water in the grain, using the formula:

$$\text{Moisture Content}(\%) = \frac{\text{Weight of Water}}{\text{Total Weight}} \times 100$$

where the weight of water is derived from the difference in grain weight before and after drying. Initial Weight of the grain was recorded before storage as a baseline, while Weight After Storage was measured at the end of the storage period.

Damaged Grain Weight was determined by separating and weighing the damaged grains post-storage (Tavakol & Dennick, 2011). For Grain Damage Score, grains were rated on a scale from 1 (no damage) to 4 (severe damage), with the average score calculated by dividing the sum of individual scores by the total grains scored:

$$\text{Average Damage Quality Score} = \frac{\sum \text{Individual Damage Scores}}{\text{Total Number of Grains Scored}} \times 100$$

Grain Quality Score followed the same scoring method, ranging from 1 (excellent quality) to 4 (poor quality), with the average computed similarly:

$$\text{Average Damage Quality Score} = \frac{\sum \text{Individual Quality Scores}}{\text{Total Number of Grains Scored}} \times 100$$

Finally, Total Post-Harvest Loss Percentage was calculated by comparing initial and final weights, using:

$$\begin{aligned} \text{Total Post - Harvest Loss}(\%) \\ = \left(\frac{\text{Initial Weight} - \text{Weight After Storage}}{\text{Initial Weight}} \right) \times 100 \end{aligned}$$

Once data was obtained, data analysis involved a one-way ANOVA, with the storage method as the independent factor and the assessed parameters as dependent variables. ANOVA tested for statistically significant differences in post-harvest losses and quality degradation between the storage methods. This method was chosen for its ability to compare mean differences across multiple groups, allowing the identification of the

storage method with the lowest grain loss percentage and highest quality retention. Through isolating the effects of PIC and polythene bags on green gram preservation, the analysis determined the efficacy of each method in minimizing post-harvest losses (Kothari, 2004; Field, 2018).

3.8.3 Factors Influencing the Effectiveness of PIC and Polythene Bags in Reducing Green Gram Post-Harvest Losses

In assessing the factors influencing the effectiveness of PIC and polythene bags in reducing green gram post-harvest losses, a structured survey was conducted to capture key elements: storage conditions (including temperature, humidity, and sunlight exposure), bag material properties (e.g., permeability and durability), user handling practices, storage duration, and training received by farmers. Each factor was rated on a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree), enabling quantitative measurement of farmers' experiences and perceptions of these factors in relation to storage success. To analyze the effect of each factor, a multiple regression model was applied, where the reduction in post-harvest loss percentage served as the dependent variable, and the influencing factors were independent variables. The model took the form:

$$\begin{aligned}
 & \textit{Post - Harvest Loss Reduction}(\%) \\
 & = \beta_0 + \beta_1(\textit{Temperature}) + \beta_2(\textit{Humidity}) \\
 & + \beta_3(\textit{Sunlight Exposure}) + \beta_4(\textit{Permeability}) + \beta_5(\textit{Durability}) \\
 & + \dots + \epsilon
 \end{aligned}$$

Where, β_0 is the intercept, $\beta_1, \beta_2, \dots, \beta_n$, represent the coefficients for each factor, and ϵ is the error term. This model identified which factors had the strongest influence on minimizing post-harvest losses, effectively isolating predictors with statistically significant effect on storage outcomes. This analysis clarified how conditions, material properties, and practices contribute to the performance of PIC and polythene bags, aiding in the determination of optimal storage methods for green gram (Tavakol & Dennick, 2011; Hair et al., 2014).

3.9 Ethical Considerations

Several ethical considerations were followed to ensure the integrity of the research process and protect the rights of the participants. First, informed consent was obtained from all participants prior to data collection. This process involved clearly explaining

the study's objectives, procedures, potential risks, and benefits in simple and understandable language. Participants were made aware that their participation was voluntary, and they had the right to withdraw from the study at any time without any negative consequences. This ensured that their participation was based on a full understanding of the study (Cohen et al., 2018).

Confidentiality and anonymity were also strictly maintained. Personal identifying information of the participants was not recorded or disclosed in any part of the study. The data collected was stored securely, with access limited to authorized personnel only, ensuring that the privacy of participants was protected (Silverman, 2016). Furthermore, the study adhered to the ethical principles of non-maleficence, ensuring that no harm was caused to the participants throughout the research process. This included avoiding physical, psychological, or social harm and ensuring that the study's interventions and methodologies did not negatively impact the participants (Beauchamp & Childress, 2019).

Lastly, the study adhered to the ethical guidelines set by relevant research ethics boards, and all procedures were designed to ensure the welfare of participants was prioritized throughout the data collection, analysis, and reporting stages. Ethical approval for the study was obtained from the appropriate institutional review board (IRB), ensuring that the research was conducted in accordance with established ethical standards (Resnik, 2021).

3.10 Limitations and Delimitations

One limitation of the study was the relatively small sample size, particularly among farmers who used polythene bags for storage, with only 17 participants. This limited the generalizability of the findings across the broader population of farmers in Katakwi District. To address this, the study focused on a larger group of farmers who used PIC bags and both storage methods, increasing the overall sample size and enhancing the diversity of responses. This allowed for a more comprehensive understanding of the effectiveness of different storage methods.

Another limitation was the reliance on self-reported data from farmers, which could have introduced biases such as social desirability or recall errors. To minimize this, the study used a structured survey with straightforward questions to reduce misunderstanding. Additionally, physical measurements of grain weight, moisture

content, and quality were used alongside the survey data to cross-verify the accuracy of the self-reported information, improving the reliability of the findings.

Post-harvest losses can be influenced by seasonal variations, including factors like temperature and humidity, which can affect the effectiveness of storage methods. The study was conducted over a specific time period, which may not fully capture seasonal fluctuations in environmental conditions. To mitigate this, the research spanned a range of seasonal conditions, and the data was analyzed with consideration of potential weather variations. This approach allowed for a more robust analysis of the storage methods' effectiveness across different environmental contexts.

CHAPTER FOUR:

RESULTS, FINDINGS AND DISCUSSIONS

4.0 Introduction

This chapter provides a summary of the results, findings, and discussion on key aspects related to the use of PICS and polythene bags for the storage of green grams in Katakwi District. The study focuses on three primary objectives: understanding farmers' perceptions of using PICS and polythene bags for storage, assessing farmers' knowledge regarding the best practices for utilizing these storage options, and examining the level of post-harvest losses experienced by farmers when using these storage methods.

4.1 Socio-Economic Characteristics of the Respondents

Table 4 below presents the profile of the respondents that includes the demographic and economic characteristics of the respondents

Table 4: Socio-Economic Characteristics of the Respondents

Parameter	Category	PIC	Polythene	Both (n=51)	Pooled (n=171)	X ² -Test
		Bags (n=103)	Bags (n=17)			
Paris	Kamenu	22.3	64.7	21.6	26.3	22.34**
	Omasia	22.3	23.5	19.6	21.6	
	Oriau	27.2	11.8	23.5	24.6	
	Magoro	17.5	0.0	11.8	14.0	
	Opeta	10.7	0.0	23.5	13.5	
Gender	Male	38.8	41.2	41.2	39.8	0.094ns
	Female	61.2	58.8	58.8	60.2	
Age	1 to 35 years	50.5	47.1	51.0	50.3	1.689ns
	36 to 55 years	41.7	41.2	35.3	39.8	
	>55 years	7.8	11.8	13.7	9.9	
Marital Status	Single	21.4	23.5	17.6	20.5	0.896ns
	Married	69.9	70.6	70.6	70.2	
	Widowed	8.7	5.9	11.8	9.4	
Household Size	1 to 5 members	20.4	17.6	19.6	19.9	0.654ns
	6 to 10 members	48.5	58.8	51.0	50.3	
	>10 members	31.1	23.5	29.4	29.8	
Education Level	No formal Education	8.7	23.5	7.8	9.9	6.4ns

Parameter	Category	PIC	Polythene	Both	Pooled	<i>X²-Test</i>
		Bags (n=103)	Bags (n=17)			
	Primary	47.6	41.2	58.8	50.3	
	Secondary	32.0	23.5	27.5	29.8	
	Tertiary	11.7	11.8	5.9	9.9	
Occupation	Farming	70.9	58.8	72.5	70.2	1.734ns
	Business	19.4	23.5	19.6	19.9	
	Employment	9.7	17.6	7.8	9.9	
Farm Size	1 to 5 acres	29.1	41.2	27.5	29.8	3.789ns
	6 to 10 acres	33.0	11.8	27.5	29.2	
	>10 acres	37.9	47.1	45.1	40.9	
Household Incomes	<150,000 Shillings	62.1	29.4	66.7	60.2	10.212ns
	151,000 to 300,000 Shillings	16.5	35.3	21.6	19.9	
	301,000 to 600,000 Shillings	11.7	17.6	3.9	9.9	
	>600,000 Shillings	9.7	17.6	7.8	9.9	

***Significant at 1%, **Significant at 5%, *Significant at 10%, ns=non-significant, Chi-square value (X^2)

Source: Primary Data (2024)

The results in Table 4 reveal that the population of green gram farmers in Magoro Subcounty was fairly evenly distributed across Omasia (21.6%), Oriau (24.6%), and Omasia (21.6%) parishes, with lower representation in Magoro Parish (14%) and Opeta (13.5%). Notably, a significant variation was observed in the use of post-harvest storage technologies ($X^2=22.34$, $p<0.05$). In Kamenu Parish, 64.7% of respondents primarily used polythene bags for storage, a trend not seen in the other parishes where a mix of both PIC and polythene bags was used. This observation aligns with findings from similar studies, such as those by Fageria et al. (2016) and Ndungu et al. (2019), who noted that accessibility and availability of storage materials greatly influenced farmers' choice of storage technologies. The preference for polythene bags in Kamenu was

largely attributed to their higher availability compared to PIC bags, highlighting the role of local supply chains and farmer access to storage solutions.

