DRIVERS OF COMPLIANCE WITH FOOD-SAFETY MEASURES AND THEIR EFFECTS ON THE PROFITABILITY OF SMALLHOLDER DAIRY FARMS IN CENTRAL UGANDA

ANDREW KIZITO SERUMA

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DECLARATION AND RECOMMENDATION

Declaration:

This thesis is my original work and has not been presented in this University or any other for the award of a degree.

Signature:.. Date: 14/10/2025

Andrew Kizito Seruma

KD23/16546/18

Recommendation

This thesis has been submitted with our approval as university supervisors.

Signature:... Date: 16/10/2025

Prof. George Owuor, PhD

Department of Agricultural Economics and Agribusiness Management

Egerton University

Signature:.. Date: 16/10/2025

Dr. Dickson Okello, PhD

Department of Agricultural Economics and Agribusiness Management

Egerton University

DEDICATION

This thesis is dedicated to my beloved parents; Prof and Mrs. Zake, my wife Phionah, children; Shalom, Shekinah and Shiloh and all my siblings. Your unwavering support, sacrifices, endless love, heartfelt prayers, and belief in me have been my greatest source of motivation. In every step of this journey, your presence has been felt in my heart. May the Almighty God bless you abundantly.

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ABSTRACT

The majority of milk production in Uganda is in controlled by smallholder farmers (90% contribution) and the informal sector who face challenges in ensuring food safety. Though food safety compliance can facilitate commercialization and profitability, adoption is low. The foucs of this study was to determine food safety compliance and its profitability effect among smallholder dairy farmers. The study's specific objectives were to determine the level of compliance with food safety measures (FSMs); determine the effect of perceived behavioural control, attitudes, and subjective norms on farmers' food safety practices; determine the leading drivers of FSMs compliance; and determine the effect of FSM adoption on the profitability of smallholder dairy enterprises in the region. Central Uganda was chosen for the research where 757 smallholder farmers were interviewed using a multi-stage sampling technique. Data was collected using structured questionnaires. Data analysis was done using SPSS, SMART PLS, and STATA. To address objective one, descriptive and inferential statistics were employed; for objective two, structural equation modeling was chosen; to address objective three, ordered logit regression was employed; and for objective four, ordered logit endogenous switching regression (ESR) was utilized. This research examined the adoption of 42 food safety measures which related to milk hygiene, storage, premises hygiene and animal health. Total adoption of FSMs was 62.88 per cent. Among the practices, milk storage was adopted to the maximum extent (73.5%) and animal health was adopted to the least extent (53.3%). Dry cow therapy and hand sanitization were adopted by less than 10%. Findings from objective two show that both behavioral control and attitude are significant predictors of the adoption of safety and hygiene control practices. In particular, they have a positive and significant effect on the outcome variable. On the other hand, subjective norms have a negative effect on safety and hygiene control practices. With respect to objective three, it was found that education of farmers, familiarity of farmers with FSMs and awareness of HACCP were important drivers of adoption. Further, the adoption significantly improved profitability by enhancing the quality of milk and market access. It was lack of farming experience, small farm size and compliance costs that were cited as barriers. The findings of objective four show that the profitability improves significantly with an increase in the adoption of FSM. This is majorly due to improvements in both, the quality of milk and premium market access. Improving the success and profitability of FSM practices requires the introduction of capacity-building, premium pricing incentives, better access to credit and supportive policies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

2SRI	Two-Stage Residual Inclusion
AI	Artificial Insemination
ATE	Average Treatment Effect
ATT	Average Treatment Effect on Treated
ATU	Average Treatment Effect on Untreated
AVE	Average Variance Extracted
BI	Behavioral Intention
CCP	Critical Control Point
CFA	Confirmatory Factor Analysis
CI	Confidence Interval
CR	Composite Reliability
ESR	Endogenous Switching Regression
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
FSMs	Food Safety Measures
HACCP	Hazard Analysis and Critical Control Points
HTMT	Heterotrait-Monotrait Ratio of Correlations
IMR	Inverse Mills Ratio
KMO	Kaiser-Meyer-Olkin Measure
NGO	Non-Governmental Organizations
PBC	Perceived Behaviour Control
RBV	Resource-Based View
RMSEA	Root Mean Square Error of Approximation
SD	Standard Deviation
SE	Standard Errors
SEM	Structural Equation Modeling
SN	Subjective Norms
SOP	Standard Operating Procedures
SRMR	Standardized Root Mean Square Residual
TPB	Theory of Planned Behavior
TVC	Total Variable Cost
UBOS	Uganda Bureau of Statistics

UDDA	Uganda Dairy Development Authority
USDHS	United States Department of Human Services
VIF	Variance Inflation Factor
WHO	World Health Organization

CHAPTER ONE
INTRODUCTION

1.1 Background to the study

About 50% of the national agriculture of Uganda is attributed to the dairy sector, and it employs over 80% of the population (Tijjani & Yetişemiyen, 2015). The dairy sector is an important part of Uganda's overall agricultural economy and is important for rural livelihoods and national food security (Sugino *et al.,* 2023; Waiswa *et al.,* 2021). Dairy farming is so common that around 25 per cent and 24 per cent of the total national dairy agricultural production is accounted by each respectively.

Presently, the employment of numerous individuals throughout the dairy value chain is in the sector, including the stages of milk production, collection, bulking, transportation, processing, marketing and distribution to market (Balikowa, 2011; Kemitare *et al.,* 2021). The dairy sectors in Uganda have made noteworthy progress due to a broad range of institutional and legislative reforms including the liberalization of trade in the dairy industry and cultural factors (FAO, 2019).

According to Abdallah (2019), Uganda has potential to produce 10 million tonnes of milk. Despite government and NGO investments and progress within the dairy sector, Uganda's milk production remains lower than potential production levels. Despite this, the country is not able to achieve this target due to problems of disease in animals, low conception rate, failure of artificial insemination, and environmental factors.

The smallholder farmers still continue to face constraints which are primarily responsible for low income and profits even as the dairy industry grew and produced surpluses during good seasons. For example, smallholder dairy farmers in Central Uganda face significant challenges because milk quality and safety are questionable. Food safety is very important for the consumers' health and confidence in dairy products. However, the smallholder farmers of the area ignored or adopted the food safety measures (FSM) very late (Ssajjakambwe *et al.,* 2017).

When animal diseases are neglected and not addressed for some time, productivity, profit and market access is affected (Ssajjakambwe *et al.,* 2017). Additionally, farmers' limited knowledge of FSMs as well as their negative attitudes towards them significantly affect their compliance with food safety standards (Brown *et al.,* 2019; Ledo *et al.,* 2019; Nyokabi *et al.,* 2018).

Being food safe is very important for food security (Ortega & Tschirley, 2017). Currently, the food standards are the demand of the day among the consumers who are concerned about healthy living. Furthermore, the standards must start at the farm level. In fact, it is the first step in the dairy production value chain. Even more, these standards should be complied with right up to the point of marketing the product. Raw or cooked food items are typically able to carry a pathogen. Dairy products, especially milk is among the riskier foods globally (Meinzen-Dick *et al.,* 2014). One of the challenges facing developing countries like Uganda is the production of quality and clean milk. Milk that we use should be made from the cleanest facility and in hygienic conditions.

Organizations in the public and private sectors are aware that improving food safety in the dairy industry is essential and have been working to promote FSMs among smallholder farmers. These efforts are meant to improve the quality of milk, minimize post-harvest milk losses and boost their market competitiveness. The government has tried to bring food policy measures in line with international practice, especially in the dairy sector, which is hindering the informal sector. In 2014, Uganda prohibited commercialization of raw milk. On the other hand, in 2015, Kenya initiated a campaign for the consumption of pasteurized milk (Alonso *et. al.* 2018). Most of Uganda's dairy production is still governed by the unreliable informal sector.

Bamuwamye *et al*. (2015), indicated that most dairy products in Uganda have high levels of contamination with microorganisms such as pests, bacteria and viruses. Drinking contaminated milk is also a major public health problem in Central Uganda, a region in the cattle corridor of Uganda that runs from Northeast to southwest Uganda (Musoke *et al,* 2016). Many factors, like farm cleanliness, cow health, milk handling and storage, management, and time of the year play a role in polluted dairy products. Food security challenges in the dairy chain occur at many points, indicating the need for control measures throughout the dairy chain. As a result, the study sought to establish the present level of FSM adoption, assess the drivers and constraints influencing the farmers' decisions, and examine the effect of adopting FSMs on the profitability of smallholder dairy farmers.

1.2 Statement of the problem

Food safety is a key part of the food security of many sub-Saharan African countries. By improving farm-level compliance, food safety can be enhanced. This is especially the case for the dairy industry. The dairy farming activity in Central Uganda contributes much to the economy of the region, representing about 24% of the total dairy production in the country. Even though the industry is becoming more important and bigger, smallholder farmer performance is poor. Due to contamination-causing unwholesomeness resulting in low-quality milk. As a result, food safety measures (FSMs) must be adopted in the dairy industry for the production and supply of safe hygienic dairy products. It is uncertain how such initiatives will affect the profitability of smallholder dairy farmers in Central Uganda. Also, there is limited research on the use of FSMs in Uganda. The study assessed the current use of FSM by the region's dairy producers, the fostering or blocking factors behind FSM adoption, and the effect of adoption of FSM on household profit by smallholder dairy farmers of Central Uganda.

1.3 Objectives

1.3.1 General objective

To contribute to the sustainable implementation of food safety measures that enhance public health, improve well-being, and reduce poverty among smallholder dairy farmers in Uganda.

1.3.2 Specific objectives

The study set out to:

i. Characterize smallholder dairy farmers' level of compliance with FSMs at the farm level in Central Uganda.
ii. Determine the influence of perceived behavioral control, attitude, and subjective norms on smallholder dairy farmers' behavior in performing safety- and hygiene-control practices in Central Uganda.
iii. Determine the drivers of compliance with food-safety measures among smallholder dairy farmers in Central Uganda; and
iv. Determine the effect of adopting food-safety measures on the profitability of smallholder dairy farms in Central Uganda.

1.4 Research questions

i. What are the characteristics of smallholder dairy farmers' level of compliance for FSMs at the farm-level in Central Uganda?
ii. What is the influence of perceived behavioral control, attitude, and subjective norms on smallholder dairy farmers' behaviour in performing safety and hygiene control practices in Central Uganda?
iii. What are the drivers of compliance to food safety measures among smallholder dairy farmers in Central Uganda?
iv. What is the effect of food safety measures on the profitability of smallholder dairy farmers' enterprises in Central Uganda?

1.5 Justification of the study

Food safety is now a borderless global issue due to the connected modern food supply chain. Food contamination remains a major problem facing many developing countries around the world. Tackling food safety at the farm level is essential in minimizing contamination throughout agricultural value chains. There is a significant burden of zoonotic and livestock-related diseases in Uganda's livestock sector. Poor hygiene and handling practices have been previously identified as key drivers of this issue. To this end, the Ugandan government is putting food safety policies in place to regulate operations in the value chain. FSMs are an integral part of the Food and Nutrition Policy of Uganda, which aims to improve nutritional status and food security and to increase incomes through a wide range of interventions. The policy also makes it mandatory that milk producers and manufacturers adhere to the food safety standards.

Sustaining food safety around the world supports households. This research study is linked to several SDGs. The study promotes SDG 2 and emphasizes food safety's importance in the end of hunger and food security. It also supports SDG 3 and SDG 12 as it will highlight food safety's role to improve health and encourage sustainable practices. The goal of this research was to support Uganda's food safety policies and global efforts. FSMs are used for producing and marketing safe and hygienic dairy products that are beneficial for human health. The results expect to show how the adoption of FSMs affects productivity, output, and profit of smallholder dairy farms. Policy makers and stakeholders to inform suitable approaches for implementing FSMs are discussed in the recommendations.

The study findings could guide policy formulation, program planning, and training programs for smallholder dairy farmers in Central Uganda and beyond. Through these initiatives, it is expected that farmers will increase their awareness, knowledge and compliance with food safety standards, which will help in the growth of the dairy industry, as well as the health and economic conditions of the country. Also, it can deepen our understanding of the effect of FSMs on smallholder dairy businesses and serve as a reference for future studies.

1.6 Scope and limitations of the study

This study focused in Central Uganda, among the smallholder dairy farmers. The study examined the drivers and barriers to the adoption of Food Safety Measures (FSMs) and the profitability impact of FSMs. The study specifically aimed to characterize the levels of conformance of smallholder dairy farmers with the application of FSMs (farm level) in Central Uganda. Further, it aimed to examine how farmers perceived behavioural control, attitude and subjective norms affect their safety and hygiene practices. Also, the study aimed to identify the factors that promote the food safety compliance of smallholder dairy farmers. Finally, it aimed to determine how FSMs impact the profitability of farmers' enterprises in Central Uganda. Smallholder dairy farmers are central in milk contamination and safety management, as the study indicates.

Data was collected in 10 districts of Central Uganda which included; Wakiso, Kampala, Mpigi, Mukono, Kayunga, Buikwe, Luweero, Nakaseke, Mityana and Butambala. The main limitation of the study was inability of smallholder dairy farmers to keep accurate farm records for their agrienterprises. Nonetheless, attempts were made to probe the farmers further on their agrienterprises. Another problem was incomplete questionnaires, which was handled by gathering respondents' contacts for follow-up calls. The producer's entire production season was considered for the last 12 months.

1.7 Operational definition of terms

Animal health measures – according to this study this include measures such as regular washing of animals, isolating sick animals, safely administering medicines to livestock, providing clean water, and dry-cow therapy. These actions make sure that the animals are well treated and the zoonotic infections are under control as well.

Commercialization – is the total amount of milk produced by smallholder dairy farmers and sold to the market to earn money.

Dairy environment measures - involve maintaining farm cleanliness through proper drainage, prompt waste disposal, use of approved chemicals, and regular inspections. These practices help reduce disease transmission and contamination risks, supporting safe, sanitary, and sustainable milk production environments.

Farm-gate prices - Prices that smallholder dairy farmers receive from selling milk either to milk vendors, cooperatives, or processors at their farms.

Food safety - involves the production, handling, storing, and preparing of food in a way that prevents infection and contamination throughout the food production chain. It also helps ensure that food quality and wholesomeness are maintained to promote good health.

Food safety measures - These are recommended good dairy farming practices that can be implemented in production to enhance food safety management along the milk value chain. According to this study, it will include milk hygiene, milk storage, dairy environment, and animal health food safety measures.

Implementation – ability of smallholder farmers to follow the rules, regulations and guidelines stipulated by the Ugandan food policy on food safety measures at enterprise level.

Milk - the lacteal secretion (whitish liquid containing proteins, fats, lactose, and various vitamins and minerals), practically free from colostrum, produced by the mammary glands of all mature, healthy cows on a dairy farm.

Milk hygiene measures – this involves maintaining cleanliness throughout milking, washing and sanitizing udders, hands, and utensils, separating milk from diseased animals, and discarding contaminated milk, to prevent microbial contamination and ensure safe, high-quality milk production at the farm level.

Milk storage measures– this focuses on hygienic handling post-milking, using clean, joint-free containers, keeping storage areas dry, pest-free, and well-ventilated, and avoiding adulteration, to preserve freshness, prevent spoilage, and maintain milk safety and quality before transportation or processing.

Profitability – this refers to the proceeds received by smallholder farmers from milk sold to different buyers minus the milk production costs.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The literature review which is based on the purpose and objectives of the study is presented in this chapter. The review also focuses on the conceptual and theoretical framework behind the study's objectives.

2.2 Overview of the dairy sector

2.2.1 Global dairy sector

The global dairy industry is a key sector of the world economy, which provides consumers with various goods that include milk, cheese, butter, and yogurt (Acosta *et al.,* 2021; Tan & Ngan, 2020). A whole lot of industry sections include dairy farming, processing, distribution, and retailing of milk. Importance of the industry could be judged from its significant contribution to employment, trade and food security. Further, a major nutritional source for small children and pregnant women, it also provides calcium, protein, and vitamins.

International trade is important for offsetting surpluses and deficits in production that may arise in the various regions in which the sector operates. FAO (2023), noted that major exporting countries such as Australia, the United States, New Zealand and the European Union together account for over 75 per cent of all exports. Another world region that is becoming an important import market is emerging economies like those in Asia and the Middle East and Africa because of their growing middle classes. You now see important changes, however, in consumer behaviour in these regions.

Increased trade liberalization through various international organizations has made the movement of dairy products easier. However, this has also made the smaller producers from developing countries more vulnerable to price and competition difficulties. As a result of demand shifts, feed costs and natural disasters, there have been changing international prices which create new uncertainties that need to be managed in both developed and developing dairy systems (FAO, 2023).

During the same time, the global dairy sector has seen greater vertical coordination and concentration, primarily of multinational dairy firms. The major distributors and processors like Nestlé, Danone and Fonterra have been able to control large parts of the dairy value chain by extending their global presence through strategic alliances, mergers and acquisitions. In addition to making things more efficient and standardizing products, the consolidation also creates challenges to fairness and inclusion, especially for smallholder dairy farmers who have limited access to global markets and opportunities for added value processing (FAO, 2023).

Developed countries are quickly using advanced dairy technology. Smallholders in developing countries lack infrastructure, cash, and expertise to use them. The global dairy sector keeps growing and developing despite these challenges (Acosta *et al.,* 2021). Genetic enhancement, mechanized milking systems, precision farming, and other technological innovations are enhancing both quantity and quality of output (Monteiro *et al.,* 2021; Vrchota *et al.*, 2023).

Moreover, marketing, distribution, and consumption of dairy products have changed due to digitalization and e-commerce. As the world's population grows and urbanizes, there is a rising demand for sustainably-produced nutritious and safe food. The dairy sector will have a major role to play in meeting this demand. The increased demand for dairy products, especially in emerging markets, due to population, income, and dietary changes pose a challenge (Acosta *et al.,* 2021; Bairagie *et al.,* 2020).

Because of this, dairy farmers are using modern technologies and improved methods to better their efficiency, profitability and sustainability. Consumer interest in organic and plant-based choices has also led to invention and diversification, which have resulted in a huge range of dairy-free offerings. The worldwide milk industry has its fair share of problems. Acosta *et al*. (2021) show that dairy production causes emissions of greenhouses gases, pollution of water and the clearing of forest areas which presents a problem for the sustainable development of the environment.

To help with this situation, quite a few dairy companies and farmers are turning to an eco-friendlier approach by managing their waste better, using water more efficiently and relying on renewable sources of energy. The monitoring of animal welfare and ethical conduct at various levels of the supply chain is another challenge which is attracting more attention and demands for stricter laws (Khedkar & Singh, 2018).

Climate change is a big challenge for the world's dairy industry. Livestock production harms land resources, leads to water shortages, and is a significant source of greenhouse gas emissions. Heat stress, feed shortages, and new diseases threaten dairy systems in the tropics and sub tropics from climate variability (Gerber *et al.,* 2013).

Initiatives such as the Dairy Sustainability Framework and the Global Research Alliance on Agricultural Greenhouse Gases are highlighting low-emission dairy pathways at the international level. This includes promoting climate-smart feeding practices, enhancing manure management, and funding climate resilient forage systems. These adaptive practices can facilitate improved long-term productivity, food security, and environmental sustainability among communities that are dependent on dairy products (Gerber *et al.,* 2013).

The global dairy industry is changing because of consumer trends and policy frameworks. Increasingly, governments and international organizations have a keen interest in sustainable production methods as they relate to quality assurance and food safety. Two regulatory tools, dairy certification schemes, which include national schemes and the Codex Alimentarius, impose safety and nutritional requirements on dairy products (Gerber *et al.* 2013).

Due to adverse consumer preferences for healthier, ethically farmed, and environmentally friendly products, the dairy industries are being advised on sustainability labels, animal welfare guidelines and circular economy models. Innovation and sustainability will grow together as essential pillars in a transparent, inclusive, and resilient future for the global dairy sector as more and more market trends and policy developments get intertwined (Khedkar & Singh, 2018).

2.2.2 Regional dairy sector

In SSA, millions of households benefit from dairy farming which provides income, jobs and nutritional security for millions of people. It is an important economic activity for rural livelihoods and national economies. According to FAO (2022), most of the African participating countries' dairy farmers are smallholders, incorporating livestock in mixed crop–livestock systems. Most of the region's milk is supplied by smallholders and they often do so through low-input extensive systems involving native or hybrid cattle. Agricultural GDP share in the region varies considerably. It is over ten percent in Kenya and Ethiopia and about three percent in Nigeria and Malawi (ILRI, 2021 & Njoroge *et al.,* 2023).

The dairy sector is an essential component of agricultural development which helps reduce poverty and strengthen rural resilience despite numerous structural constraints. Over the last 20 years, the dairy industry in Africa has developed substantially owing to urbanization, population growth, and rising income levels which have led to growing demand for animal-based foods (Omore et al., 2019). Milk and dairy intake are predicted to double by 2050, particularly in South Africa, Nigeria, Kenya, and Uganda, according to FAO 2021.

Governments and private investors are strengthening milk value chains to update collection, processing and marketing systems, thanks to increased demand. Ethiopia and Tanzania have focused on set up of genetic improvement initiatives and dairy policy reforms towards attaining higher productivity. In contrast, Kenya and Rwanda have established strong co-operative models, facilitating bulk aggregation and formal marketing of milk (Makoni *et al.,* 2020).

Like these Southern African nations such as Malawi and Zambia who have rolled out smallholder inclusive schemes linking rural farmers with processors, boosting the quality of milk and incomes. Although good things are happening, structural problems are still preventing the African dairy industry from competing and being sustainable. Challenges still exist and these include low productivity per animal, limited access to superior breed, poor quality feeds and frequent illness of animals (Habiyaremye *et al.,* 2020; Mangesho *et al.,* 2021).

Post-harvest milk losses in various nations are substantial, reaching approximately 15–25 percent of total output. This scenario occurs mainly due to a lack of infrastructure, such as inadequate rural roads, insufficient cold chain, and erratic electricity (Ndambi *et al.,* 2019). Just 20% of milk marketed was processed as most milk marketing outlets are informal (ILRI, 2022).

Because of how they have been handled, using the milk products with low hygiene and quality control systems in place, these markets pose food and safety health risks in spite of providing a means of survival and low-cost milk to the poor. Changing weather patterns make these problems worst. In particular, they reduce feed supply, water accessibility and animal health. Becoming much more vulnerable to droughts and outbreaks of disease are the Highland systems in Ethiopia and Kenya. Ongoing dry spells in Sahelian countries, such as Niger and Mali, are curtailing fodder production (Thornton *et al.* 2022).

The essential focus of East Africa's dairy sector is Kenya, Uganda, Tanzania, Rwanda and Ethiopia (Tricarico *et al.,* 2020). These countries depend on their dairy sectors' economic and food systems. Dairy farming offers an essential income source for the smallholder farmers, generates jobs and promotes rural development. Omondi *et al.* (2017), report that there is a traditional and commercial dairy production in the sector with many small-scale farmers keeping dairy cattle for milk. In milk consumption, Uganda comes third after Kenya and Tanzania.

In East Africa, the population has grown, the cities have grown, and the diet has changed, increasing the demand for milk (Bosire *et al.,* 2017). Accordingly, the farmers and processors are expanding their business and increasing production. Governments and development agencies have recognized the importance of the dairy sector and have taken several initiatives to promote the sector. Farmers will be offered training and extension services; the farmers will have better access to loans and other inputs; there will be value addition and better market linkages.

The dairy industry in East Africa has a bright potential but faces hurdles. Farmers can only access low-quality supplies due to limited access. As a result, farmers use inferior feed or breeds. Or they do not have access to veterinary care. So, their prices become unproductive and unprofitable. Poor roads make it hard to bring milk from farms to processing centres especially in the countryside. Hence, there are post-harvest losses. The sector is also vulnerable to climate change as unfavourable conditions disturb feed availability and animal health. Thus, there are initiatives aimed at financing R&D, developing applicable infrastructure, and creating new regulations (Habiyaremye *et al.,* 2021, Maleko *et al.,* 2018).

Although the dairy sector in East African countries faces a multitude of challenges, it has great potential for economic growth, poverty alleviation and food security. If smallholder dairy farmers make worthwhile investment in infrastructure, technology, and human capacity, they can improve their livelihood while meeting growing demand for dairy products. Collaboration between governments, development organizations, and the private sector is necessary to design and implement long-term strategies that enhance productivity, add value, open up new markets, ensure environmental sustainability, and add inclusivity across all players in the dairy value chain. (Maleko *et al.,* 2018).

Farmers may remain competitive by strengthening institutional coordination; investments in cold chain may be promoted; and access to veterinary care, credit, and training needs to be enhanced. To strengthen consumer trust and lessen milk contamination, integrating traceability systems, HACCP and Good Hygienic Practices (GHPs) will also be important. Besides that, regional economic communities such as SADC and EAC are important for promoting cross-border trade and harmonizing dairy standards. Africa's dairy industry needs to achieve sustainable transformation which will ensure resilient, inclusive and safe dairy value chains which will have positive outcomes for economic growth as well as nutritional health. This can be only possible if governments, the academia, private sector, and farmers work together. (Habiyaremye *et al.,* 2021).

2.2.3 Uganda's dairy sector

The dairy industry in Uganda has evolved considerably and experienced many changes. In the past, dairy production in Uganda has predominantly been subsistence based, smallholder farmers raising a few animals for home use. Milk was mainly meant for home consumption in the past; anything surplus was made into ghee, and yogurt. In the 1980s, Uganda adopted economic liberalization policies that promoted private investment and reforms in the dairy industry (Balikowa, 2011). Due to this, dairy farming became more commercialized with central and multinational companies setting milk processing plants. In addition, the introduction of improved dairy breeds such as Friesians and Jerseys led to an increase in milk yield.

The dairy industry is an important segment of Uganda's agri-food economy and is one of the fastest-growing in the Sub-Saharan Africa region. Over 2 million farmers depend on it directly or indirectly for their livelihoods, and 9% of agricultural GDP (DDA, 2021 & MAAIF, 2020). Since the 1990s liberalization, the sector transformed from a state enterprise Uganda Dairy Corporation (UDC)to a more open private sector dominated industry (Mbowa *et al.,* 2018) The transformation of these failure areas, particularly in the cattle corridor area from southwest to north east Uganda, has led to the establishment of many processors, collection centres, and producer cooperatives which has enhanced rural development and job creation.

The dairy sector in Uganda has grown significantly in recent years. Thanks to regular growth of milk supply country is a net exporter of dairy products and milk. The Uganda Bureau of Statistics notes that milk production increased from 11 billion liters in 2010 to 20 billion liters in 2019. The growth results from a rise in investment in dairy farming, easier access to improved breeds and quality inputs, as well as farmer uptake of better management practices (DDA, 2021 & MAAIF, 2020).

Uganda produces an estimated 20bn litres of milk each year; the third largest producer in East Africa after Kenya and Tanzania. Smallholder dairy farmers provide about 70% of this, according to the DDA (2017). Dairy production takes place mainly in the districts of Mbarara, Kiruhura, Ssembabule, Lyantonde, and Nakaseke, which are collectively Uganda's milk basin. Most of the farmers use semi-intensive or extensive system. They use native or crossbred cattle. Also, they have a low input system.

The sector has good growth potential notwithstanding productivity constraints after domestic demand, urbanization and prospect of export to regional market such as Kenya, Rwanda, South Sudan and Democratic Republic of the Congo. According to a DDA document from 2021, 70 to 80% of milk trade nationally happens through informal markets. This phenomenon is regarded as a key characterization of the sector. Informal traders in the last-mile milk distribution network play a pivotal role in making milk affordable to low-income people. Due to the informal nature of raw milk handling and processing, contamination, adulteration, and violation of hygienic regulations are serious threats to food safety (Kikafunda *et al.,* 2019; Mwebaze *et al.,* 2022).

The Dairy Development Authority (DDA) and the Uganda National Bureau of Standards (UNBS) have quality certification programs and other legal frameworks such as the Dairy Industry Act (1998) to stimulate compliance with FSMs. Nonetheless, weak enforcement occurs since smallholders and milk traders are not aware enough, there is lack of laboratory infrastructure, and low capacity of institutions. Democratic Republic of the Congo (FAO, 2020; ILRI, 2021). The government and development partners remain focused on efforts in the dairy industry, employing different strategies to overcome challenges and promote growth.

Dairy cooperatives are working on food safety to help smallholder farmers get improved market access and financing. Plans are also being devised to push up the processing of milk and adding value by making cheese, curd and powder milk for the domestic as well as export market. Recent policies and investments –such as the Dairy Master Plan (2021–2030), the National Dairy Strategy (2018–2023) and collaborations with East African Dairy Development (EADD) and SNV TIDE II programs– aim to enhance milk quality, strengthen market links and promote formalization (DDA, 2023; SNV, 2022) by providing farmer training, cooling infrastructure and veterinary and extension service access. To enhance food safety and ensure competitiveness in the domestic and international markets, the focus of these programs is largely on the adoption of SOPs, HACCPs and GAPs.