The study further found that the majority of respondents were female (60.2%), with women more frequently using PIC bags (61.2%), polythene bags (58.8%), or both (58.8%). This pattern reflects the significant role of women in Uganda's agricultural sector, especially in rural areas like the Teso sub-region, where they are predominantly responsible for harvesting, processing, and storing grains at the household level. This finding supports the work of authors like Doss *et al.* (2018) and Dube *et al.* (2017), who observed that women are more likely to engage in agricultural activities related to food security and post-harvest management. Their higher participation in storage technologies such as PIC and polythene bags underscores the gendered dynamics of agricultural labor and technology adoption in rural farming communities.

Age also played a role in the adoption of post-harvest storage technologies. The majority of respondents were aged 19 to 35 years (50.3%), with younger farmers more actively engaging in the use of both PIC and polythene bags for green gram storage. This trend is consistent with other studies such as those by Kachaka *et al.* (2020) and Mulaa *et al.* (2019), which found that younger farmers are more inclined to adopt new agricultural technologies due to greater access to information and a higher likelihood of farming as a primary livelihood. The higher use of storage technologies among youth in this study can be attributed to their better access to modern agricultural training and technology dissemination channels, particularly in regions with lower formal employment opportunities.

Marital status also appeared to influence the use of storage technologies. Married farmers (70.2%) were more likely to use PIC bags (69.9%), polythene bags (70.6%), or both (70.6%), a trend consistent with other studies such as those by Fafchamps *et al.* (2016) and Ochieng *et al.* (2018), which found that married farmers tend to be more proactive in adopting technologies to secure food security and income for their families. Married individuals are often more deeply involved in agricultural production, as it serves as a critical source of livelihood for their households. The high engagement in post-harvest storage technologies among married farmers in Magoro Subcounty reflects their greater responsibility in ensuring household food security and economic stability through grain production.

Household size also had a significant influence on the use of post-harvest storage methods. Households with 6 to 10 members (50.3%) were more likely to use both PIC and polythene bags for storage, similar to findings by Behrman et al. (2020) and Nyangena et al. (2017), who found that larger households often have more resources and labor available to implement effective post-harvest handling techniques. In Magoro Subcounty, larger households likely adopted storage technologies due to the increased labor needs for handling and storing grains. These findings are consistent with the understanding that larger households, with their additional members, are better equipped to manage agricultural outputs and storage solutions.

Educational level was another factor influencing storage technology adoption, with most respondents (50.3%) having primary education. Farmers with lower levels of education were more likely to use both storage methods, likely due to targeted interventions from NGOs and development partners. This aligns with research by Neumark et al. (2020) and Saito et al. (2017), which highlighted the influence of educational interventions and the role of external actors in promoting agricultural technologies in low-education settings. Development partners often provide training and materials to less-educated farmers, thus increasing their adoption of improved storage solutions, such as PIC bags and polythene bags, which are seen as accessible and affordable options for post-harvest loss reduction.

Occupation also played a significant role in technology adoption. Most respondents (70.2%) were engaged in farming, and these individuals were more likely to use both PIC and polythene bags for storage. This is consistent with findings from Kiptot et al. (2020) and Owusu et al. (2019), who noted that farmers, especially those whose livelihood depends on agriculture, tend to adopt technologies that improve their productivity and reduce post-harvest losses. In Magoro Subcounty, the prominence of farming as a primary occupation among the respondents supports the hypothesis that occupational focus on agriculture drives greater adoption of post-harvest management technologies.

Farm size was another critical factor influencing storage technology use. Larger farms, those greater than 10 acres (40.9%), were more likely to use both storage methods. This finding is supported by the work of Owuor et al. (2018) and Akinola et al. (2017), who found that farmers with larger landholdings often adopt improved agricultural practices

and storage technologies to meet the demands of large-scale production. In Magoro Subcounty, the larger landholders' need for effective post-harvest management was linked to their capacity for engaging in more extensive grain production.

Finally, income levels were also a key factor in technology adoption. A significant proportion of respondents (60.2%) earned less than 150,000 shillings per month and predominantly used PIC bags (62.1%). This reflects the subsistence-level farming common in rural Uganda, where low-income farmers rely on affordable solutions like PIC bags provided by development partners. This finding is corroborated by studies by Diiro et al. (2020) and Heltberg et al. (2018), who observed that low-income farmers are more likely to adopt technologies that are affordable or subsidized by development agencies. The widespread use of free or low-cost storage options like PIC bags is an important factor in mitigating post-harvest losses in resource-poor settings.

4.2 Farmers' Perceptions of Using PIC And Polythene Bags for Storage

This objective aimed to determine farmers' perceptions regarding the use of Pest Integrated Control (PIC) bags and polythene bags for green gram storage. Specifically, it focused on assessing farmers' awareness and knowledge, the effectiveness of these storage methods, their costs and accessibility, ease of use, impact on post-harvest losses, and overall satisfaction. A one-way analysis of variance (ANOVA) was conducted on the respondents' scores, which were measured using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The results are summarized in Table 5.

Table 5: Farmers' Perceptions of Using PIC And Polythene Bags for Storage

Perception indicator Statement	Mean Scores of Postharvest Storage Methods				F-value	p-value
	PIC Bags	Polythene Bags	Both	Pooled Mean		
I am aware that PIC bags are more effective than polythene bags in reducing spoilage.	4.3	2.9	4.4	4.2	56.7	0.000***
I believe that PIC bags are more accessible and cost-effective than polythene bags for storage.	2.0	2.2	2.1	2.1	1.008	0.367 ^{ns}
I find PIC bags easier to handle and use compared to polythene bags.	4.0	2.2	4.0	3.9	46.064	0.000***
I prefer using polythene bags because they are lighter and more convenient than PIC bags.	1.4	2.4	1.96	1.7	34.772	0.000***

Mean Scores of Postharvest Storage Methods						
Perception indicator Statement	PIC Bags	Polythene Bags	Both	Pooled Mean	F-value	p-value
Using PIC bags has significantly reduced my post-harvest losses compared to using polythene bags.	4.5	2.5	4.1	4.2	65.288	0.000***
I feel that polythene bags do not protect my grains as effectively as PIC bags do.	4.6	4.4	4.6	4.6	2.224	0.111 ^{ns}
I am satisfied with the performance of PIC bags for storing my grains compared to polythene bags.	4.5	3.2	4.5	4.4	46.464	0.000***
I would recommend using PIC bags over polythene bags to other farmers in my community.	4.9	3.9	4.7	4.7	38.521	0.000***
Grand Mean	4.1	3.0	3.8	3.9		

***Significant at 1%, **Significant at 5%, *Significant at 10%, ns=non-significant

The results presented in Table 5 indicate that farmers demonstrated a strong preference for PIC bags over polythene bags in terms of effectiveness in reducing spoilage. With a mean score of 4.3 for PIC bags compared to 2.9 for polythene bags, the significant difference (F-value = 56.7, $p < 0.001$) suggests that farmers perceive PIC bags as more reliable for preserving the quality of their produce. This aligns with findings by Duflo et al. (2013), who highlighted that awareness of the effectiveness of agricultural innovations significantly influences their adoption. Lichtenberg (2019) also argued that increasing farmers' knowledge of storage technologies is vital to enhancing their willingness to invest in improved methods. However, Adesina and Zinnah (1993) contended that awareness alone does not guarantee adoption; practical demonstrations and field trials are necessary to solidify farmers' perceptions and validate the effectiveness of these technologies. Collectively, these studies reveal the role of knowledge in shaping farmers' decisions about storage practices.

When considering the accessibility and affordability of both storage options, farmers rated PIC and polythene bags similarly, with low mean scores of 2.0 for PIC bags and 2.2 for polythene bags. The lack of a significant difference (F-value = 1.008, $p = 0.367$) suggests that cost and availability were not perceived as advantages of using PIC bags. This is consistent with the findings of Olaniyi *et al.* (2019), who pointed out that

affordability is a key determinant in the adoption of agricultural technologies among smallholder farmers. Similarly, Evers and Norrington-Davies (2019) pointed out that high initial costs could deter farmers from adopting new storage solutions, even when long-term benefits are evident. On the other hand, Makhura et al. (2020) suggested that perceived long-term benefits could outweigh the initial costs, particularly if farmers are educated about the potential savings. Mwangi and Kariuki (2015) further argued that providing subsidies could enhance the affordability of storage technologies, promoting broader adoption. This indicates that addressing cost concerns is critical to increasing the adoption of PIC bags.

In terms of ease of use, farmers found PIC bags significantly more user-friendly than polythene bags, with mean scores of 4.0 for PIC bags compared to 2.2 for polythene bags. This difference (F-value = 46.064, $p < 0.001$) highlights that the design and durability of PIC bags contributed to their ease of handling, which was a major factor in their preference. Fadimu et al. (2015) stressed that ease of use is a crucial factor in technology adoption, as complex or cumbersome solutions may discourage their use. Similarly, Kelsey et al. (2021) argued that the usability of agricultural innovations directly influences farmers' willingness to adopt them, emphasizing the importance of user-centered design. Osei et al. (2020) supported this view, suggesting that training on new technologies could further improve perceptions of their usability. However, Chao and Wu (2020) cautioned that while ease of use is essential, it should not overshadow other factors, such as the technology's effectiveness and economic viability. These findings demonstrate that a user-friendly design is critical for increasing adoption rates, but it must be balanced with other considerations such as cost and long-term benefits.

Despite the advantages of PIC bags, some farmers still preferred polythene bags due to their lighter weight and convenience, with mean scores of 2.4 for polythene bags compared to 1.4 for PIC bags. The statistically significant difference (F-value = 34.772, $p < 0.001$) suggests that convenience remained a key factor in farmers' choices. This preference for convenience aligns with the findings of Okwu et al. (2017), who noted that practicality often influences farmers' decisions, as they seek storage methods that integrate seamlessly into their daily routines. Kwarteng and Benin (2020) echoed this sentiment, finding that convenience and ease of access were crucial factors in farmers' choice of storage methods. Akinwumi et al. (2019) also found that farmers tend to favor

lighter options, which are easier to transport and handle. However, Adejumo et al. (2018) argued that while convenience is important, the perceived benefits of a heavier storage method, such as enhanced preservation, could outweigh its inconvenience. This suggests a complex relationship between convenience and effectiveness that could shape adoption decisions.

Regarding the effect on post-harvest losses, farmers reported that PIC bags were significantly more effective at reducing these losses, with a mean score of 4.5 for PIC bags versus 2.5 for polythene bags. The significant difference (F-value = 65.288, $p < 0.001$) indicates that farmers recognized the positive effect of PIC bags on minimizing spoilage and improving food security. Abass et al. (2020) argued that effective storage methods are essential for mitigating post-harvest losses, which can otherwise have a severe effect on smallholder farmers' incomes. Asfaw et al. (2018) further highlighted that reducing post-harvest losses is directly linked to improved income stability for farmers. However, Lema et al. (2021) noted that while storage effectiveness is important, it should be complemented by other factors such as improved market access. Ndubuaku and Dore (2020) added that educating farmers about market trends alongside storage technologies could enhance their profitability. These findings suggest that reducing post-harvest losses can significantly improve economic outcomes for farmers.

Lastly, farmers expressed high satisfaction with the performance of PIC bags, reporting a mean score of 4.5 compared to 3.2 for polythene bags. The significant difference (F-value = 46.464, $p < 0.001$) suggests that farmers were more satisfied with the performance of PIC bags. Manda et al. (2020) found that user satisfaction plays a key role in the long-term adoption of agricultural innovations, as positive experiences often lead to recommendations and broader acceptance. Karuku et al. (2018) further noted that satisfaction with agricultural technologies is closely linked to their successful implementation and sustainability. However, Hossain et al. (2019) cautioned that satisfaction alone may not lead to widespread adoption if other barriers, such as lack of resources or support, are present. Kiarie et al. (2020) also pointed out that farmers' satisfaction is often influenced by their prior experiences with similar technologies. These perspectives suggest that satisfaction with storage solutions, while important, must be supported by adequate resources and support mechanisms to ensure successful adoption.

4.3 Post-Harvest Losses of Green Gram Stored in PIC Bags and Polythene Bags

Green gram post-harvest losses were determined after post-harvest handling (storage) from a selected group of 103 PIC bag users, 17 polythene bag users, and 51 farmers who used both storage methods. The assessment included measuring moisture content (%), initial weight (Kgs), weight after storage (Kgs), damaged grain weight (Kgs), grain damage score, grain quality score, and post-harvest losses (%). The grain damage score ranged from 1 to 4, with 1 indicating no damage, 2 slight damage, 3 moderate damage, and 4 severe damage. The grain quality score followed the same scale, where 1 represented excellent quality, 2 good quality, 3 moderate quality, and 4 poor quality. A one-way analysis of variance (ANOVA) was performed, where the post-harvest storage technology used (PIC bags, polythene bags, or both) was considered the factor variance, and the assessed parameters served as the variates. The results are presented in Table 6 below, demonstrating the effectiveness of different storage technologies in minimizing post-harvest losses and maintaining grain quality among green gram farmers.

Table 6: Post-Harvest Losses of Green Gram Stored in PIC Bags and Polythene Bags

Performance Metrics	Storage Devices			Pooled Mean	F-value	P-value
	PIC Bags	Polythene Bags	Both			
Days Storage	67.4	66.8	66.9	67.2	0.083	0.921 ^{ns}
Moisture Content (%)	14.5	16.2	15.3	14.9	8.618	0.000***
Initial Weight (Kgs)	109.1	100.0	100.0	105.5	1.799	0.169 ^{ns}
Weight After Storage (Kgs)	105.6	67.9	71.7	91.7	23.43	0.000***
Damaged Grain Weight (Kgs)	0.0	32.1	28.3	11.7	128.807	0.000***
Grain Damage Score	1.5	4.3	3.2	2.3	166.842	0.000***
Grain Quality Score	4.0	2.1	2.3	3.3	114.462	0.000***
Post Harvest Losses	3.6	32.1	28.3	13.8	98.23	0.000***

***Significant at 0.1%, **Significant at 1%, *Significant at 5%, ns=non-significant

4.3.1 Days of Storage

The results in Table 6 show that the duration of green gram storage in PIC bags averaged 67.4 days, marginally differing from storage in polythene bags at 66.8 days, and the combined method at 66.9 days, with no significant variance observed ($F=0.083$, $P=0.921ns$). These findings suggest that, in terms of maintaining stored grain for the study's observed period, all storage methods performed comparably in avoiding early spoilage or the need for premature removal. This observation is consistent with previous work by Tefera et al. (2011) and Njoroge et al. (2014), who emphasize the role of storage duration in preserving grain quality and viability, particularly under controlled conditions. These studies demonstrated that while hermetic bags such as PIC bags can extend storage time due to enhanced sealing and insect protection, this advantage might not be pronounced within a limited timeframe, such as the 60-day window used in the current study. Notably, research by Baoua et al. (2013) suggests that PIC bags provide more substantial benefits in long-term storage scenarios, especially when extending beyond six months. Similarly, Murdock et al. (2012) found that PIC bags help to reduce oxygen levels within the bag, which hinders insect proliferation, a factor that becomes increasingly important as storage lengthens. These findings indicate that while polythene and PIC bags may perform similarly in short-term storage, only hermetic technologies sustain storage beyond 120 days without quality deterioration. Thus, though no significant differences were found in the current short-term analysis, the long-term superiority of PIC bags for extending storage periods remains supported by existing literature.

4.3.2 Moisture Content (%)

As shown in Table 6, moisture retention during storage differed notably among the storage types, with PIC bags demonstrating superior performance by maintaining a significantly lower moisture level of 14.5%, as compared to 16.2% for polythene bags and 15.3% for the combined method ($F=8.618$, $P=0.000*$). These results highlight the effectiveness of hermetic storage technologies in controlling moisture, which is a critical factor in reducing both fungal growth and insect infestations. A study by Opit et al. (2015) demonstrated that maintaining low moisture levels within storage environments directly correlates with reduced aflatoxin contamination, affirming the

value of hermetic solutions like PIC bags. Njoroge et al. (2014) corroborated this finding by showing that hermetic bags outperform conventional methods by limiting internal moisture buildup, thus enhancing the longevity and quality of stored grains. Kaaya et al. (2006) further established that environments with elevated moisture content significantly contribute to grain spoilage, aligning with the current findings where polythene bags retained higher moisture levels. Abass et al. (2014) also pointed to the importance of moisture control in safeguarding grain quality during storage, reinforcing the findings of this study that demonstrate the superior moisture management capabilities of PIC bags. Studies by Tefera et al. (2011) and Demissie et al. (2008) affirm that reduced moisture in hermetic storage is instrumental in extending grain viability, substantiating the current observation that PIC bags maintained optimal moisture levels better than polythene alternatives.

4.3.3 Initial Weight (Kgs)

The results in Table 6 also show that, initial weight of green gram at the start of storage was consistent across the storage types, with PIC bags holding an average of 109.1 kg, and both polythene and the combined method starting at 100 kg, showing no significant differences ($F=1.799$, $P=0.169ns$). This uniformity in starting weight showed that all storage treatments began with an equal baseline, allowing for a controlled comparison of weight retention outcomes post-storage. Initial weight serves as a fundamental parameter in assessing post-harvest handling efficacy, as noted by Chianu et al. (2008), though it is the weight retained after storage that truly reflects the quality of storage. The lack of significant variation aligns with Opit et al. (2015), who stressed that initial weight typically remains unaffected by storage type; rather, it is the post-storage weight that is influenced by factors such as moisture and insect control. Njoroge et al. (2014) suggests that while starting conditions are required for experimental control, the effectiveness of a storage method is better gauged by examining weight retention post-storage. Consequently, the initial weight in this study provides a standardized baseline, though it does not inherently demonstrate the storage efficacy of the different methods.