Despite some gains, the dairy industry in Uganda still faces challenges. Farmers' profits have been limited to quality inputs including improved breeds and infrastructure (Kiggundu *et al.,* 2021; Mugisha *et al.,* 2014). Diseases in livestock and pests may threaten the smallholder dairy farming due to climate change. To keep the consumers and competition in check, dealing with the issue of food safety and milk quality is important. In other words, the negligence of best practices is damaging. The chances of contamination remain high at every stage of the value chain, especially during milk collection, transportation and informal retailing. To bridge the gaps and promote sustainable and compliant practices, an integrated policy approach consisting of market intelligence, incentive-based regulation, and farmer capacity building is vital (Mwebaze *et al.,* 2022).

2.3 Empirical review

2.3.1 Food safety practices among smallholder dairy farmers

To produce and distribute safe and wholesome dairy goods, on-farm food-safety practices among smallholder farmers is very important. Smallholder farmers often find it difficult to comply with food safety procedures due to a lack of resources, limited infrastructure and little access to knowledge and training. According to Alonso *et al.* (2018) and Nyokabi *et al.* (2021), this explains the necessity of safety practices of smallholder dairy farmers to safeguard public health and enhance sustainability and competitiveness of the dairy sector.

To ensure a safe milk product, hygiene must be maintained in the production, handling and storage of milk, smallholder dairy producers must keep their milking equipment clean and sterilized. This should be coupled with proper udder washing and milk collection and storage techniques (Muloi *et al.,* 2018). Regular cleaning and sanitization of all milk containers and milking equipment can prevent harmful bacteria and other contaminants from building up in the equipment. These bacteria can lead to the spoilage of milk.

There are some inexpensive cooling methods to maintain the temperature of milk. The method includes immersing the milk vessel in a bucket of cold water. It is important to build capacity in dairy management for smallholder dairy farmers to effectively adopt and follow the food safety standards (Nyokabi *et al.,* 2021) To empower the targeted food safety training of smallholder dairy farmers and the design of educational materials, important roles can be played by governments, extension services, and dairy sector stakeholders. Education could include milking hygiene, milk storage and transportation (both on-farm and off-farm), and better farming practices (Njage *et al.,* 2018).

Several studies on food safety in Uganda have been done on quality-based milk payments (Daburon & Ndambi, 2019), microbial load in unpasteurized milk (Kateregga *et al.,* 2019; Sugino *et al.,* 2023), practices of pastoral communities, microbial quality and health risk from raw milk (Majalija *et al.,* 2020) and prevalence of subclinical mastitis and its association with milking practices (Miyama *et al.,* 2020). According to a study conducted by Lunner-Kolstrup and Ssali (2016), Ugandan dairy farmers need to be made aware of the health and safety issues and the knowledge that they require. Nonetheless, only a handful of these studies have looked at compliance with or adoption of food safety practices. Moreover, the effect of food safety measures (FSMs) adoption on smallholder dairy farm profitability has not been studied by many.

It is often difficult for those who make the policy and those who implement the policy to ensure proper measures are taken to prevent foodborne infection, encourage safe food practices, educate the dairy farmers, suppliers and consumers and develop the dairy industry economically (Kenny, 2013). According to Kenny (2013), the management of food safety is where microbiological hazards in foods are prevented or kept at acceptable levels. As per Sinhga *et al.* (2011), herd size, location of the milk collection centre, temperature of the milk at the inlet, presence of the cold chain, transportation, and time, are some of the main factors impacting microbiological load.

Milk quality is still the same as prior to udder infection. Hasan and Frank (2011) indicated that the quality of milk still depends on control in entry as well as the growth of micro-organism. Further process on the dairy will change the organism and do different process. The dairy industry puts raw milk in the spotlight. This shows how important it is to have a farm-level system for the safety of milk supply (Valeeva *et al.,* 2005). One of the best ways to enhance food safety is a risk-based, farm-to-fork approach that focuses on cost-effective prevention and controls throughout the supply chain, support capacity building and supply chain coordination, and improve (market) incentives for food safety management (Unnevehr, 2015).

A policy and legislative framework for food safety and quality along with the use of modern technologies, infrastructure and capacity building of the inspectors, are necessary to adopt integrated preventive approach through the adoption of food safety management system during processing in the milk value chain. Kenny (2013), stated that this is key to allow effective control. Giffel and Wells-Bennik (2010), recommend good dairy-farming practices that can be used in milk production.

Practices like, keeping check on animal health, maintaining good milking hygiene, ensuring proper feeding, take care of animal welfare, provide supportive environment, efficient socioeconomic management. To improve food safety, reduction of contamination at the farm level by controlling microbial contaminant in feed, keeping the facilities clean, keeping the cows clean, practicing good animal health management to avoid mastitis, cleaning and disinfecting milking equipment properly, and cooling milk to 4ºC or lower quickly (Giffel & Wells-Bennik, 2010).

In addition to these practices, it is equally important to promote traceability and record keeping in key areas, such as agricultural chemicals, veterinary medicines, animal feed and identification of individual animals (Burgess, 2010). There is need to involve dairy experts in production on an urgent basis. This includes the farmer's expertise, the health of cows, sanitation of milking equipment and environment, management of waste, timing and temperature of transport of milk to collection centre, sanitation of containers, and milk safety hazards (hygienic practices and conditions, safe feed and water, proper use of antibiotics/drugs with withdrawal times and pesticide). As a result, dairy farmers must obtain the necessary training and education to be competent and have the money to make the adjustments needed to comply with quality standard (Chamberlain & Cowan, 2003).

Smallholder dairy farmers require information on food safety measures. That is why the sharing of knowledge on milk quality standards and hygiene practice on the farm must have a gradual development. On top of this, simple and effective hygiene actions have to be implemented to uplift food quality (Hamann, 2010). Everyone involved in the milk value chain must ensure that safety is maintained at all times. As farmers produce milk, collection centers, cooperatives, and processing plants shall implement raw-milk quality control measures through tests such as lactometer readings (for detection of adulteration) and alcohol tests (for detection of fermentation).

The goal is to guarantee that the milk on offer to consumers is safe (Kasozi *et al.*, 2018). There is limited research regarding the evaluation of food safety measures (FSM) at smallholder dairy farms, especially in developing countries like Uganda. Many investigations target stage intermediaries, notably their exporters (Dou *et al.,* 2015; Handschuch *et al.,* 2013), processors (Buckley 2015), manufactures, and retailers. Nevertheless, not much empirical data exist on how smallholder dairy farmers implement FSM. The aim of the study was to evaluate the FSM adoption at smallholder farm level.

2.3.2 Influence of perceived behavioral control on smallholder dairy farmers' behavior in performing safety and hygiene-control practices

Studies on agricultural behaviour have focused increasingly on perceived behavioural control (PBC) or the conviction that farmers have the ability to follow food safety procedure. A study carried out by Adu-Gyamfi et al in Ghana used the Theory of Planned Behaviour (TPB) and structural equation modeling (SEM) to assess how control beliefs affect farmers' hygienic milking practices.

According to their research, perceived behavioral control was the most predictive of TPB constructs. It accounted for 41% variation in hygienic behavior. The technical knowledge, financial capacity for hygienic maintenance, cooling access and other indicators indicate an empowerment-based infrastructure has more importance than awareness-based areas.

Using a binary logistic regression model, Alemayehu *et al.* (2022), assessed the uptake of sanitary milking and milk-handling practices by Ethiopian dairy farmers. As per the findings, farmers with high self-efficacy in maintaining cleanliness of equipment and health of animals were significantly more likely ($p < 01$) to comply with safety regulations in milk. The result supports what Ajzen (1991), suggests that PBC impacts behavior indirectly via intention and directly predicts behavior. This study recommends that rural extension services facilitate the expansion of their material and psychological capacity to enhance compliance.

According to Kimani *et al*. (2020), in Kenya, when structural obstacles such as limited electricity and water access were significant, perceived control was insignificant in predicting safety behavior. They determined that perceived control only matters when enabling conditions are there. They triangulated their findings through a survey and an observation analysis showing that these constructs rely on the situation in question. Systemic support can encourage self-efficacy to translate into behaviour even when self-efficacy is high, their findings show.

Nguyen and Le (2023), also studied the impact of collective perceived control on compliance with hygienic standards in smallholder dairy cooperatives in Vietnam through multilevel modelling. They showed that perceived control greatly increased for farmers when they worked within organized networks with shared equipment and peer monitoring. In areas where resources are limited, group efficacy rather than self-efficacy could enhance compliance. Because shared resources can offset individual limitations, these results are especially relevant to Uganda's cooperatively managed dairy industry. Research by Bashir *et al*. (2021), examined farmer perceptions regarding their ability to control food safety hazards in Pakistan, despite lax regulatory oversight.

According to PLS-SEM analysis, extension agents trust and access to training are important mediation factors between perceived control and hygiene behaviour. Nabirye *et al*. (2021), studied the PBC and milk handling practices of the unofficial milk producers and traders in Uganda. Through conducting ordered probit regression, it was found that participation in the formal market and having a lower rate of spoilage of milk related significantly to the perception that one can meet the regulatory requirements. But the qualitative results suggested that inconsistent enforcement and low institutional trust weakened PBC. This shows that PBC has been found to predict behavior in terms of empirical support, the PBC works within a larger system of institutions that weaken its impact.

2.3.3 Influence of attitude on smallholder dairy farmers' behavior in performing safety and hygiene-control practices

A farmer's intention to adhere to hygiene and safety practices in dairy production is significantly influenced by his attitude towards food safety practices. The term attitude, in this case, refers to the level of favourable or unfavourable evaluation associated with behaviour. Mwangi and Bett (2020) using a probit regression framework and the TPB assessed this relationship among 380 smallholder dairy farmers of Nakuru County, Kenya. The results indicate that farmers with a good demeanor toward hygienic milking are 32% more likely to wash their hands regularly, use sanitized milking containers, and implement sterilization of utensils.

The research showed that attitudes seem to be influenced by perceived benefits to reputation and economy. This includes the sentiment that milk safety builds consumer trust and expands access to formal markets. These insights illustrate the dual creation of attitude: on the one hand, on the side of the ethical responsibility towards the consumers and, on the other profit motive and spoilage of milk. Farmers' attitudes are not psychological but depend on broader socio-economic rationalities underpinned by process motivations that ensure compliance.

Farmers knowing zoonotic infection, consumer complaint or milk spoilage incidence have a positive attitude towards compliance behaviour. The emotional experiences of vulnerability and loss in humans can significantly influence one's attitude towards hygiene, which can be explained from the experiential learning perspective. Thus, it may prove more effective to utilize simulations, testimonies, or experiential learning (which usually do not emphasize risk).

Turyahikayo *et al.* (2022), conducted a study in Uganda and used hierarchical regression analysis to assess the attitude towards hygiene of smallholder dairy farmers in Mbarara District. The study found that 78 percent of farmers expressed a favorable opinion regarding the filtration of milk, cleaning the udder with water on the farm before milking. But just 54 percent made sure to put these in actions. The gap between attitude and actual behaviour was ascribed to optimistic bias that is the cognitive distortion or farmers believed that the quality of their milk and access to the market will not be affected directly.

While a positive attitude is necessary for a change in behaviour, they are not sufficient unless the farmer feels vulnerable and accountable. The results give some insight into bounded rationality: the limited behaviour causing problem is not the ignorance of risk, but rather the false sense of immunity to it. This nuance greatly affects Uganda's food safety communication strategies, which should match behavioral expectations with perceived outcomes.

According to Bekele *et al*. (2023), an additional review looked into the mediating role of attitude linking knowledge to behavior in Ethiopia through the end-to-end behavioral and socioeconomics modelling of three regional dairy clusters. Through SEM and path analysis, they found that participating in cooperative marketing and exposure to training on milk quality significantly improved positive attitudes towards safety of food.

The relationship between knowledge and behavior was fully mediated by attitude. It means that farmers do not want to follow the technical advice until they develop a positive attitude towards it. This finding contradicts the traditional extension model which assumes that a direct link exists from knowledge to practice. Farmers will consistently adopt hygiene practices only through successful behaviour change programmes that foster internalized positive judgments rather than through mere awareness generation.

Mugisha and Asiimwe (2025), researched the complicated journey that shapes people's attitudes towards milk-safety regulation. The authors used a mixed-method sequential explanatory approach. According to their quantitative findings, positive attitude correlate strongly with perceived profit benefits ($\beta = 0$, $p < 01$). According to the study, farmers perceive compliance as a fundamental part of their identity as professional or modern farmers. By including identity-based motivations, the Theory of Planned Behavior (TPB) can be expanded. As a result, attitudes appear not just to be evaluative judgments but also a reflection of one's social self-concept. For instance, suggesting that cleanliness shows a professional or market-ready mindset can help behavioral initiatives that take advantage of identity signaling.

2.3.4 Influence of subjective norms on smallholder dairy farmers' behavior in performing safety and hygiene-control practices

The subjective norms or social pressure experienced to either accede to or refrain from any behaviour, remain one of the most important determinants influencing food safety practices in any agri-system. Li *et al.* (2020), performed a SEM analysis on 512 dairy farmers in China and found that consumers, extension agents and peer's normative pressure significantly increased the milkers' adherence to sanitary milk-handling guidelines. Peer reputation and cooperative accountability were shown to be the strongest predictors of hygiene behaviour, indicating that what the group thinks about you, social signaling, leads to compliance, rather than personal choice, in collectivist societies.

Farmers used safety measures in their farming environments to earn symbolic capital, recognition, and social acceptance. Apparently, the norm activation theory states the perception of social cues triggers a moral obligation. In the light of this, this finding, which states that moral obligations get triggered by social cues is such norm activation theory. Social pressure can be a powerful instrument for policy change in the dairy sector in Uganda. Peer groups and communal learning structures are still highly valued. These strategies may also assist in compliance with food safety.

Omondi *et al*. (2021), used an instrumental variable probit regression model to investigate the influence of subjective norms on clean milk-handling practices by smallholder farmers in Kenya. According to their findings, farmers that were a part of self-help groups or producer organizations were 47 percent more likely to adopt hygienic practices like washing the udder before milking and storing the milk properly. The research found that social norms influenced behavior through two key channels, normative advice given without adapting the advice and social comparison, where farmers mimic acts they find successful or respectable.