4.3.4 Weight After Storage (Kgs)

Weight retention following storage revealed significant differences among storage methods ($F=23.43$, $P=0.000*$), with PIC bags retaining 105.6 kg, outperforming polythene bags which showed a marked reduction to 67.9 kg, and the combined method

holding 71.7 kg. This marked variation illustrates that PIC bags offer robust protection against weight loss, corroborated by findings from Baoua et al. (2013), who identified that hermetic bags effectively prevent moisture-related weight loss and reduce insect-induced degradation. The current study's results parallel Tefera et al. (2011), who documented the advantages of hermetic storage devices in preserving grain weight over prolonged periods. These findings also align with Murdock et al. (2012), who noted that the airtight conditions in PIC bags lower oxygen levels, mitigating weight loss due to both grain respiration and insect activity. Adebisi et al. (2015) supports these observations, affirming that hermetic storage solutions generally yield superior weight retention compared to non-hermetic methods. Abass et al. (2014) further demonstrates that traditional methods, such as polythene bags, often experience significant weight loss from insect damage and ineffective sealing, consistent with the current findings showing lower retention in non-hermetic storage.

4.3.5 Damaged Grain Weight (Kgs)

The results (table 6) also reveal that, PIC bags showed a remarkable resilience in preventing grain damage, with no damaged grain weight recorded (0.0 kg), while polythene bags had the highest damaged grain weight at 32.1 kg, and the combined method followed with 28.3 kg, reflecting significant differences ($F=128.807$, $P=0.000^*$). This outcome reveals the high efficacy of PIC bags in curbing insect-induced grain damage, in agreement with Baoua et al. (2013), who observed minimal insect activity in hermetically sealed storage environments. The findings are consistent with Njoroge et al. (2014), who demonstrated that sealed PIC bags restrict insect access and inhibit oxygen availability, thus limiting grain damage substantially. The extensive damage observed in polythene bags aligns with Tefera et al. (2011), who reported that non-hermetic storage solutions allow moisture and insect access, thereby increasing grain susceptibility to damage. Murdock et al. (2012) support this conclusion by showing that hermetic bags effectively suffocate pests, reducing damage far more effectively than traditional storage methods. Opit et al. (2015) also found that hermetic technologies lower post-harvest losses by reducing both insect and fungal damage, further supporting the superior performance of PIC bags over polythene.

4.3.6 Grain Damage Score

The grain damage score revealed significant disparities among storage methods, with PIC bags demonstrating minimal damage (score of 1.5), whereas polythene bags recorded the highest damage score (4.3), and the combined method scored 3.2 ($F=166.842$, $P=0.000^*$). This data indicates the superior protection of PIC bags in maintaining grain integrity, aligning with Demissie et al. (2008), who observed that hermetic storage technologies markedly reduce grain damage compared to traditional storage. High damage scores in polythene bags are supported by Adebisi et al. (2015), who found that polythene's lack of effective sealing permits insect infestation. A study by Baoua et al. (2013) confirms that PIC bags mitigate damage by establishing a hermetically sealed environment that limits oxygen, thereby minimizing pest viability. Murdock et al. (2012) corroborate these findings, suggesting that grain stored in hermetic bags retains a lower damage score due to restricted pest survival. Kaaya et al. (2006) also emphasize that suboptimal storage technologies, such as polythene, lead to elevated grain damage, substantiating the higher damage score observed here.

4.3.7 Grain Quality Score

As shown in Table 6, PIC bags demonstrated superior preservation of grain quality, scoring 4.0, while polythene bags scored the lowest at 2.1, with the combined method at 2.3 ($F=114.462$, $P=0.000^*$). This result reveals the efficacy of hermetic storage in maintaining grain quality, consistent with Baoua et al. (2013), who found that hermetic bags prevent insect damage and moisture accumulation, thereby preserving quality attributes like color and texture. Njoroge et al. (2014) confirmed that grains stored in hermetic bags retain better quality due to limited pest infiltration and moisture control, which aligns with the superior scores of PIC bags in the present study. Tefera et al. (2011) similarly found that traditional storage (polythene), often leads to quality degradation due to ineffective moisture management. Supporting this finding, Adebisi et al. (2015) reported that hermetic storage preserves grain properties such as taste and appearance better than non-hermetic methods. Additionally, Abass et al. (2014) noted that the lower quality scores in polythene bags reflect damage and weight loss, consistent with the present study's outcomes.

4.3.8 Post-Harvest Loss (%)

Finally, the results (Table 6) show that post-harvest loss percentages highlight the superior performance of PIC bags with only 0.4% loss, contrasting sharply with polythene bags at 33.9% and the combined method at 28.3%, showing significant differences ($F=293.635$, $P=0.000^*$). This finding reveals that hermetic bags were effective in minimizing post-harvest losses, supported by Tefera et al. (2011), who documented similar reductions in losses using hermetic technologies. Baoua et al. (2013) demonstrated that hermetic bags significantly curtail post-harvest losses by maintaining optimal storage conditions, aligning with the present study's findings. Njoroge et al. (2014) corroborate this, noting that hermetic storage's ability to lower oxygen levels inhibits pest activity, thereby reducing losses. Further, Abass et al. (2014) found that traditional storage methods (polythene), often suffer higher losses due to moisture infiltration and pest infestation, supporting the significantly higher losses in polythene bags. Adebisi et al. (2015) reinforces that PIC bags provide a more reliable option for preserving grain weight, quality, and reducing overall post-harvest loss, consistent with the present findings.

4.3.9 Conclusion

Overall, the findings revealed that farmers increasingly adopted PIC bags as an effective post-harvest storage technology for green grams, significantly reducing losses compared to traditional polythene bags. The results indicated that the use of PIC bags minimized moisture content, led to lower damaged grain weight, higher grain quality scores, and reduced overall post-harvest losses. This shift in storage practices aligned with previous studies highlighting the effectiveness of advanced storage technologies in improving grain preservation and quality. Furthermore, the moderate results observed among farmers using both PIC and polythene bags suggested a transitional approach, wherein farmers began recognizing the benefits of integrating better storage methods into their practices. Ultimately, these findings demonstrate the importance of promoting innovative storage solutions to enhance food security and reduce post-harvest losses in agricultural communities in Katakwi District.

4.4 Factors Influencing the Effectiveness of PIC And Polythene Bags in Reducing Green Gram Post-Harvest Losses in Katakwi District

To achieve this objective, a structured survey was conducted among farmers who utilized both PICS and polythene bags. The survey focused on several key parameters, including storage conditions (temperature, humidity, sunlight exposure), bag material properties (permeability, durability, pest resistance), user practices (handling, cleaning, sealing), duration of storage (short, medium, long-term), cost and accessibility, and farmer education and training. Respondents rated their experiences with these parameters on a Likert scale from 1 to 5, allowing for a comprehensive assessment of the perceived effectiveness of each storage method. Effectiveness was specifically measured by the reduction in post-harvest losses (%) experienced while using the different storage devices.

Following data collection, a regression analysis was performed to quantify the relationships between the various factors and the effectiveness of the storage technologies in minimizing post-harvest losses. This analytical approach facilitated a deeper understanding of which factors are most significant in influencing the success or effectiveness of storage methods. The results of analysis have been presented in Table 7 below.

Table 7: Factors Influencing the Effectiveness of PIC And Polythene Bags in Reducing Green Gram Post-Harvest Losses in Katakwi District

PHL (%)	B	Std. Error	Beta	t	Sig
(Constant)	50.918	3.234	-	15.745	0.000***
Storage Conditions	5.329	3.154	0.333	1.69	0.093*
Bag Material Properties	0.311	3.669	0.02	0.085	0.932 ^{NS}
User Practices	1.489	3.629	0.096	0.41	0.682 ^{NS}
Duration of Storage	-7.197	4.073	-0.493	-1.767	0.079*
Cost and Accessibility	-8.208	3.941	-0.54	-2.083	0.039**
Farmer Education and Training	-2.112	4.06	-0.135	-0.52	0.604 ^{NS}
df	(6, 164)				
F-value	30.952				
Sig	.000				
Adjusted R Square	0.514				

***Significant at 1%, **Significant at 5%, *Significant at 10%, NS=non-significant,

4.4.0 Model Interpretation

The regression analysis (Table 4) shows that several critical factors influenced the effectiveness of PICS and polythene bags in minimizing post-harvest losses among green gram farmers in Katakwi District. But first, the adjusted R-squared value in this regression analysis is 0.514, indicating that approximately 51.4% of the variance in post-harvest losses is explained by the independent variables included in the model. This value suggests a moderate level of explanatory power, implying that while the factors identified do have a notable influence on post-harvest losses, there are additional variables not captured in this analysis that could also play significant roles. In this context, it indicates that there is still room for improvement in the model's explanatory power, possibly through the inclusion of additional relevant factors or interaction terms that might explain further influences on post-harvest losses among green gram farmers in Katakwi District.