This diffusion mechanism is similar to Rogers' Diffusion of Innovations Theory which identifies peer credibility and imitation as keys to adopting behaviours. This approach advocates the use of social networks to spread hygienic norms as an alternative to top-down regulation. This is especially pertinent to Uganda where the district-based networks have been expanding, for example Mbarara and Kiboga.

Banda *et al*. (2022), performed an analysis of social network analysis (SNA) of smallholder dairy in Zambia. The findings show that hygienic milk-handling behaviour is predicted more strongly by the number and quality of network ties than by attitude or perceived behavioural control. According to the study, network density can cause social pressure that results in normative fatigue–meaning fatigue that originates from social norms–which can affect compliance action negatively.

Theoretical significance is attached to this finding as it questions the assumption that additional social influence leads to more positive consequences. To avoid compliance burnout, normative interventions should support autonomy as well as reinforcement. It is important to find a proper normative influence to come up with an effective community-based food safety program in Uganda. This is due to the large differences in cohesion and leadership of such dairy cooperatives.

Nansubuga *et al.* (2023), used ordinal logistic regression to analyze the normative determinants of hygienic milk production among 300 smallholder farmers of the Central Region. The perceived expectations of veterinary officers and cooperative leaders significantly increase the likelihood of following hygiene procedures, their results show. In comparison, the scores associated with expectations from family and society were less pronounced. We see that there is a gradual movement away from traditional social pressures to more institutionalized social norms that are spread by the cooperatives and the extension system.

This means that the informal normative systems in Uganda's dairy industry are getting replaced due to commercialization. According to the study's conclusion, behavioral expectations indicators have resulted from the influence of institutional actors. Hence, this indicates that raising the legitimacy and visibility of these actors may lead to greater compliance with the standards. This view of institutions helps current PhD study to understand how modernization alters the social foundation of food safety standards in transitional agricultural economies.

According to Kibet *et al*. (2024), among Kenyan dairy sector actors, moderated mediation analysis was applied to age and gender as moderated subjective norms. The activities of male farmers were more influenced by peer competition and market forces, while the activities of female farmers were more influenced by social recognition and approval. Farmers aged below 35 were more likely to follow the group norms and with the digital information network and modernity concept norms.

The study by Akello *et al.* (2025) estimated subjective norms in Ugandan dairy cooperatives. This estimate was by distinguishing between individual and group factors influencing compliance behaviour through a two-level hierarchical linear model. According to the findings, wise expectations of cooperation had a strong influence on the individual farmer's hygienic practices, mainly through mutual supervising and group identity mechanisms.

Farmers in strong cooperatives were able to maintain safety and hygiene standards without outside inspections because of a sense of responsibility. The findings indicate that taking joint accountability, gaining publicity recognition, and submitting to peer assessments is more effective than the punitive regulation for voluntary compliance. It is consistent with the collective efficacy theory which says the importance of shared belief in achieving a goal.

2.3.5 Drivers of food safety compliance by smallholder dairy farmers

Most countries in the world have laws and food safety systems. These systems include regulations and quality controls along with many other things in milk. In the US, before a farmer provides raw milk to a dairy plant, dairy processors subject every incoming milk to tests for safety and quality parameters such as organoleptic, bacterial and antibiotic tests as well as milk components. If the tanker load of milk fails to meet safety standards, it will not be accepted. The dairy farm from which the stock is sourced will also pay for the full tanker load. Agencies of states and regulatory bodies monitor what dairy processor does through surprise visits to take milk samples and check industry information (USDHS, 2000).

In addition, milk processing plants establish the system HACCP on the manufacturing steps to help monitor and lessen food safety risks. Milk quality and safety are a shared responsibility between government at the federal, state and local levels, and all players in the dairy industry and consumers (USDA and USDHS, 2000). The industry is expected to adhere to standards relating to milk production and processing. They may also adopt various voluntary measures to protect the dairy products. Moreover, the USFDS and state regulators work with dairy farmers and processors to establish compliance with regulations and best practices to ensure a safe milk supply (USDHS *et al.,* 2005). The FDA regulates milk which is distributed from one state to another (Dairy Council Digest, 2002).

In the European Union, food safety is regulated by three organizations: the Directorate-General for Public Health and Consumer Protection; the Food and Veterinary Office; and the European Food Safety Authority (Zheng, 2012). They aim to achieve high food safety and animal and plant health by putting in place coordinated measures from farm to table, monitoring and ensuring the proper functioning of the market in the EU. But the USA has tight laws about food safety, and the European Union (EU) food laws are also strict. On the other hand, China's laws are not developed adequately in terms of scope, overlap, and consistency. Even though there're numerous food safety certification and labeling programs, both mandatory and voluntary. According to the sources, almost half (50%) of all Chinese private firms under inspection for Western food distributors and retailers failed to meet the safety requirements of the customer. In addition, the firm had neither the means nor the training to ensure food safety (Chen *et al.,* 2015).

China's food safety division at the farm level is under the Ministry of Agriculture while the Administration of Quality Supervision, Inspection and Quarantine is responsible for Food Safety during processing and at import and export points. The State Administration for Industry and Commerce supervises food safety management in marketing and the State FDA is responsible for catering services and health safety. Also, risk surveillance and risk assessment are conducted by the National Health and Family Planning Commission (Chen *et al*. 2015).

Efforts will be made to harmonize standards across East Africa (FAO, 2011). The measures being taken include registration of primary producers, considering permits for the transportation of milk from place to place, grant of licenses for the sale of milk and milk products, formulation of specific materials and standards for dairy equipment, certification of premises-by-public health officials for sale of milk, inspection of milk handlers to check compliance to health requirements, and licensing of dairy managers after meeting specific educational standards (FAO, 2011). In Kenya, the Dairy Industry Act (CAP 336) as well as Public Health Act (CAP 242) provide safety standards and regulations for milk and dairy products (MDPs) which are enforced by law.

In a cross-country study covering Kenya, Uganda and Tanzania, Muliro *et al.* (2021), investigated compliance with milk safety and hygiene regulations in the East African Dairy Regulations. Farmers selling milk to either a cooperative or processor are two to three times more likely to comply with safety and hygienic regulations than those selling milk informally, according to their mixed-methods design. Having access to routine inspections, being trained milk quality and availability of cooling infrastructure predicted compliance. According to the analysis, it is mainly market-driven incentives that make buyers demand compliance with safety norms. Despite a handful of facilities claiming 100 percent compliance, the enforcement of national quality regulations is weak in the region and technical support is limited

A study by Habiyaremye *et al.* (2022), was conducted in Rwanda. The study examined the effect of farmers' risk perception and training exposure on food safety compliance. According to a probit model, the understanding of the farmers regarding risks of transmission of zoonotic disease significantly increased compliance with antibiotic withdrawal and milk hygiene restrictions. In Rwanda, 39% of untrained farmers applied preferable milking and udder hygiene procedure compared to 72% of trained farmers. Ugandan farmers who felt that their customers' health depended on food safety demonstrated higher adherence levels. The study established the importance of creating awareness regarding foodborne hazards and continuous training and sensitizing farmers and especially smallholders who sell raw milk directly to consumers or through informal markets to enhance adherence.

Muriuki *et al.* (2023), study voluntary certification programs and cooperative member effects on smallholder farmer compliance with food safety regulations in Kenya's Rift Valley. According to the study, the use of propensity score matching (PSM) to estimate treatment effects found that access to group certification extension service plus collective training increased the likelihood of full compliance with milk safe by 28%. Farmers who took part in the certification programs also reported keeping better records, using stainless steel containers and following antibiotic withdrawal procedures.

The research finds that lower monitoring costs and greater reputational benefits to farmers can encourage compliance by way of third-party certification as well as collective action mechanisms. Because certification can be expensive and smallholders often lack awareness, adoption remains low. Studies in Ethiopia and Nigeria enhance the relevance of governance frameworks and the regulation in determining compliance behaviour.

Oluwatayo *et al*. (2024), checked whether the milk was safe through carrying out a logistic regression in Oyo and Kaduna states in Nigeria. The frequency of effective local government inspections, availability of milk collection facilities and the presence of extension officers were the key compliance determinants as per findings. Feyisa *et al.* (2023) in Ethiopia found that farmers in districts with veterinary presence and active dairy cooperatives comply with hygiene standards more than those in areas with weak governance. The findings of the studies indicate that levels of compliance depend more on institutional coordination and enforcement consistency than mere presence of laws. To have a safe milk supply chain, Uganda and the wider East African region require improvement in regulatory capacity and monitoring systems.

2.3.6 Factors influencing adoption of food safety practices at farm level

According to a study by Feyisa *et al*. (2024), they examined the implementations of milk-safety practices in Ethiopia. Moreover, the study uses truncated Poisson and ordinary least squares methods. Researchers noted that a more educated dairy farmer with more dairy production training would adopt more milk-safety practices. They also said access to information about milk-safety, availability of credit and experience with inspections would boost rates. On the other hand, higher numbers of lactating cows, greater distances from sources of water, and greater shares of milk consumed at home were negatively associated with the adoption of the milk-safety practices.

Nyokabi *et al.* (2024), used Ordinary Least Squares linear regression in Ethiopia to identify factors influencing FSM adoption. The results showed that herd size, education level of the farmer, expertise in dairy farming, and involvement in the formal milk value chain have a positive influence on adoption of FSM. In other research, Korale *et al.* (2023), employed multiple linear regression, an ordered logit model, and seemingly unrelated regressions to examine factors impacting the integration of food safety practices in Sri Lanka. They found that access to training for safe milk production and subsidies to build animal sheds encourage the adoption of FSM. Moreover, Mwambi *et al*. (2020), investigated the effects of producer organization (PO) membership on farmers' safe food production behavior by propensity score matching analysis. According to the findings, membership in POs positively and significantly impacts the implementation of food safety measures by smallholders, enhancing safety in milk storage and the milking area.

Yang *et al.* (2019), studied factors affecting on-farm milk safety adoption in Northern China using a Poisson regression model to find out the driving forces behind farmers' adoption of voluntary milk-safety measures. According to the findings, complex and scaled dairy farms implement more safety features than backyard dairy farmers do. In addition, the likelihood of employing safe raw milk production practices positively correlates with farm size. For example, using OLS and ordered probit models, in Asia, Kumar *et al*. (2017), analyzed factors influencing FSM adoption in Nepal. The researchers observe that a larger herd size causes the farmer to adapt foreign animal disease more frequently. However, such compliance has a decreasing marginal cost.

Access to information and the occurrence of safety and quality checking inspections also contributed to the increase in the use of FSMs. Nyokabi *et al.* (2023), studied biosecurity practices in the smallholder dairy farms of the Oromia and Addis Ababa regions of Ethiopia. Using cross-sectional survey data and the Biocheck scoring tool (external and internal biosecurity), their research revealed that external biosecurity lagged (49.1%) while internal biosecurity scores averaged about 55.5%. Given the high benchmark reference score of 76%, researchers believe the moderate uptake of biosecurity can still improve significantly.

Participation of the farm in formal milk value chains, frequency of contact with animal health services, access to veterinary extension, and farmer education were important factors positively associated with increased adoption of biosecurity. On the other hand, when it comes to farms that relied heavily on informal markets, which had less exposure to extension services, or which had less awareness of pathogens, these were associated with lower biosecurity adoption. The results underscore the relevance of the institutional and experiential factor, necessitating interventions that reinforce the institutional and extension environment on promoting safe milk and disease control, besides the farmer behaviour.

Investigating the Knowledge, Attitudes, and Practices regarding milk quality and food safety among smallholder dairy farmers in Central Kenya (Laikipia, Nakuru and Nyandarua counties) (ILRI, 2021). The participants believed basic hygiene was adequate which is why they would not implement tougher safety measures like cooling down of milk, antibiotic withdrawal period and use of clean containers. Farmers who were more literate, more accessible to extension services and whose training had taken earlier had a higher adoption rate. The results show that the clean water, good containers, cooling and market incentives are essential since knowledge alone is not enough. The continuing challenges remain limited resources, lack of trust in inspectors and absence of premiums for safe milk.

Ronnie *et al*. (2024), studied the effect of sustainable dairy management practices on farm income in Rubaya Sub-County, Mbarara District, Uganda. This study looked at sanitation and environmental management and milk hygiene but was not limited to FSMs. They used their approach of income indicators and cross-sectional survey data. Farms that utilized more sustainable practices, with regard to housing, availability of clean water and better disposal of wastes achieved higher profits than farms that did not. Adoption was enabled due to extension services, farmer group membership, and credit access. Although they do not focus exclusively on milk safety, the findings show that FSM procedures as part of sustainable management can enhance revenue significantly.

In 2022, Kenyan researchers assessed the safety and hygiene levels of milk supplied to processors by smallholder farmers in Bomet, Nyeri and Nakuru counties, looking at the microbial quality of milk (ILRI, 2021). Their study included microbiological analysis of milk samples collected from various supply channels including direct suppliers, traders, and cooperatives with and without chillers, along with observations and interviews. According to the findings, the bacterial loads in the milk of farmers following specific hygienic procedures (cleaning the teat before milking, milking into clean containers, cooling the milk quickly and proper storage) were quite less.

However, milk that was poorly handled or transported long distances without cooling had higher contamination. While we did not determine profitability impact directly, we suspect that less contamination means less rejections by processors which would lower losses and improve revenue. Similarly, independent suppliers often do not adhere to hygiene standards as effectively as cooperatives with cooling facilities. Improved hygiene practices were connected to being close to the processors, belonging to cooperatives and some level of education.

The last review discussed a number of the factors affecting farmers' adoption of FSMs. Though many studies have been undertaken on FSMs at the farm level, the majority of these studies have been conducted outside Uganda; hence, Uganda lacks adequate empirical evidence on FSMs. There was a need for this study and especially in the light of the disease outbreaks experienced by the Ugandan dairy sector (Sugino *et al.,* 2023).

2.3.5 Effect of food safety measures on the profitability of smallholder dairy farms

Many studies (Kumar *et al.,* 2017; Kumar *et al*., 2020; Paraffin *et al.,* 2018) reveal a positive relationship between food safety practices and productivity among smallholder dairy farmers. Proper practices in agriculture like good animal healthcare, sanitary handling of milk, and sufficient storage will limit the chances of contamination and spoilage of milk. The overall quality of the milk and its shelf life improve which helps to boost productivity. Also, the adoption of FSMs results in less loss and waste, which means more milk can be sold in the market (Paraffin *et al.,* 2018).