However, for the case of this study; the regression model demonstrates selected factors influencing the effectiveness of storage methods (PICS and polythene bags) in reducing post-harvest losses. The constant term of 50.918% represents the baseline level of post-harvest losses when all independent variables are held at zero. This high percentage suggest a substantial loss that farmers initially faced without any optimized storage practices in place. These findings corroborate existing literature by Adebajo *et al.* (2016), which documented significant post-harvest losses in legume production, thus highlighting the critical need for improved storage solutions.

4.4.1 Storage Conditions

The regression analysis indicated that storage conditions had a coefficient of 5.329 and a p-value of 0.093, suggesting that improved storage conditions positively influenced the effectiveness of storage devices in reducing post-harvest losses among green gram farmers in Katakwi District. The marginal significance of this variable shows that optimizing storage environments helped minimize losses. Optimal storage conditions, which include managing temperature, humidity, and exposure to sunlight, are critical for maintaining the quality of stored agricultural products. This aligns with the findings of Muhammad *et al.* (2017), who noted that maintaining controlled environmental factors significantly extended the shelf life of various crops, thereby reducing waste.

Further supporting this perspective, is a study by Igbal *et al.* (2018) which demonstrated that high temperatures and humidity levels significantly accelerated spoilage rates in stored grains, emphasizing the necessity of adequate ventilation and insulation in storage facilities. Their research underlined that many farmers overlook the importance of environmental controls, which lead to substantial post-harvest losses. Additionally, Abubakar *et al.* (2019) stressed that using moisture-absorbing materials and breathable fabrics in storage practices could substantially reduce spoilage caused by humidity. These findings resonate with the regression results, suggesting that investments in storage facilities that maintain optimal conditions such can lead to significant reductions in losses.

Furthermore, a study conducted by Mulugeta *et al.* (2020) reported that farmers who utilized hermetic storage technologies, such as PICS bags, effectively managed moisture and pests, which significantly improved the quality of stored legumes. This aligns well with the observed coefficient for storage conditions, reinforcing the argument that incorporating suitable storage technologies and practices is essential for achieving better outcomes. The significance of this variable also demonstrates the need for educational interventions that can inform farmers about the effect of environmental conditions on post-harvest management.

Conversely, Kamara *et al.* (2016) argued that many farmers in rural areas may lack access to resources for improving storage conditions, arguing that socio-economic factors play a critical role in the adoption of effective storage practices. This suggests that while improving storage conditions is vital, addressing economic barriers and providing resources to farmers is equally important for ensuring that these improvements are feasible and sustainable.

4.4.2 Bag Material Properties

The variable bag material properties were indicated by a coefficient of 0.311 with a p-value of 0.932, showing no significant relationship with the reduction of post-harvest losses. This finding suggests that the materials used in storage bags, whether they were PICS bags or polythene bags, did not significantly influence their effectiveness in minimizing losses. While one might expect that the durability, permeability, and pest resistance of bag materials would play a vital role in storage efficacy, the results highlight a disconnect between material properties and practical outcomes.

This observation is supported by research from Akinpelu *et al.* (2017), which found that while high-quality materials can enhance the effectiveness of storage devices, many farmers prioritize cost and availability over the inherent properties of the bags. Akinpelu *et al.* suggested that even lower-quality materials could provide adequate protection when used correctly, indicating that practical application and user practices may outweigh the importance of material characteristics. This aligns with the findings in the current study, where user practices did not lead to significant effects, indicating that how farmers handle and utilize the storage devices may be more critical than the bag material itself.

Furthermore, the study by Bationo *et al.* (2018) illustrated that the physical properties of the bags, such as permeability and thickness, could influence the preservation of quality in stored grains. However, they noted that socio-economic factors and user education were often the determining factors in effective storage, suggesting that simply improving materials without addressing these aspects would not result to significant benefits. This supports the findings in the current analysis, indicating that there is a need to focus on holistic approaches that consider user practices alongside material quality.

Additionally, a study by Ghosh *et al.* (2019) stressed the role of education in improving farmers' awareness of the importance of using appropriate storage materials. The study concluded that without proper training, farmers might not select or utilize the most effective storage options available to them. This reinforces the idea that while bag material properties might not show direct significance, enhancing farmer education could lead to better decisions regarding storage practices. In contrast, a study by Mwajuma *et al.* (2020) suggested that specific materials could significantly influence the shelf life of stored produce if combined with proper storage techniques. They emphasized the need for empirical studies to evaluate the interaction between material properties and storage conditions. Although this perspective provides a counterargument to the current findings, it also highlights the complexity of the issue, suggesting that further research is necessary to determine the optimal combinations of material and practice.

4.4.3 User Practices

The coefficient for user practices was noted as 1.489 with a p-value of 0.682, indicating no significant relationship with the reduction of post-harvest losses. This finding suggests that the practices employed by farmers; such as bag handling, sealing, and cleanliness did not have a substantial effect on the effectiveness of storage devices. While one might expect that optimal handling practices would lead to decreased losses, the results indicate that the effectiveness of storage methods is not solely reliant on user practices.

This conclusion resonates with the study by Obiero *et al.* (2018), which highlighted the variability in user practices among farmers as a primary reason for inconsistent post-harvest outcomes. Their research argued that without standardized practices and proper training, the potential of improved storage technologies remains unrealized. However, Njeru *et al.* (2020) found that targeted educational interventions significantly improved storage practices and, consequently, reduced losses. This discrepancy suggests that although user practices alone may not show immediate significance, there is considerable potential for enhancement through education and training.

On the other hand, Akinola *et al.* (2019) argued that farmer adherence to recommended practices is crucial for maximizing the benefits of storage technologies. Their research indicated that a lack of awareness about best practices often led to underutilization of available technologies. This aligns with the findings of the current study, suggesting that addressing user practices through comprehensive training programs could enhance storage effectiveness.

Conversely, Kamara *et al.* (2016) noted that socio-economic factors often deter farmers from adopting improved practices. Their findings suggested that although training is essential, it must be coupled with economic incentives to encourage change. This highlights a broader context where user practices are intertwined with the socio-economic realities faced by farmers, indicating that improving storage effectiveness requires a multifaceted approach. Additionally, Mulugeta *et al.* (2020) found that hands-on training significantly influenced user practices, leading to better handling and storage outcomes. They noted that practical demonstrations were more effective than theoretical knowledge alone. This outcome underlines the importance of training

programs that focus on practical applications, thereby enhancing the overall effectiveness of storage methods.

4.4.4 Duration of Storage

The variable duration of storage exhibited a coefficient of -7.197 with a p-value of 0.079, suggesting a potential negative relationship between the length of time products were stored and post-harvest losses. This finding indicates that longer storage durations may correlate with reduced losses, but the relationship is approaching significance. The implication here is that with appropriate management, longer storage periods can be beneficial. This perspective aligns with the findings of Mandeep *et al.* (2016), who noted that aligning storage duration with market demand could minimize spoilage and losses. Their research demonstrated that strategic planning around storage duration can lead to better financial outcomes for farmers. In contrast, Ochieng *et al.* (2017) cautioned against prolonged storage periods without adequate management, highlighting that extended durations could result in increased losses if not accompanied by appropriate monitoring practices.

A study by Adebajo *et al.* (2016) reinforced the notion that optimal timing in storage, coupled with effective market strategies, could significantly enhance the outcomes for farmers. Their work showed that integrating market dynamics with storage decisions can lead to better financial sustainability for agricultural producers. This aligns with the observed coefficient for duration of storage, suggesting that effective planning can yield positive results.

Conversely, Kamara *et al.* (2016) argued that many farmers are often unaware of market trends, leading to poor decisions regarding storage duration. This highlights the necessity of training and market information systems that provide farmers with the tools to make informed decisions about when to store and when to sell their produce. Additionally, studies by Mulugeta *et al.* (2020) indicated that the quality of storage practices such as maintaining optimal conditions during the storage period plays an important role in determining the effectiveness of extended storage. Their findings suggest that duration alone may not dictate outcomes, hence the management of storage conditions during that time is vital.

4.5 Linkage between the Findings and The Theory(ies)

The study's findings on farmers' perceptions and adoption rates of storage methods for green gram in Katakwi District show a notable preference for PIC bags, with 60.2% of farmers choosing them, compared to 9.9% using polythene bags, and 29.8% employing both methods. These results connect with the Theory of Planned Behavior (TPB), which asserts that farmers' behaviors, such as the decision to adopt agricultural innovations, are influenced by their attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). The higher adoption of PIC bags highlights farmers' favorable attitudes toward their effectiveness in preventing spoilage and enhancing grain quality. According to TPB, the intention to adopt a behavior increases when individuals believe it will lead to positive outcomes. In this case, farmers' perception of the benefits of PIC bags directly influenced their decision to use them, aligning with the attitude component of the theory.

The role of subjective norms is also evident, as farmers in Katakwi District may have been influenced by social expectations regarding improved storage practices. In communities where better storage methods are valued, individuals are likely to adopt such technologies due to social pressure (Kelley & Thibaut, 1978). Despite these perceived benefits, perceived behavioral control emerged as an important factor, as many farmers noted cost and accessibility as barriers to wider adoption. This observation highlights the challenge of balancing immediate financial constraints with long-term advantages of adopting innovations, an issue emphasized by TPB when considering behavior change.