Kiambi *et al.* (2020), studied the governance of the Nairobi dairy value chain and food safety. They pointed out that although FSMs are necessary for-profit enhancement, many constraints impede their functioning. Farmers receive little food-safety training, and there is the distribution of poor-quality, adulterated milk along with no policy for managing milk wastage. Still, several farmers who reported not having these problems noted increased profits after receiving food sanitary training. The development of dairy farming is up to the mark but there is lots of scope left to unlock efficiency and additional benefits from food-safety measures.

On-farm food safety measures can boost a farm's bottom line, according to research. Kumar (2020), who used farm-level data and rigorous econometric techniques to show that an additional food safety practice would lead to a modest and significant increase in milk yield and profit. After controlling farm and household characteristics, the study finds that yields rose by around 1% and profits by 2-3% per extra FSM. As per our knowledge, the data shows a basic causal chain – improved milk quality widens geographical distribution of espresso and enables to save on waste losses and enhance profitability.

The revelation that FSM promotion can benefit smallholders while also yielding a profit is significant since it reflects the financial returns on what are typically considered primarily public health investments. Later studies with different measuring systems, and in other countries, have localized and enlarged on this finding. According to a study done by Nyokabi *et al*. (2024) in Ethiopia, higher farm incomes and food-security indicators are associated with the adoption of milk-safety and biosecurity practices, control of mastitis, safe storage and hygienic milking.

On market and extension service access effects vary depending on context (Feyisa *et al.*, 2023 & Nyokabi *et al.,* 2024). The studies demonstrate two important nuances: first, having a formal milk buyer or cooperative that pays a premium for quality increases the returns to farmers' investment; and second, the profitability gains from behavioural practices are greatly enhanced by training and functional infrastructure (clean containers, chillers). FSMs are good by themselves, but their economic value is dependent on the market link and supporting infrastructure. More and more studies show the importance of these institutional and collective mechanisms for effective FSM adoption.

When producers implement collective action, it reduces the private costs involved in complying with processors' requirements like sharing chilling centres, pooled transport, group training, and enhancing bargaining power with processors, which eventually enables producers to fetch higher prices for safer milk (Arshad *et al.,* 2023; Mwambi *et al.,* 2020). Research indicates that farmers involved in productive producer organizations are not only more likely to adopt full FSM bundles, but also benefit from price premiums that convert small hygiene investments into large profit margins.

A number of recent impact assessments and observation studies highlight that the profitability depends on: (i) investment needed (is it about infrastructures or simply low-cost behavioural changes), (ii) quality specifications of the community; and (iii) sticking to improved methods (Katoch, 2024; Korir *et al.,* 2023). While there may be long-term benefits, capital-intensive milk handling and on-farm chilling can adversely affect short-term cash flow if adopted without credit or secure market connection because they involve a high upfront cost and longer payback period. The findings recommend an approach that is systematic, starting with low-cost, high-impact interventions before formalizing these and putting the requisite infrastructure in place.

Recent studies now implement more advanced causal methods, including propensity-score matching, instrumental variables, and ESR-type methods. It emphasizes the importance of taking into account selection bias and endogeneity when estimating the FSM effects on profits. While these methods still have some effect, they have weaker effects compared to the simple OLS estimates, suggesting some selection bias, as FSMs are adopted by wealthier, better farmers who are likely to earn more income anyway. Between the years of 2020 to 2024, experts agree that FSMs can help smallholders raise their profitability. They achieved this by adding essential support systems. These include providing financial, technical, organized marketing channels, and necessary infrastructure. A good policy bundle will also lower compliance costs. This will help farmers get a better price for safer milk.

According to Mutua *et al.* (2022), smallholder farmers who follow the Kenya Dairy Board's milk-hygiene guidelines receive 10–15% more payments than those who did not. A similar analysis by Mekonnen *et al.* (2023), based on Ethiopian data revealed that farmers who joined dairy cooperatives with organized food safety protocols earned more in total as they had easier access to processors in the city. In addition, milk from farmers who joined cooperatives was less rejected. The findings indicate that food safety compliance functions as a kind of market passport for smallholders to access less volatile and higher-value markets. As per them, scattered smallholder systems which use food safety management systems (FSMs) can better sustain financial benefits if they have institutional enforcement and group monitoring systems. According to recent studies coming from South Asia and Southern Africa, food safety practices have resilience benefits as well.

Ncube *et al.* (2023), observed that those Zimbabwean farmers who adopted quality-control and hygienic handling practices before the outbreak of COVID-19 experienced less income loss and loss of market access during and after the COVID-19 in Bangladesh. Assurances from customers about the safety of the milk and live contracts with the processors have helped these households maintain more stable cash flows. The resilience factor, which was a blind spot in earlier studies, indicates that FSMs serve as a risk mitigation tool during crises and enhance profitability during normal periods.

The findings are particularly pertinent in low-income settings, where the profits of smallholders can be rapidly impacted by shocks, such as disease outbreaks, droughts, and changes in the prices of inputs. Smallholder dairy businesses can be supported to achieve forward sales margins (FSMs) by financing digital traceability systems and aligning their standards with cooperatives.

2.5 Theoretical framework

2.5.1 Resource-based view theory

This research uses resource-based view (RBV) theory of Penrose (2009). The study uses RBV theory to analyze a farm's internal resources in order to understand how a farm is achieving competitive advantage and subsequently preserving it. It stresses the significance of a farm's resources and capabilities for success. Utilization of the FSM system in dairy farming is a resource or capability that is thought to enhance productivity, output and revenue. Barney (1991) argues that resources are all capabilities, organizational processes, assets, attributes of a firm, knowledge, skills and information a company has.

Implementing FSMs can boost productivity and profits. FSMs can help with improved hygiene standards, better quality control, and more effective traceability. These reduce food poisoning and recalls. With this, a smallholder dairy farmer earns an identity of reliable safe supply of dairy. With the customer's trust and loyalty increasing, it drives more demand which adds a greater sale that maximizes profit.

Also, it is better you invest in technology when adopting FSMs. The cost of these combine automation and process improvement which make operations smoother and reduces the labor and time cost, such as, automated milking. Therefore, dairy farmers' income and profits can benefit from higher productivity and savings resulting from increased efficiency. Using FSMs can also allow access to premium market segments and new markets.

Consumers in developed counties are more concerned about food safety and quality. By following safety regulations and obtaining necessary certifications, dairy producers can distinguish themselves from the competition and gain consumers' trust in safe and high-quality products. Dairy farmers can receive higher margins in these markets or segments which lift their profits, therefore, dairy farmer profit drivers. Due to the value that adopting Frontier Supply Models (FSMs) will have for smallholder dairy farmers, the RBV theory will be essential for understanding how FSMs increase production and profitability. It allows farmers to make use of FSM-related resources and capacities, such as better food-safety practices, technology investments and premium market access.

2.5.2 Theory of the firm and utility maximization theory

According to the theory of the firm, each business is motivated by the goal of maximizing profits. This theory influences decisions related to resource allocation, production methods, pricing adjustments, and production practices. Both the theory of the firm and the theory of utility maximization were considered in this study. Therefore, the focus is on modeling the market decision-making process of smallholder farmers using these theories. Economic theories explaining farmers' decision making are generally based on utility or profit maximization (Griliches, 1957).

Utility is explained based on the profits that value-chain actors can gain from their activities. Households can earn different levels of profit depending on the context, and it is believed that their choices about what to produce, how to produce it, and whom to supply are influenced by their relative profit prospects (Doll & Orazem, 1984). It is assumed that farmers aim to maximize profit, and therefore, they maximize utility by achieving the highest possible profit. Consequently, the decision to implement food safety measures is expected to make their products more acceptable in the market, enabling farmers to transition into commercial dairy farming. The ultimate goal is to choose levels of food safety that expand market access, increase sales, and ultimately generate higher profits from commercialization.

Using this theories, a farmer's decision to adopt a given food-safety measure is assumed to be motivated by a desire to maximize the expected utility or profit he or she expects to gain from this practice (Salvatore, 2003). This utility is a function of a vector of factors (X_a^A), unknown parameters β_a and an error term ε, assumed to be independently N (0,σ^2) distributed (Equation 1). Farmers make decisions about whether or not to choose a given food-safety measure by evaluating the gains in their expected utility, taking into account the related investments and costs (Kelsey, 1994; Lazear & Rosen, 1981). It is expected that farmers will adopt food safety measures that promise the most positive utility. The expected difference in utility is expressed as follows:

$$U_j = \left(\pi_{ij}^A - \pi_{ij}^0\right) = X_a^A \beta_a + \varepsilon^A \quad \text{......(1)}$$

Where U_j is the unobserved expectation operator representing the expected utility difference, is the utility derived from measure *i* if selected by farmer *j*, and is stream of utility if measure i is not selected. Farmers make a subjective comparison of different attributes of food-safety measures and their own capacities to meet the market demands. They only adopt milk hygiene, milk storage, dairy environment and animal health food- safety measures when they perceive adoption to offer higher utility than alternative options. From equation 1, we can infer the adoption of food-safety measures decision model as being:

$$Y_{ij}^A = \begin{cases} 1 \; if \; \left(\pi_{ij}^A - \pi_{ij}^0\right) \geq 0 \Leftrightarrow X_a^A \beta_a \geq -\varepsilon^A \\ 0 \; if \; \left(\pi_{ij}^A - \pi_{ij}^0\right) < 0 \Leftrightarrow X_a^A \beta_a \geq -\varepsilon^A \end{cases} \quad \text{......(2)}$$

The farmer j decision to select the food safety measure i is defined as Y and the choice of farmer j to adopt a food safety measured i Y 1 or not Y 0 is expressed as follows:

$$Y_{ij}^A = \begin{cases} \left(1 = if \; Y_{ij}^A = X_{ij}^A \alpha_{ij} + \varepsilon^A \geq 0 \Leftrightarrow X_{ij}^A \alpha_{aij} \geq -\varepsilon^A\right) \\ \left(0 = if \; Y_{ij}^A = X_{ij}^A \alpha_{ij} + \varepsilon^A < 0 \Leftrightarrow X_{ij}^A \alpha_{aij} \geq -\varepsilon^A\right) \end{cases} \quad \text{......(3)}$$

Where αij is a vector of estimators, ... is a vector of error terms under the assumption of normal distribution, is the dependent variables, and is the combined effects of the explanatory variables the decision to adopt the usage of food safety measures or not depends on whether the smallholder farmer gets a higher utility than not adopting the food safety measures. The key assumption under this methodology is that smallholder farmers are faced with only two alternative choices and that any choice an individual makes depends on their characteristics (Pindyck *et al.,* 1997).

2.6 Conceptual framework

This study was conceived within a framework where the characteristics of smallholder dairy farmers, the farm, the market, the institution, and food-safety measures serve as the independent variables, while production and profitability of the smallholder dairy farm are the dependent variables. In this framework, it is assumed that the farmer's characteristics, the farm, and the market directly influence the adoption of food-safety measures, as well as production (milk yield and quality) and profitability (income and profits) of smallholder dairy farms, as shown in Figure 2.1.

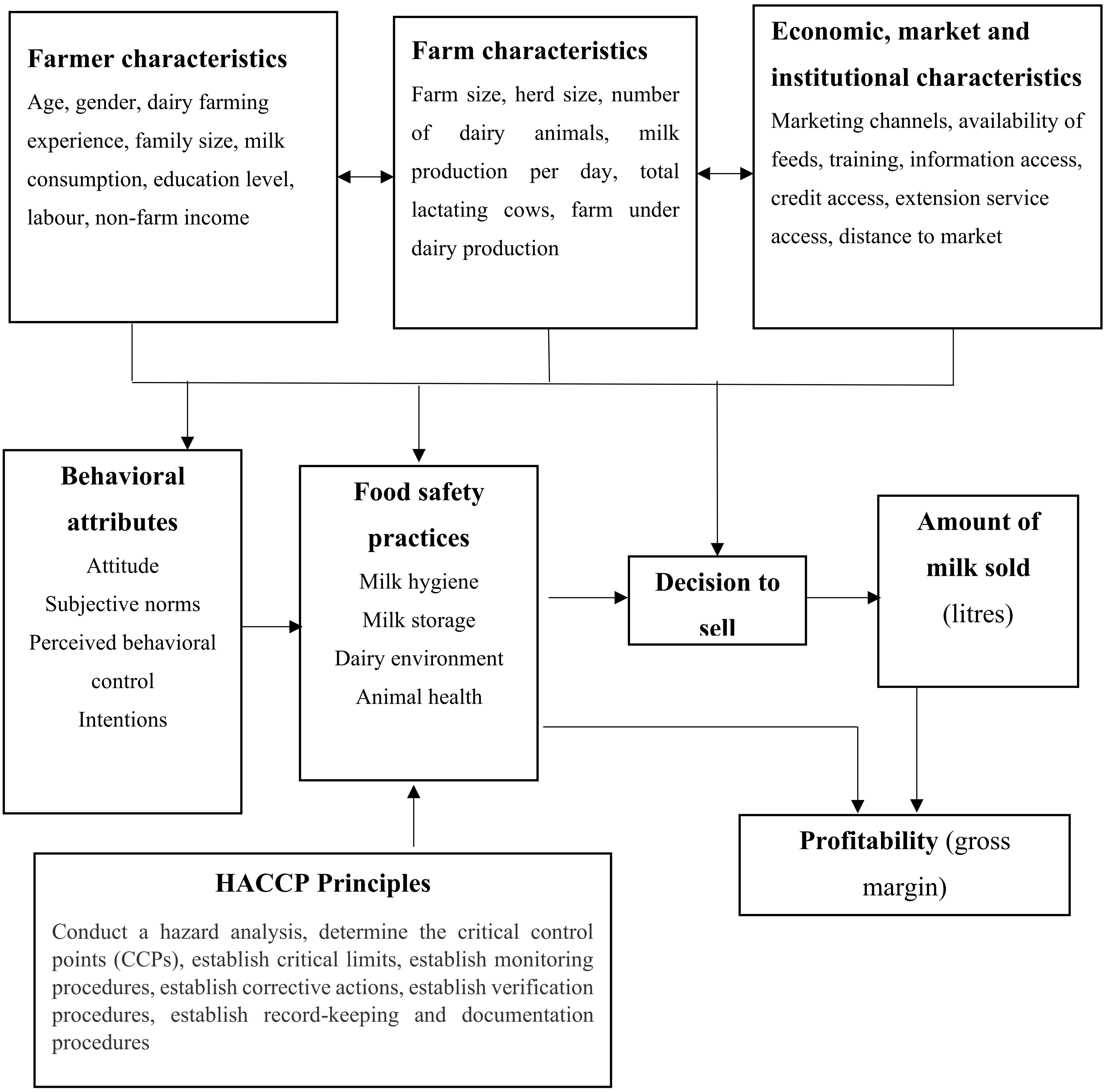


Figure 2.1: Conceptual framework of the study

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents a systematic description of the methodology that was used to conduct the research. It comprises sections on the study area, research design, population, sampling frame and sampling procedures, data-collection procedure, pilot study and data analysis.

3.2 Study area

The research was conducted in Central Uganda, one of four regions within Uganda's administration (Figure 3.1). This area is 61,403.2 km² wide made up of 24 districts with Kampala City being the main city. According to the census of 2014, it has 9,529,227 people (Uganda Bureau of Statistics, 2015). Uganda is very famous for tourism. Notable tourist attractions are the Buganda Kingdom heritage site and Lake Victoria. The country has diverse culture, and it is a big tourist spot in Africa. Agriculture is the mainstay of economy and tea and coffee is produced in plenty. Along the shoreline of the Lakes Victoria, Kyoga, and Wamala fishing is a key economic activity.

The region was selected for multiple reasons. Central Uganda is the second largest producer of milk in Uganda accounting for 34% of the country's total milk output, hence a good place to study the adoption of food safety measures (FSMs) in the dairy sector. Moreover, agriculture is the economic backbone of the region. Important activities are tea and coffee growing and fishing.

In the context of dairy farming in the area, an understanding of food safety practices enhancement of its profitability was important for the region as well as the country. Moreover, important tourists' attractions in Central Uganda includes the Buganda Kingdom, which is also popularly known as the Republic of Uganda. The cultural potential of the region and its agricultural value could provide an opportunity to assess the link between food safety, agriculture and community development.

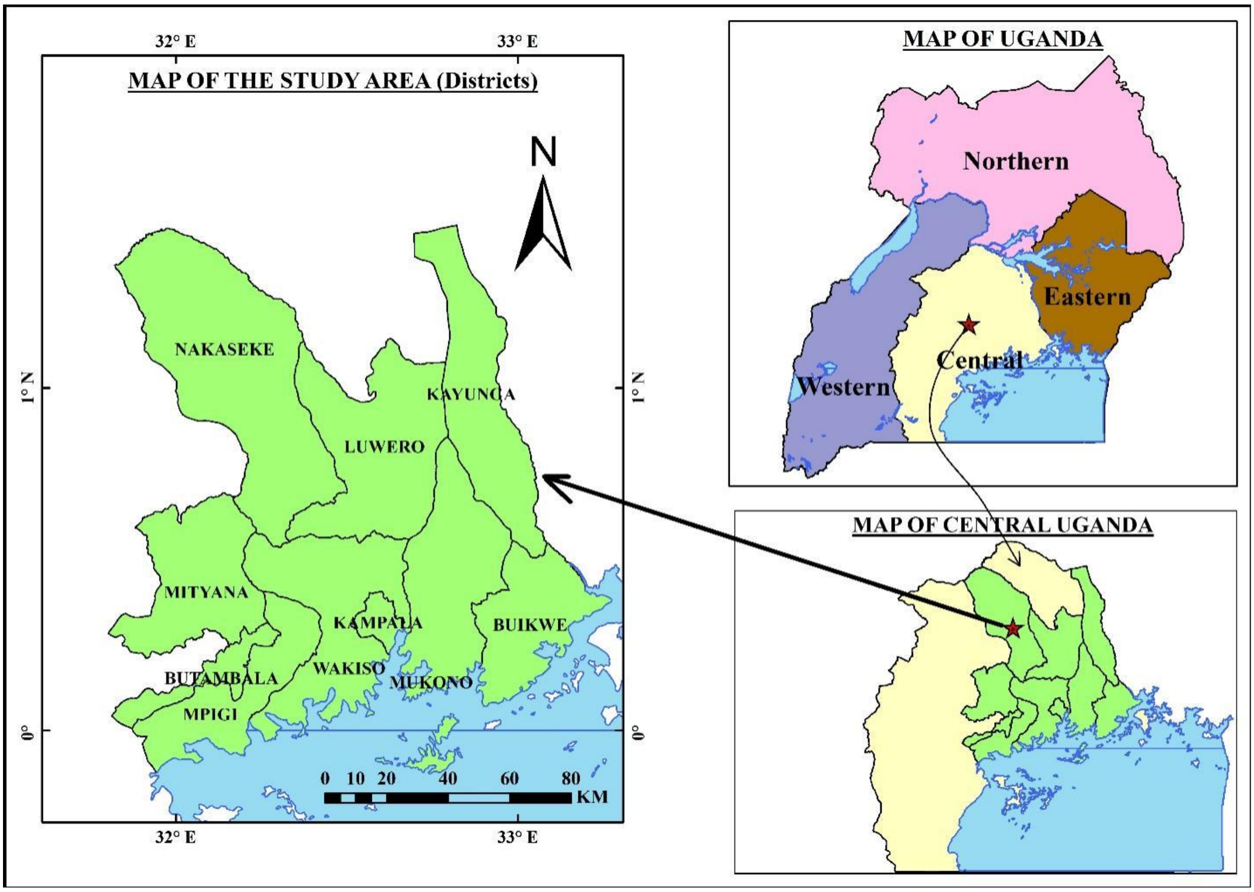


Figure 3.1: Map of study area

3.3 Research design

This study used a survey design through a cross-sectional and quantitative method. The cross-sectional approach does not allow us to determine causation as data is only collected at one point in time and it only captures associations, not changes over time. It may also be influenced by recall bias and unobserved differences among respondents. Nevertheless, this approach was suitable for the study because it enabled efficient data collection from a large number of smallholder dairy farmers within limited time and resources, providing a reliable snapshot of their adoption patterns and the factors affecting food safety measures.

3.4 Target population

The study focused on smallholder dairy farmers in Central Uganda, specifically in Wakiso, Kampala, Mpigi, Mukono, Kayunga, Buikwe, Luweero, Nakaseke, Mityana, and Butambala districts, who are actively involved in producing milk and dairy products.

3.5 Sample size determination and sampling

3.5.1 Sample size determination

The determination of the sample size followed a proportionate to size sampling methodology as specified by (Cochran, 1963) as follows:

$$n = \frac{z^2 pq}{e^2} \text{..(4)}$$

Where:

n = sample size,

p= implies maximum possible variance

q = 1-p,

z = the standard value at a given confidence level (α = 0.04),

e = the acceptable error (precision).

Since the study required a bigger sample size to represent the total population, a 96 percent confidence level and a 4 percent precision level, with a z score of 2.05 was chosen. The study assumed that p=0.5, assuming that about 50 percent of smallholder dairy farmers since variation of the dairy farmers targeted was not known before the survey took place. Therefore, a conservative variance of 0.5 was assumed.

The sample will be determined as:

$$n = \frac{(2.05^2)(0.5)(0.5)}{(0.04^2)} = 656.6 \text{..(5)}$$

Although the calculated sample size was 657 smallholder dairy farmers, the study collected data from 757 respondents to account for potential non-response, incomplete questionnaires, and data-cleaning losses. This oversampling technique makes the dataset more reliable and representative. This is necessary to maintain statistical power after deleting invalid responses. According to Vaughan (2017) in survey research recommendations, it is beneficial to oversample by 10-20% to obtain robust, generalizable results.

3.5.2 Sampling

In respect to current study sampling unit dairy farmers were individual and the unit of analysis was compliance behaviour at household level. A multi-stage sampling technique was applied to determine the sample size of the study. The first step involved intentionally selecting Central Uganda, where dairy farming is a predominant economic activity and accounts for approximately 34% of Uganda's national milk production (Ekesa *et al.,* 2015). The second step involved purposively selecting ten districts: Wakiso, Kampala, Mpigi, Mukono, Kayunga, Buikwe, Luweero, Nakaseke, Mityana, and Butambala, because of their high milk production in Central Uganda. The third stage used a stratified random sampling method, dividing smallholder dairy farmers into ten strata based on districts. A proportionate-to-size, random sampling method was then employed to select respondents from each stratum, followed by systematic random sampling of smallholder dairy farmers. This process was carried out to determine the sample size and select respondents from the ten strata, as shown in Table 3.1.

Table 3.1: Distribution of respondents per strata

Strata	Population size	Proportion to size	Sample
Mukono	596,804	0.096	63
Kampala	1,507,080	0.250	165
Kayunga	368,082	0.060	40
Wakiso	1,997,418	0.320	210
Mpigi	250,548	0.039	26
Buikwe	422,771	0.068	45
Luweero	456,958	0.073	50
Nakaseke	197,373	0.031	20
Mityana	328,964	0.052	34
Butambala	100,840	0.018	4
Total	6,226,838	1	657

3.6 Pilot study

A pilot study was conducted before the actual data collection to test the reliability and validity of the data collection tool. While reliability pertains to the consistency with which a data-collection instrument provides the same results after repeated trials at different times under similar conditions, validity concerns how accurately the instrument measures what it is intended to measure (Mugenda & Mugenda, 2013). Content validity was confirmed through administering questionnaires to subject matter experts, including supervisors, who reviewed the tools and offered feedback.

To evaluate the reliability of the research instruments, a pretest was conducted in Sembabule District, part of the larger Central Uganda region, targeting 66 dairy farmers or 10% of the final study sample. Confirmatory factor analysis was employed to assess the validity and reliability of the questionnaire items, including internal consistency, convergent validity, and discriminant validity. The analysis instruments of the research were tested for Cronbach's Alpha (α) test, Kaiser–Meyer–Olkin (KMO) test, Composite Reliability (CR), and Average Variance Extracted (AVE). The pilot study enabled modification of the final questionnaire that was used for data collection.

3.7 Data collection methods and tools

The study utilized four types of data collection with their tools to gather secondary and primary data through the documentary review, questionnaire administration, interviews, and observation. For gathering both qualitative and quantitative primary data, a semi-structured questionnaire was provided. The questionnaire included questions about farmer characteristics, farm features, market and institutional factors, food safety practices, and the overall performance of smallholder dairy farms in terms of productivity and profitability. Respondents' contact information was included in the questionnaires to facilitate follow-up calls aimed at clarifying and completing any vague or incomplete responses after data collection. To enhance the discussion of the study results, secondary data from published books, research articles, journal papers, and relevant websites were also utilized.

3.8 Data analysis

The quantitative data were cleaned, coded and analyzed, using both Statistical Package for Social Sciences (SPSS) and STATA.

3.9 Analytical framework

Objective 1. To characterize smallholder dairy farmers' level of compliance with FSMs at the farm-level in Central Uganda

Since several food-safety practices exist, the study adopted four FSMs used by (Kumar et al., 2017) and shown in Table 3.2 below: milk hygiene (16 FSMs), milk storage (10 FSMs), dairy environment (11 FSMs), and animal health (5 FSMs). Because farmers may adopt one, different combinations, or multiple FSMs, both descriptive and inferential statistics were used to assess the levels of FSM implementation by dairy farmers compared to the standards set by the Uganda Dairy Board. This involved calculating means, percentages, standard deviations, t-tests, Chi-squared tests, ratios, and frequency distributions. The descriptive statistics helped describe, explain, compare, and contrast the different food-safety practices adopted by smallholder dairy farmers.

A food-safety measure index was further created to assess different levels of FSM adoption among smallholder dairy farmers. The index had three levels: low adoption (50% and below), medium adoption (51%-70%), and high adoption (71% and above), based on Kumar *et al.* (2016).

Table 3.2: Proposed milk food-safety practices

Milk Hygiene	Milk Storage	Dairy Environment	Animal Health
Cattle milked separately from stall	Milk from diseased animal kept separately	Floor of stall feed area kept well drained daily	No feces in the animal body
The floor of milking area kept well-drained daily	Milk from seriously diseased/ infected animals discarded	Floor of stall feed area kept clean daily	Diseased animals Isolated
Floor of milking area cleaned daily	Milk stored separately from the animal shed	Dung disposed immediately after Excretion	Animals washed Regularly
Hands washed before Milking	Floor of milk storage area dried regularly	Urine drained immediately after Excretion	Animals drink clean water
Hands sanitized before milking	Milk storage area swept regularly	Chemicals used in dairy area	Dry cow therapy
Utensils without joints	Milk storage area washed regularly	Chemicals used as per instruction	
Utensils dried before Milking	Milk storage area kept free of pests	Workers wear suitable clean clothes	
Utensils cleaned before milking	Milk containers without joints used for bulking	Farmers nails trimmed regularly	
Utensils sanitized before milking	Milk containers used for bulking washed regularly	Farmers Cuts/wounds covered with appropriate waterproof dressing	
Utensils washed immediately after milking	Milk mixed with powder/baking soda before selling milk	Dairy farm inspected regularly to ensure safety of overall farm	
Milk discarded after use of medicine		Empty containers/utensils stored in	

	refrigerator	
Udders/teats cleaned before milking		
Udders/teats dried before milking		
Udders sanitized before milking		
Milk pasteurized and Labeled		

Objective 2: To determine the influence of perceived behavioral control, attitude and subjective norms on smallholder dairy farmers' behavior to perform safety and hygiene control practices in Central Uganda

To achieve this goal, the theory of planned behavior was used to examine how perceived behavioral control, attitude, and subjective norms influence smallholder dairy farmers' behavior regarding safety and hygiene practices on their farms. Farmers' actual behaviors—that is, the application of important safety and hygiene practices—are assumed to be affected by attitude (the farmers' own willingness to apply these practices), subjective norm (the extent to which others perceive this behavior to be a good thing), and perceived behavioral control (the ease or difficultness farmers feel about applying these practices). The interaction of these factors influences the decision to follow safety protocols, which is illustrated in Figure 3.2.

The farmer's behavioral attributes had indicators that were measured in a statement on a 5-point Likert scale (1 = not important, 2 = slightly important, 3 = somewhat important, 4 = important, and 5 = very important) as indicated in Appendix 1. The dairy farmer's responses to TPB components regarding safety and hygiene practices were measured by ranking the importance of each practice using Likert statements. These frequencies demonstrated the changes in behavior related to compliance with milk safety and hygiene practices. To test the predictive ability of attitudes, subjective norms, and perceived behavioral control on the intention to perform the selected safety and hygiene control practices, structural equation modeling (SEM) was used.