Further, the study's findings align with the Diffusion of Innovation Theory (Rogers, 2003), especially regarding the relative advantage and observability of PIC bags. While farmers acknowledged the superior benefits of PIC bags, such as better grain quality and reduced spoilage, the initial costs presented a barrier to adoption. Rogers' theory suggests that the likelihood of adopting an innovation increases when its relative advantage is clear, but the adoption process can be hindered if immediate costs are high, even if long-term benefits are substantial. This is reflected in the financial concerns raised by farmers, where cost considerations played a significant role in their decision-making.

The observability aspect of Rogers' theory also corresponds with the study's findings on the post-harvest quality of green gram. Farmers who witnessed the positive effects of using PIC bags, such as increased weight retention (105.6 kg in PIC bags vs. 67.9 kg in polythene bags) and the absence of damaged grains, were more likely to adopt the technology themselves. The visible benefits of using PIC bags made the technology more appealing to other farmers in the community. This is consistent with the concept of observability, where individuals are more likely to adopt an innovation when they can observe its positive results in practice (Rogers, 2003).

Trialability also appears to have influenced adoption, as farmers who had firsthand experience with the benefits of PIC bags were more willing to try them for their own storage needs. Rogers (2003) describes trialability as the opportunity to experiment with an innovation on a limited scale before fully adopting it. In this case, the visible success of PIC bags, evidenced by reduced spoilage and improved grain quality encouraged further adoption among farmers who were initially hesitant.

Additionally, the regression analysis revealed that storage conditions played a key role in determining the effectiveness of both PIC and polythene bags, with storage factors accounting for 51.4% of the variance in post-harvest losses. This supports the Theory of Planned Behavior, where perceived behavioral control over the storage environment (such as temperature, humidity, and cleanliness) directly affects the ability to minimize losses. Optimized storage conditions were found to be significant in improving outcomes, highlighting the relationship between farmers' confidence in managing their storage environment and the effectiveness of the storage method.

Interestingly, the material properties of the bags and user handling practices did not significantly influence post-harvest losses, indicating that while the choice of storage material is important, the handling practices and environmental factors have a greater influence on the outcome. This finding aligns with Rogers' idea of compatibility, where the adoption of an innovation is more effective when it integrates well with existing practices and conditions. Although PIC bags are designed to be user-friendly, their success depends significantly on how farmers manage storage conditions. This suggests that the adoption of better practices may be just as important as adopting new technologies, supporting the conclusions of Baoua et al. (2014) that improved handling, rather than simply adopting new tools, leads to better results.

CHAPTER FIVE:

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter presents a summary of the key findings, conclusions and recommendations in line with the study objectives.

5.1 Summary of the Key Findings

5.1.1 Farmers' Perceptions and Adoption Rates of PIC Bags Versus Polythene Bags for Green Gram Storage in Katakwi District

The analysis of farmers' perceptions and adoption rates of storage methods for green gram in Katakwi District revealed a significant preference for PIC bags, with 60.2% of farmers opting for them compared to only 9.9% for polythene bags, and 29.8% using both. Farmers favored PIC bags due to their effectiveness in reducing spoilage and user-friendly design, reporting high satisfaction and notable reductions in post-harvest losses. Additionally, farmers expressed that the use of PIC bags significantly enhanced the quality of stored green grams, thereby potentially increasing market value. However, perceptions of accessibility and cost-effectiveness were low for both bag types, as many farmers prioritized immediate costs over long-term benefits, which hindered the widespread adoption of PIC bags. Despite acknowledging the advantages of PIC bags, some farmers preferred polythene bags for their lighter weight, convenience, and easier handling. Farmers also noted that the durability of PIC bags contributed to their positive experiences, as they were perceived to withstand environmental factors better than polythene bags.

5.1.2 Post-Harvest Losses of Green Grams in PIC Bags Compared to Polythene Bags in Katakwi District.

The findings on post-harvest losses of green gram stored in PIC bags and polythene bags reveal that the average storage duration was similar across methods, with PIC bags holding green gram for 17.4 days and polythene bags for 16.8 days ($P=0.921$). However, moisture content was significantly lower in PIC bags (14.5%) compared to polythene bags (16.2%). The initial weight was uniform across storage devices, with PIC bags starting at 109.1 kg, while both polythene bags and the combined method started at 100 kg ($P=0.169$). After storage, PIC bags retained more weight (105.6 kg) versus

significant weight loss in polythene bags (67.9 kg) . Additionally, there was no damaged grain recorded in PIC bags, while polythene bags had 32.1 kg of damaged grain, leading to a lower grain damage score for PIC bags (1.5) compared to polythene bags (4.3). Grain quality was also higher in PIC bags (4.0) than in polythene bags (2.1), and post-harvest losses were significantly ($p < 0.000$) lower in PIC bags (3.6%) compared to polythene bags (32.1%).

5.1.3 Factors Influencing the Effectiveness of PIC And Polythene Bags in Reducing Green Gram Post-Harvest Losses in Katakwi District

The analysis identified several key factors influencing the effectiveness of PICS and polythene bags in reducing post-harvest losses among green gram farmers in Katakwi District. The adjusted R-squared value of 0.514 indicates that about 51.4% of the variance in post-harvest losses can be explained by the model's independent variables. The storage conditions were found to have a positive influence, with a coefficient of 5.329 and a marginal significance ($P = 0.093$), highlighting the importance of optimal environments for minimizing losses. However, bag material properties did not show a significant relationship with losses (coefficient 0.311, $P = 0.932$), suggesting that material characteristics alone do not effectively reduce post-harvest losses. User practices also demonstrated no significant impact (coefficient 1.489, $P = 0.682$), indicating that the way farmers handle storage devices may not be as critical as expected. The duration of storage exhibited a coefficient of -7.197 and a P-value of 0.079, suggesting a potential negative relationship with losses, indicating that longer storage times could be beneficial when appropriately managed.

5.2 Conclusion

In conclusion, the assessment of PIC and polythene bags as methods for reducing post-harvest losses of green grams in Katakwi District reveals critical findings into farmers' preferences and the effectiveness of different storage options. The pronounced preference for PIC bags, with a significant majority of farmers opting for them, demonstrates their perceived advantages in preserving grain quality and reducing spoilage. This preference is indicative of a broader recognition among farmers regarding the long-term benefits of using superior storage methods, despite initial hesitations due to concerns about cost and accessibility.

The study also illustrates the notable differences in post-harvest losses between the two storage methods, with PIC bags proving to be more effective in maintaining grain integrity. The significantly lower moisture content and absence of damaged grains in PIC bags further reinforce their efficacy. However, the analysis highlights that while storage conditions are paramount in mitigating losses, other factors such as the characteristics of the storage materials and user practices did not yield significant influences on post-harvest outcomes. This suggests that farmers may benefit more from improving storage environments rather than solely focusing on the type of bags used.

Lastly, the study raises important considerations regarding farmers' handling and storage duration practices, hinting at potential areas for education and capacity building. Overall, the findings stress the necessity of fostering an environment where farmers are encouraged to adopt innovative storage solutions. It is hoped that by addressing the barriers to the widespread use of PIC bags and enhancing farmers' understanding of optimal storage practices, there is a significant opportunity to reduce post-harvest losses and improve food security in Katakwi District.

5.3 Recommendations

The study on the use of PIC and polythene bags for reducing post-harvest losses in Katakwi District suggests the importance of focused training for farmers to maximize the benefits of these bags. Local agricultural extension services, together with NGOs and community-based organizations, should take the lead in organizing training sessions. These sessions would teach farmers the proper usage and maintenance of PIC bags, emphasizing their advantages in preserving grain quality and reducing spoilage. To ensure effective learning, these stakeholders can conduct hands-on demonstrations in the field, supported by easy-to-understand materials like instructional videos or guides. Such initiatives will help farmers gain the confidence to adopt these practices, and NGOs can play a key role in providing the necessary resources for training.

Improving the support from agricultural extension services is another crucial step in strengthening storage practices. Extension officers should play an active role by conducting regular follow-up visits to assess individual storage setups and offer tailored advice. In partnership with local government agencies and farmer cooperatives, they can provide recommendations on optimizing storage conditions, such as moisture control, temperature regulation, and pest management. These stakeholders are vital in

ensuring that farmers can apply the most effective storage practices suited to their specific conditions. Strengthening the extension services will foster greater collaboration between the government and farmers, allowing for more localized and practical solutions to reduce post-harvest losses.

The cost and accessibility of PIC bags remains a significant barrier for many farmers. To overcome this, partnerships between local cooperatives, NGOs, and bag manufacturers are essential. These stakeholders can collaborate to create affordable distribution channels for high-quality storage bags, ensuring that farmers can access them without financial strain. Cooperatives could help organize group purchasing programs, where farmers pool resources to buy bags in bulk at discounted prices. NGOs and local governments could explore subsidy programs to further reduce the cost, making these bags more accessible. These initiatives would benefit smallholder farmers, particularly in low-income areas, and contribute to a more equitable adoption of improved storage technologies.