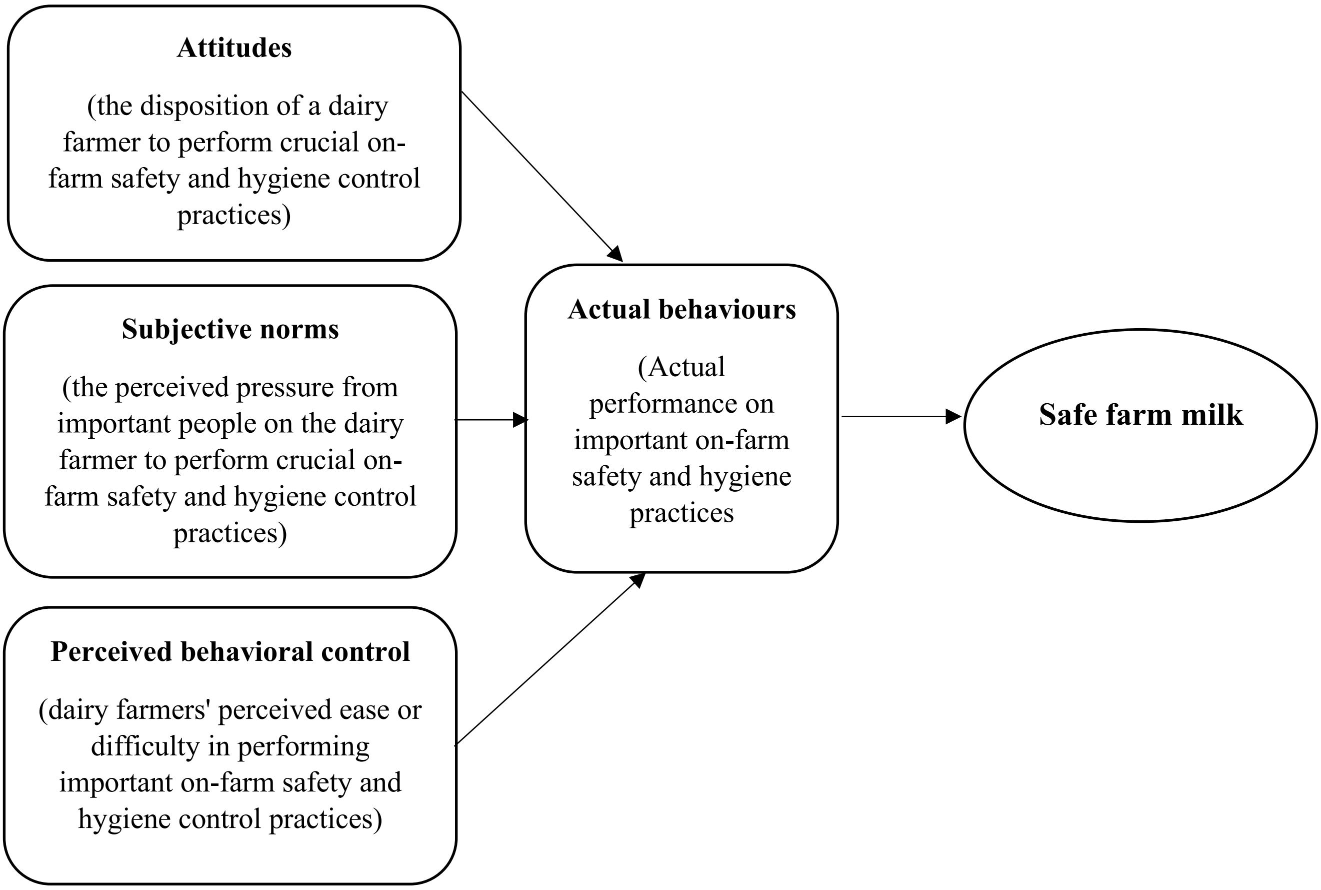


Figure 3.2: Model estimation for perceived dairy farmers' behavior towards use of on-farm safety and hygiene practices

As previously mentioned, a set of questions on behavioral attributes was included in the data-collection tool, comprising 29 indicators (Attitude = 8 questions, subjective norms = 7 questions, perceived behavioral control = 7 questions, and intentions = 7 questions). According to the main characteristics of the variables in the conceptual framework—which included multiple outcome variables, both observed and unobserved—SEM is regarded as an appropriate model for measuring objective one. This model is suitable because it enables the analysis of both structural and measurement models, as well as the inclusion of unobserved and observed variables within the same framework (Hair *et al.,* 2017). The method also provides measures of fit to evaluate the overall model and manages measurement errors in exogenous variables with multiple indicators using confirmatory factor analysis (CFA).

The general model is represented by the equations below, which are made up of measurement and structural models:

$$Y = \nu + \Lambda_m + \varepsilon \qquad (6)$$

$\eta = \alpha + B_\eta + \xi$ ....(7)

where Y is the vector of k observed variables in a considered study $(k > 1)$, ν the $k \times 1$ vector of observed variable mean intercepts, Λ is the $k \times m$ matrix of factor loadings, η is the of $m \times 1$ latent factors assumed in it $(m \times 1)$, ε is the vector of k pertinent residuals (error terms), α is the $m \times 1$ vector of latent variable intercepts, B is a $m \times m$ matrix of latent regression coefficients and ξ is the $m \times 1$ vector of corresponding latent disturbance terms. The simultaneous regression ($p < 0.05$) will be used to allow the correlation of the different variables in order not to assume that one variable is a better predictor than the other one (Leech *et al.,* 2014).

Objective 3: To determine drivers of compliance with food-safety measures by smallholder, dairy farmers in Central Uganda

As shown in Objective One, the food-safety compliance index was categorized into three groups: 0=low adoption (50% or below), 1=medium adoption (51%-70%), and 3=high adoption (71% or above). The food-safety compliance index (dependent variable) was a categorical variable. Since the study aimed to identify the factors influencing smallholder farmers to be low, medium, or high adopters of the FSMs, and given the ordered nature of the dependent variable, the study employed an ordered probit model. Alternatively, a logit or probit model could have been used, but neither was appropriate due to their binary nature (yes or no). The Ordered Logit (OL) model extends logistic regression for situations where the dependent variable is ordinal with more than two categories. The ordinal variable Y is derived from a latent variable Y*, which is continuous and unmeasured, with several cutoff points. The observed value depends on whether this latent variable crosses certain thresholds, as shown in the following formulas.

$Y_i = 1$ if $Y_i \leq k_1$ .... (8)

$Y_i = j$ if $k_i \leq Y_i^* \leq k_{i-1}$ .... (9)

$Y_i = M$ if $Y_i^* \geq k_{M-1}$ ....(10)

The continuous latent variable is equal to:

$Y_i^* = \sum_{k=1}^{K} \beta_k X_{ki} + \varepsilon_i$ .... (11)

in which there is a random disturbance term ε_i normally distributed. The error term reflects the fact that the variables may not be perfectly measured, and some relevant variables may be not introduced in the equation. The vector of β parameters will be estimated by the Maximum Likelihood method, and generally the goodness-of-fit of the ordered logit model will be verified by Nagelkerke R^2 (Eboli & Mazzulla, 2009). The statistical impact of variables was based on the p-values of the Wald tests (Eboli *et al.,* 2016). Table 3.3 presents the description of variables and the hypothesized signs that were used in the ordered logit model.

Table 3.3: Description of variables to be used in the ordered logit model

Variables	Measurement	Hypothesis
Dependent variable		
Low adoption (Y=0)	If a dairy farmer adopts less than 50% of the food safety practices	
Medium adoption (Y=1)	If a dairy farmer adopts between 51% and 70% of the food safety practices	
High adoption (Y=2)	If a dairy farmer adopts more than 70% of the food safety practices	
Independent variables		
Age	Number of years	+/-
Gender	Dummy 1=Male; 0= Female	+/-
Level of education	Number of years	+
Farming experience	Number of years involved in dairy farming	+
Family size	Number of individuals/dependents in the household	+
Information access on FSMs	Dummy 1=yes; 0=no	+
Land size	Land size under dairy farming in acres	+/-
Type of livestock breed	Dummy 1=Improved/exotic; 0=Indigenous	+/-
Herd size	Total number of livestock kept	+
Cows milked	Number of cows milked	+
Distance to nearest market	Distance in kilometers	+/-
Credit access	If access to credit, 1, otherwise 0	+/-
Training	Received training on dairy farming Dummy 1=yes; 0=no	+
Group membership	Dummy 1=yes; 0=no	+

Familiar FSMs	Dummy 1=yes; 0=no	+/-
FSMs inspection	Inspection on FSMs at the farm, Dummy 1=yes; 0=no	+/-
Cost of compliance to food safety	Dummy, 1=if there is cost in FSMs compliance, otherwise 0	-
Compliance perception	Likert :5=Very important,4 =Agree, 3=Neutral, 2=Disagree, 1=Strongly disagree	+/-
Extension access	If dairy farmer has access to extension =1, otherwise 0	+
HCCP awareness	Dummy, 1=Awareness of HACCP principles in dairy production operations, otherwise 0.	+/-
Standard operating procedures (SOPs)	Dummy, 1=if a farmer has a standard operating procedure (SOPs) in ensuring milk safety, otherwise 0	+/-
Milk contamination	Dummy, 1=Experienced milk contamination in the farm, otherwise 0.	-
Government role in FSMs	Perceive the role of government agencies and regulatory bodies in promoting food safety compliance (Dummy 1=supportive; 0=not supportive)	+/-

Objective 4: To determine the effect of food safety measures on profitability of the smallholder dairy farms in Central Uganda

The profitability of a smallholder, dairy farm was measured using the Gross Profit Margin indicated as follows:

$$Gross\ Profit\ Margin = \frac{Total\ revenue - Total\ expenditure}{Total\ revenue} * 100$$

Ideally, the type of food safety measures a smallholder dairy farmer adopts depends on the gains and costs associated with those measures (Kumar et al., 2017). While total revenue was calculated from the amount of milk produced and sold multiplied by the average price per liter, total expenditure was the sum of the variable costs incurred in milk production. The dependent variable for this objective was a count variable representing the number of food safety measures a smallholder dairy farmer in Uganda adopts. It is assumed that dairy farmers can adopt one or several FSMs from the list of 42 farm-level practices (milk hygiene, milk storage, dairy environment, and animal health) (see Table 3.4).

It was further assumed that dairy farmers adopted a food safety measure based on profitability comparisons among the measures. To model this, the ordered logit endogenous switching regression (ESR) was used. To implement the ESR in this study, the treatment variable was divided into three categories, ensuring that the sample households were split into three comparable groups. Following the works of Bekele *et al.* (2018), Haji (2022), and Kumar *et al.* (2017), the 30th and 70th percentiles were used to classify households into low-, medium-, and high-adoption categories. The ESR estimation involved two distinct stages, allowing for the robustness of the data to be evaluated across all model estimates.

The first stage was done using the ordered probit model. The ordered logit can be constructed on the latent (unobservable) random variable as follows:

$$P_i^* = X'\beta + \varepsilon \quad (15)$$

where P_i^* is unobserved dependent variable, X' is a vector of independent variables, β is unknown parameters to estimated, and ε is the error term. Since P_i^* is unobserved, what actually observed is Pi which shows the placement of the smallholder dairy farmers into the three adoption levels. Assume the 30th and 70th percentiles are represented by μ_1 and μ_2, respectively; the observed ordered outcome Pi, can be defined as:

$$P_i = 1, if\ P_i^* \leq \mu_1 \quad (16a)$$
$$P_i = 2, if\ \mu_1 < P_i^* \leq \mu_2 \quad (16b)$$
$$P_i = 3, if\ \mu_2 < P_{i\ 1}^* \quad (16c)$$

Then, the probabilities of the smallholder dairy farmers being in each adoption category (low, medium and high) is given as follows:

$$P_r(P_i = 1) = P_r(P_i^* \leq \mu_1) = \Phi(\mu_1 - X'\beta) \quad (17a)$$
$$P_r(P_i = 2) = P_r(\mu_1 < P_i^* \leq \mu_1)) = \Phi(\mu_2 - X'\beta) - \Phi(\mu_1 - X'\beta) \quad (17b)$$
$$P_r(P_i = 3) = P_r(\mu_1 < P_i^*) = 1 - \Phi(\mu_2 - X'\beta) \quad (17c)$$

Where Φ (.) represents the standard normal cumulative distribution function such that the sum of the above probabilities is equal to one of both the treated and control groups individually. The regime outcome equations, according to Sileshi *et al.* (2022), are specified as follows:

$$\begin{cases} \text{Regime 1}: Y_{i1} = \beta_1 z_{i1} + \sigma_1 \lambda_{i1} + \omega_{i1} if \ j = 1 \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad (i = 1,2,3,...,n : j = 1,2) \text{..................................}(18) \\ \text{Regime 2}: Y_{ij} = \beta_1 z_{ij} + \sigma_1 \lambda_{ij} + \omega_{ij} if \ j = k \end{cases}$$

Where; Y_{ij} indicates the profitability outcomes of the i^{th} household in the j^{th} adoption category; Zi is a vector of observed explanatory variables, βj is unknown parameters to be estimated, ωi is the error term, σj is the covariance between the error terms of selection equation and outcome equations, λj is the inverse mills ratio (IMR) computed from the selection equation, which corrects for the smallholder dairy farmers' self-selection bias into different level of adoption.