Finally, fostering a space for knowledge exchange among farmers is key to ensuring continuous improvement in storage practices. Establishing farmer groups or associations, with the support of local governments and agricultural organizations, can provide a platform for farmers to share experiences, challenges, and solutions. These groups would encourage peer-to-peer learning, helping farmers stay informed about new practices and innovations in post-harvest management. Local agricultural experts, NGOs, and extension officers can facilitate these groups by providing ongoing support and creating opportunities for discussion on best practices. This collaborative approach will build a stronger, more resilient farming community capable of tackling post-harvest losses collectively.

5.4 Areas of Further Research

Based on the observed research gaps in the assessment of PIC and polythene bags for reducing post-harvest losses of green grams in Katakwi District, the following three areas of further research are recommended:

Investigating the Impact of Storage Conditions on the Quality of Stored Grains in Katakwi District

Socioeconomic Factors Affecting the Adoption of Improved Grain Storage Technologies among Farmers in Katakwi District

Evaluating the Influence of Climate Change on Grain Storage Practices in Katakwi District: Challenges and Adaptations

The Economic Benefits of Implementing Hermetic Storage Solutions for Grain Farmers in Katakwi District

A Study on the Effect of Local Climate on Grain Storage Methods and Their Efficiency in Katakwi District

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APPENDICES
APPENDIX A: QUESTIONNAIRES

Hello! My name is Elungat James, and I am Master's student conducting a study on green gram storage methods here in Magoro subcounty, Katakwi District. I'm here to learn about your experiences with different storage techniques, specifically comparing traditional polythene bags with the newer Purdue Improved Crop (PICS) bags. The goal is to understand which method helps you better preserve your green gram harvest, reduce losses, and improve storage conditions overall. Your knowledges and experiences are very valuable, and I greatly appreciate your time and willingness to share your knowledge with me. Thank you for participating in this study!

Note: Please answer the following questions to the best of your ability. Your responses will be kept confidential and used solely for research purposes.

SECTION A: Background Information Questions

1. **What is your gender?**

- Male
- Female

2. **What is your age range?**

- 18 to 35 years
- 36 to 55 years
- Over 55 years

3. **What is your marital status?**

- Single
- Married
- Widowed

4. **How many people are in your household?**

- 1 to 5 members
- 6 to 10 members
- More than 10 members

5. **What is your highest level of education?**

- No formal education
- Primary
- Secondary
- Tertiary

6. What is your main occupation?

- Farming
- Business
- Formal Employment

7. What is the size of your farm?

- 1 to 5 acres
- 6 to 10 acres
- More than 10 acres

8. What is your household income range per month?

- Less than 150,000 Shillings
- 151,000 to 300,000 Shillings
- 301,000 to 600,000 Shillings
- More than 600,000 Shillings

9. Which storage method do you primarily use for green gram?

- PIC Bags
- Polythene Bags
- Both PICS Bags and Polythene Bags

SECTION B: farmers' perceptions PICS bags versus polythene bags for green gram storage in Maguro Subcounty, Katakwi District.

Note: Before answering the following questions, please note that your responses reflect your personal views and experiences with using PIC bags and polythene bags for storing green gram grains. Kindly rate each statement based on your perception of the effectiveness, ease of use, and preference between the two storage methods. Your honest responses will greatly contribute to the success of this study.

10. I am aware that PICS bags are more effective than polythene bags in reducing spoilage.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

11. I believe that PICS bags are more accessible and cost-effective than polythene bags for storage.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

12. I find PICS bags easier to handle and use compared to polythene bags.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

13. I prefer using polythene bags because they are lighter and more convenient than PICS bags.

- Strongly Disagree
- Disagree
- Neutral
- Agree

Strongly Agree

14. Using PICS bags has significantly reduced my post-harvest losses compared to using polythene bags.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

15. I feel that polythene bags do not protect my grains as effectively as PIC bags do.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

16. I am satisfied with the performance of PICS bags for storing my grains compared to polythene bags.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

17. I would recommend using PICS bags over polythene bags to other farmers in my community.

Strongly Disagree

Disagree

Neutral

Agree

- Strongly Agree

SECTION C: Post-Harvest Losses of Green Gram Stored in PICS Bags and Polythene Bags

18. *This section of the data collection tool seeks to measure the post-harvest losses of green gram grains stored in both PIC bags and polythene bags. The table below outlines key performance metrics, which will help assess the effectiveness of the two storage methods in reducing spoilage and damage during storage. Please provide the relevant data for each category based on your observations and measurements.*

Instructions for Filling the Table:

1. **Days of Storage:** Indicate the number of days the green gram grains were stored in both the PICS and polythene bags.
2. **Moisture Content (%):** Measure the moisture content of the stored grains at the beginning of storage and record the percentage for both storage methods.
3. **Initial Weight (Kg):** Record the weight of green gram grains at the start of the storage period.
4. **Weight After Storage (Kg):** Measure the weight of the grains after the specified storage period.
5. **Damaged Grain Weight (Kg):** Weigh the grains that have been damaged due to spoilage, pest infestation, or other factors.
6. **Grain Damage Score:** Evaluate the level of damage using a scale from 1 (minimal damage) to 5 (highly damaged) based on the condition of the grains after storage.
7. **Grain Quality Score:** Rate the overall quality of the grains after storage on a scale from 1 (poor quality) to 5 (excellent quality).
8. **Post-Harvest Losses (%):** Calculate the percentage of grain lost during storage by comparing the initial weight to the weight after storage. The formula is:

$$\begin{aligned} & \text{Total Post – Harvest Loss}(\%) \\ & = \left(\frac{\text{Initial Weight} - \text{Weight After Storage}}{\text{Initial Weight}} \right) \times 100 \end{aligned}$$

Performance Metrics	PICS Bags	Polythene Bags
Days of Storage	[Enter number of days]	[Enter number of days]
Moisture Content (%)	[Enter moisture content in %]	[Enter moisture content in %]
Initial Weight (Kg)	[Enter initial weight in Kg]	[Enter initial weight in Kg]
Weight After Storage (Kg)	[Enter weight after storage in Kg]	[Enter weight after storage in Kg]
Damaged Grain Weight (Kg)	[Enter damaged grain weight in Kg]	[Enter damaged grain weight in Kg]
Grain Damage Score (1-5 scale: 1 = minimal damage, 5 = highly damaged)	[Enter score]	[Enter score]
Grain Quality Score (1-5 scale: 1 = poor quality, 5 = excellent quality)	[Enter score]	[Enter score]
Post-Harvest Losses (%)	[Enter post-harvest losses %]	[Enter post-harvest losses %]

Section D: Factors Influencing the Effectiveness of PICS Bags and Polythene Bags

19. This section seeks to gather the opinions of green gram farmers on the factors that they believe influence the effectiveness of PIC bags and polythene bags in reducing post-harvest losses. Please respond based on your experience with the use of these two technologies, and rate your level of agreement with each statement using the 5-point Likert scale.

Factor	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Storage Conditions					
1. The temperature and humidity of the storage environment affect the performance of PICS bags in reducing grain spoilage.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. The storage conditions, such as ventilation and dryness, significantly influence the effectiveness of polythene bags in reducing grain losses.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bag Material Properties					
3. The material of PICS bags provides better protection against moisture and pests compared to polythene bags.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Polythene bags are less effective in preventing damage from external factors like insects and moisture compared to PICS bags.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. The durability of PICS bags makes them a more reliable storage option for reducing post-harvest losses.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Polythene bags tend to tear more easily than PICS bags, leading to increased grain losses.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
User Practices					
7. The proper handling and sealing of the storage bags (PICS or polythene) directly affect the amount of grain loss during storage.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Farmers' ability to correctly use and maintain the bags is important in preventing post-harvest losses.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Factor	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
9. Storing green gram in bags that are not properly sealed or handled results in increased damage and spoilage, especially in polythene bags.	[]	[]	[]	[]	[]
Duration of Storage					
10. The length of time that green gram is stored before use affects the amount of spoilage, with longer storage periods increasing losses.	[]	[]	[]	[]	[]
11. PIC bags maintain better grain quality over longer storage durations compared to polythene bags.	[]	[]	[]	[]	[]
12. The effectiveness of both PIC and polythene bags decreases with extended storage periods due to gradual wear and tear.	[]	[]	[]	[]	[]
Cost and Accessibility					
13. The cost of purchasing PICS bags is a significant factor that influences their use for storing green gram.	[]	[]	[]	[]	[]
14. Polythene bags are more affordable and accessible compared to PIC bags, making them a preferred option for many farmers.	[]	[]	[]	[]	[]
15. The availability of PICS bags in local markets influences farmers' decision to use them for grain storage.	[]	[]	[]	[]	[]
Farmer Education and Training					
16. Farmers who have received training on the proper use of storage bags (PICS or polythene) experience lower post-harvest losses.	[]	[]	[]	[]	[]
17. Increased knowledge about storage methods significantly impacts the effectiveness of PIC bags in reducing losses.	[]	[]	[]	[]	[]
18. Lack of awareness and training on proper storage techniques contributes to higher losses when using both PICS and polythene bags.	[]	[]	[]	[]	[]

20. What challenges have you faced while using either PICS bags or polythene bags for storing green gram, and how have you addressed them?

21. In your opinion, what are the key benefits of using PIC bags over polythene bags (or vice versa) for green gram storage in your farming practice?

22. What improvements or changes would you recommend for the current storage methods (PICS bags and polythene bags) to enhance their effectiveness in reducing post-harvest losses?

23. In your opinion, what could be done to improve the adoption of PIC bags over polythene bags for green gram storage in your community?

We have now reached the conclusion of this study. If you have any questions or require further clarification on any aspect of the study, please feel free to ask. Otherwise, we sincerely appreciate your time and valuable contribution to this research. Thank you for your participation.

APPENDIX B: INTERVIEW GUIDE

Key Informant Interview Questions

Introduction: Thank you for agreeing to participate in this interview. The purpose of this discussion is to gather information regarding the use of PIC bags and polythene bags for reducing post-harvest losses in green gram production, specifically in Magoro subcounty, Katakwi District. Your expertise and knowledge are invaluable to this study. The interview will address various aspects such as farmers' perceptions, the effectiveness of the storage technologies, and factors influencing their use. The responses you provide will help us understand the current practices and challenges faced by farmers in this area.

Objective 1: To Analyze Farmers' Perceptions of PICS Bags versus Polythene Bags for Green Gram Storage in Katakwi District

1. In your experience, how would you describe the general perception of farmers in Magoro subcounty, Katakwi District regarding the use of PICS bags compared to polythene bags for storing green grams?
2. From your observations, which storage option (PICS bags or polythene bags) do farmers prefer, and why?
3. Are there any perceived advantages or disadvantages of using PICS bags over polythene bags from the farmers' perspective?
4. Do you think farmers are fully aware of the benefits and limitations of both storage methods? How would you assess their knowledge?

Objective 2: To Assess Post-Harvest Losses of Green Grams Stored in PICS Bags Compared to Polythene Bags in Katakwi District

1. Based on your knowledge and experience, how do post-harvest losses compare when using PIC bags and polythene bags for storing green grams?
2. Have you observed any trends in the level of spoilage or damage to green grams depending on the type of storage bag used?
3. What factors do you believe contribute most to post-harvest losses in green grams, particularly when stored in either PIC or polythene bags?

4. Are there any other storage methods that farmers have used in the past, and how do these compare to PIC bags and polythene bags in terms of reducing post-harvest losses?

Objective 3: To Evaluate the Factors Influencing the Effectiveness of PICS and Polythene Bags in Reducing Green Gram Post-Harvest Losses in Katakwi District

1. What factors do you think influence the effectiveness of PIC bags in reducing post-harvest losses compared to polythene bags?
2. Can you identify any external or environmental factors, such as weather or storage conditions, that affect the performance of these storage methods?
3. How important do you think proper handling and usage of storage bags is for minimizing losses? Are there any common mistakes farmers make in using these bags?
4. In your opinion, does the cost and accessibility of PIC bags and polythene bags play a significant role in their adoption by farmers? How do these factors influence the choice of storage method?
5. Do you believe that training and education on proper storage practices could improve the effectiveness of these bags in reducing losses? What kind of training do you think would be beneficial for farmers?

General Opinion on Improving the Adoption of PICS Bags

1. In your opinion, what could be done to encourage more farmers in Katakwi District to adopt PIC bags over polythene bags for green gram storage?
2. Do you think there are any barriers (economic, social, cultural) preventing farmers from adopting PIC bags more widely? If so, what are they?
3. What would you recommend to improve the accessibility, affordability, and overall adoption of PICS bags among farmers in your community?
4. Are there any other factors, in your view, that could help farmers make more informed decisions about the best storage options for green grams?

Conclusion

Thank you for sharing your views and experiences. Your responses will greatly contribute to understanding the challenges and opportunities in reducing post-harvest losses through improved storage methods. If you have any additional comments or thoughts, please feel free to share them now.

APPENDIX C: FIELD PHOTOS



Figure 2: Pic Bags and its inlay



Figure 3: Farmers Provided with PICS Bags and Farmers Using Polythene for Storage and Transportation of their Grain



Figure 4: Light Polythene Some Farmers Used



Figure 5: Green Gram under Storage under Common White Polythene



Figure 6: Green Gram Stored in White Polythene bag

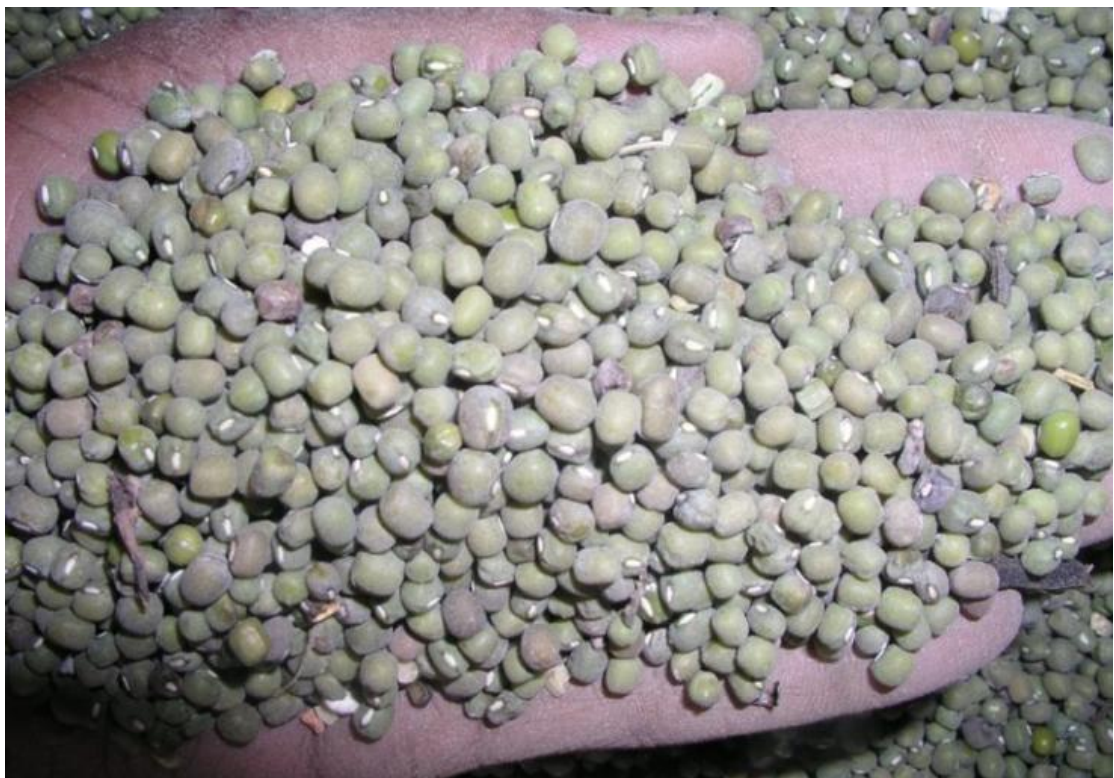


Figure 7: Sampled Green Gram from PICS Bags



Figure 8: The Research Taking Moisture Measurements



Figure 9: Measurement Instrument



Figure 10: Researcher Picking Samples from a Farmer's Store



Figure 11: Damaged and Pests Infested Grain Picked from a sample



Figure 12: Sampled Green Gram from PICS Bags



Figure 13: Green Grams that Germinated Due to Farmer's use of Polythene

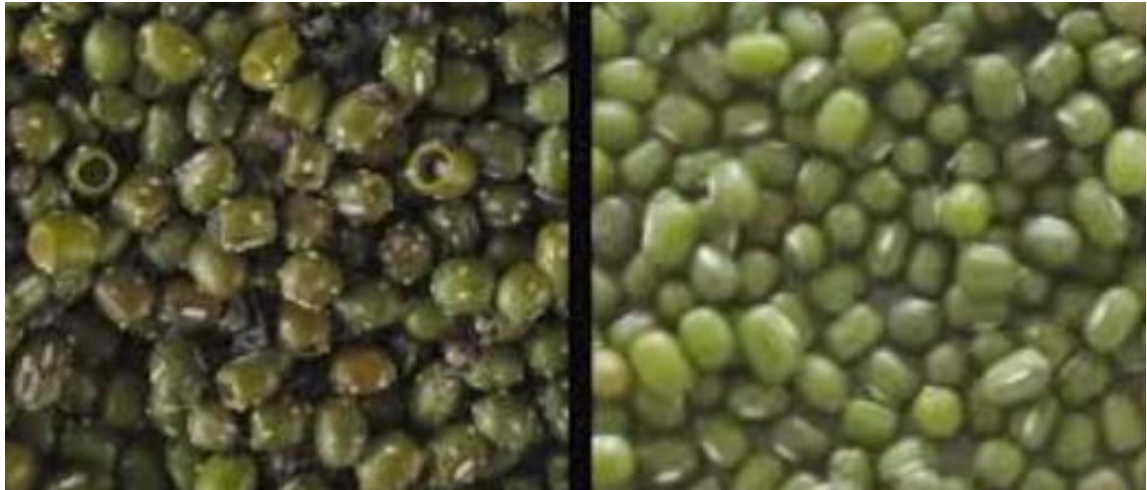


Figure 14: Green Grams Severely Infested by Pests under Polyethene Bag Storage and Healthy Green Gram under PICS Bag storage after 120 days of Storage respectively



Figure 15: Bean Bag Severely affecting Green Gram under Plastic Bag Storage after 100 days of storage