Following the second stage of the ESR, the average treatment effects of adopting milk safety practices on smallholder dairy farmers' indicators were estimated under two separate scenarios for each adoption category. The average treatment effect on the treated (ATT) was calculated for farmers in the medium and high adoption categories by comparing their observed profitability (real outcomes) with what their profitability would have been if they had been in the low adoption category (counterfactuals). Similarly, the average treatment effect on the untreated (ATU) was estimated for farmers in the low adoption category by comparing their observed profitability with what their profitability would have been if they had been in the medium- or high-adoption categories (counterfactuals). The observed profitability outcomes of smallholder dairy farmers in each alternative adoption category (real scenarios) are given as:

$$\begin{cases} E(Y_{i1} | j = 1) = \beta_1 Z_{i1} + \sigma_1 \hat{\lambda}_{i1} \ (real \ for \ low \ adopters) \text{..}(19) \\ E(Y_{i2} | j = 2) = \beta_2 Z_{i2} + \sigma_2 \hat{\lambda}_{i2} \ (real \ for \ medium \ adopters) \text{..}(20) \\ E(Y_{i3} | j = 3) = \beta_3 Z_{i3} + \sigma_3 \hat{\lambda}_{i3} \ (real \ for \ high \ adopters) \text{..}(21) \end{cases}$$

The profitability outcomes of smallholder, dairy farmers if they were in an alternative adoption category (counterfactual scenarios);

$$\begin{cases} E(Y_{2i} | j = 1) = \beta_2 Z_{i1} + \sigma_2 \hat{\lambda}_{i1} \ (low \ adopters \ if \ they \ were \ in \ medium \ category) \text{................}(22) \\ E(Y_{3i} | j = 1) = \beta_3 Z_{i1} + \sigma_3 \hat{\lambda}_{i1} \ (low \ adopters \ if \ they \ were \ in \ high \ category) \text{.....................}(23) \\ E(Y_{1i} | j = 2) = \beta_1 Z_{i2} + \sigma_1 \hat{\lambda}_{i2} \ (medium \ adopters \ if \ they \ were \ in \ low category) \text{ ....}(24) \\ E(Y_{1i} | j = 3) = \beta_1 Z_{i3} + \sigma_1 \hat{\lambda}_{i3} \ (high \ adopters \ if \ they \ low \ in medium \ category) \text{.................}(25) \end{cases}$$

Then, ATT was obtained as the difference between equations 20 and 21 and Equations 24 and 25. The average treatment effect of being in the medium adoption category were computed as the difference between Equations 20 and 24 for each outcome variables separately. This implies that:

$$ATT = E(Y_{i2}|j=2) - E(Y_{i1}|j=2) = (\beta_2 Z_{i2} + \sigma_2 \hat{\lambda}_{i2}) - (\beta_1 Z_{i2} + \sigma_2 \hat{\lambda}_{i2}) = Z_{i2}(\beta_2 - \beta_1) + \hat{\lambda}_{i2}(\sigma_2 - \sigma_1) ..(21)$$

In the same manner, ATU was obtained by comparing the expected profitability of the low adopters (Equations 22 and 23) with the Equation 19 for each outcome variable. The ATU of smallholder, dairy farmers in the low-adoption category if they were in medium adoption category will be estimated as follows:

$$ATT = E(Y_{i2}|j=1) - E(Y_{i1}|j=2) = (\beta_2 Z_{i1} + \sigma_2 \hat{\lambda}_{i1}) - (\beta_1 Z_{i1} + \sigma_1 \hat{\lambda}_{i1}) = Z_{i1}(\beta_2 - \beta_1) + \hat{\lambda}_{i1}(\sigma_2 - \sigma_1) ..(21)$$

Table 3.4: Description of variables to be used in the ordered logit endogenous switching regression (ESR) model

Variables	Measurement	Expected sign
Treatment variable		
Percentage of milk safety practices adopted		
Outcome variable		
Profit (Ugx/Litre)		
Independent variables		
Demographic characteristics		
Age	Number of years	+/-
Sex of household head	Dummy 1=Male; 0= Female	+/-
Education	Years of education of household head	+/-
Family size	Number of individuals/dependents in the household	+
Dairy farming related factors		
Total milk produced	Total amounts of milk output produced by a household/farmer	+/-
Farming experience	Number of years involved in dairy farming	+

Dairy training	Received training in dairy farming, equals 1 if yes, 0 otherwise	+
Total lactating cows	Number of lactating cows	+/-
Milk price	Price of milk sold per litre	+/-
Market-related and Institutional factors		
Distance to nearest market	Distance in kilometers	+/-
Credit access	If access to credit, 1, otherwise 0	+
Cooperative membership	Dummy 1=yes; 0=no	+
Access to milk safety information	Dummy 1=yes; 0=no	+

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Descriptive statistics

4.1.1 Sex, age, education, land tenure types, and breeds owned by respondent are possible socio-economic variables.

The gender breakdown of household heads illustrated by smallholder dairy farmers in Central Uganda is depicted in figure 4.1. Results suggest that 69.6% are male while 30.4% are female. In Uganda's Central region, it is usually men who lead and manage dairy on-farm activities. In Uganda, Men Likely Use Agricultural Technologies than Women. The gender gap reflects broader structural and socio-cultural trends in Uganda's agriculture, where men typically control key productive resources such as land, livestock, and financial capital (Seruma *et al.,* 2025).

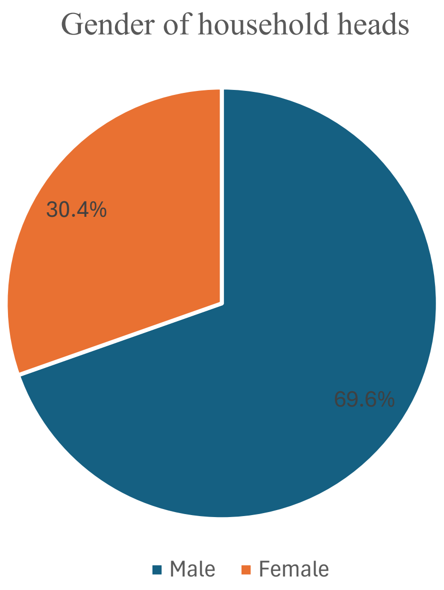


Figure 4.1: Gender of household heads

In general men decide about the dairy production, marketing and investment, the results show. This is because male farmers have better access to productive assets, extension services, and credit, making it easier for them to adopt modern technologies and expand their farms (Ouma *et al.,* 2024). Also, because men play a larger role in owning the farm and making marketing decisions, they are expected to be the household head and economic provider.

Women face lack of attention since only 30.4% smallholder dairy farmers are women (female head). Women perform dairy activities on a day-to-day basis. Milking, feeding and maintenance of hygiene are all in their purview. Still, they have a number of challenges. They have land rights that are not secure, formal credit access that is limited, and being under-represented in farmer groups (Nambi *et al.* 2024). These problems stop women from fully joining in commercial dairy activities. They also stop women from adding to the household income and food security.

The gender gap that is shown in these findings shows inequality in resource control and decision making among rural farmers. Mugisha *et al.* (2022), observed that women are active players in dairy production but mostly men are controlling sales and income. These imbalances can worsen inequalities across households and generate disincentives on quality improvement or new technology use by women.

Almost half of smallholder farmers in this region, Central Uganda, are aged over 51 years. Specifically, 47% of respondents were aged above 51 years and 46% were aged between 30 and 50 years (see Figure 4.2). That is, the majority of dairy farmers are middle aged or above. According to the pattern, in the study area dairy farming is usually done by older adults who are very experienced in farming and practical situations. The research finds that older farmers are in general better resource managers than their younger counterparts since they have the skill to manage land and livestock and this behaviour leads to stability and continuity of dairy production systems.

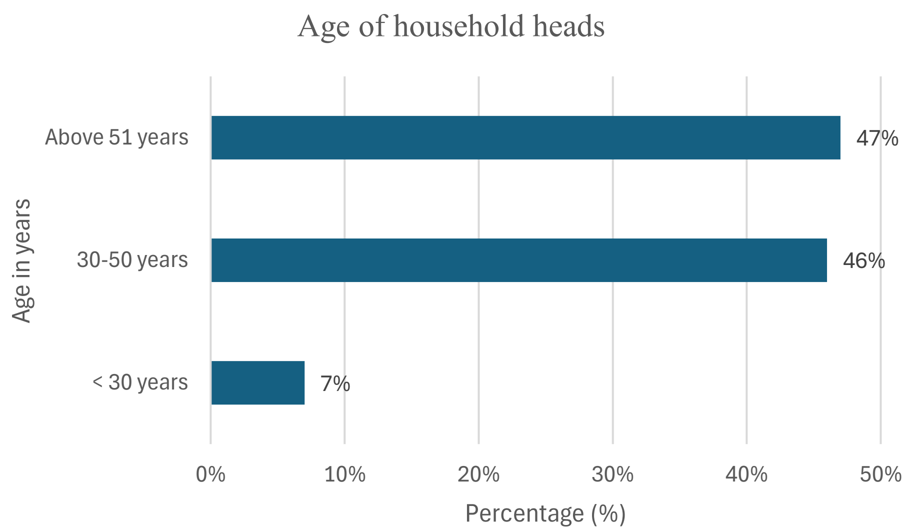


Figure 4.2: Age of household heads

However, older farmers being more common raises sustainability challenges. According to Ouma *et al.* (2024), the aging farmer population reduces the chances of farming innovation and technology adoption in the long run. Older farmers aren't likely to welcome modern dairy technologies like bred improvement, digitised record keeping and advanced feed. This is often due to lack of exposure or resistant to change. So, while experience can increase efficiency in older forms of production, it can also delay the implementation of innovations that can increase milk yield and safety.

Forty-six percent (46%) of the population comprises farmers aged between 30 to 50 years. They likely have stronger bodies and the resolve to experiment and engage in market-led production. According to Mugisha *et al.* (2022), they may have greater access to financial services, information networks and extension programs. This group is large enough to suggest that the sector has a live wire that can bridge traditional and modern dairy systems with appropriate training and incentives.

Youth involvement in dairy farming was low as only 7 percent of the respondents were youth in Uganda increasingly perceive farming as less gainful, more laborious, and more perilous than urban jobs. (Majajila *et al*., 2020). Young people aren't getting into dairy because they don't have easy access to land, money and other materials. If issues like succession planning and youth engagement are not addressed, the generational gap due to a lack of young people could undermine innovation and compromise long-term sustainability of the sector.

Based on respondents' education level, Figure 4.3 above shows that most (35%) completed primary school. As many smaller farmers are literate and numerate and understand extension messages and maintain simple records and use of market information. But they might not be very familiar with modern dairy technologies or strong analytical skills. Farmers at the primary level of education moderate use food safety and herd management practices. Farmers face limited technical knowledge and limited access to information other than the community through this kind of work (Seruma *et al.,* 2025; Mugisha *et al*., 2022).

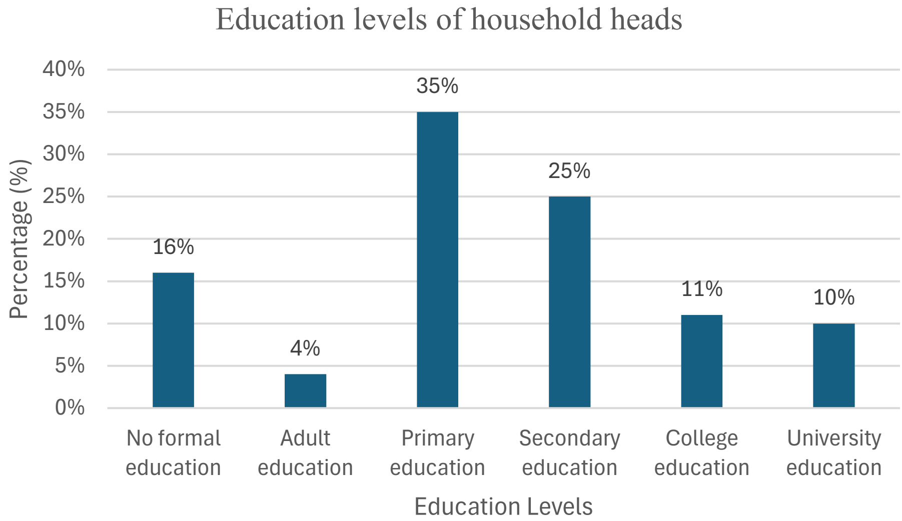


Figure 4.3: Education levels of household heads

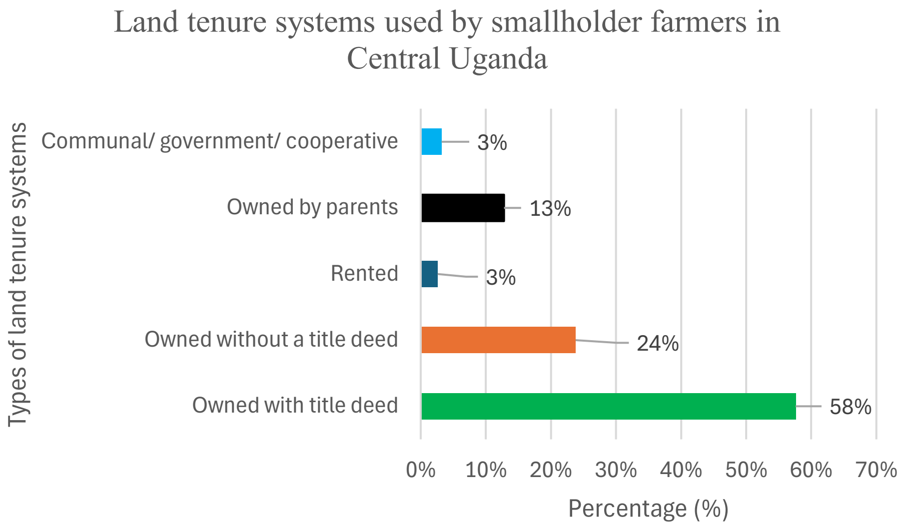
A further 25 per cent of respondents would have completed secondary, which would mean that they are a more educated group. It also suggests that they are likely to accept new farming technologies. Farmers with this level of education are generally better decision-makers, manage risk better, and are able to interact with formal institutions (including cooperatives, veterinary officers, and financial service providers) more effectively (Nambi *et al.,* 2024). The higher literacy of these workers makes it easier for them to grasp training content and keep proper records – and that, in turn, helps them to be more productive and profitable.

Around eleven percent of household heads have gone to college and ten percent to university. The group comprises educated farmers who are generally more entrepreneurial and open to using scientific methods in their dairying practices. Training and exposure to modern production systems make it more likely that they will adopt food safety measures (HACCP) and milk quality assurance (Seruma *et al,* 2025). However, the relatively low share of smallholders shows that education beyond secondary level is largely limited among rural smallholders. The educated youth often migrate to urban areas in search of jobs (Ouma *et al.,* 2024).

Land is a critical resource in dairy farming. This is especially true with smallholder farmers that can invest in growing fodder and forage for dairy animals. According to figure 4.4, most of the farmers (58 percent) own the land with title deeds. With rights being established on the land, ownership of land gives security of tenure and encourages investment in long-term improvements like the creation of pastures, fencing and better animal shelters.

With land title in hand, smallholder farmers are able to secure credit lines for his farm. According to Mugisha *et al.* (2022) and Seruma *et al*. (2025), the security of land tenure is highly linked to the uptake of improved dairy practices and productivity by smallholders.

Twenty four percent (24%) of respondents who owned land said they did not have title deeds to that land. Even though these farmers have some control over the land, they do not have the documentation to access loans or the latitude for long-term land development. Many are reluctant to invest permanently in soil fertility or dairy infrastructure due to the fear of losing land or land tenure disputes (Taramuel-Taramuel *et al.,* 2025). In Uganda, people operate under customary land law, where obtaining formal registration is often too expensive



or burdensome.

Figure 4.4: Land tenure systems used by smallholder dairy farmers in Central Uganda

Around 13% of farmers mentioned that their land belongs to their parents, which means they farm inherited and family-owned land. Having this arrangement isn't too bad but it can limit the independent use of the land, especially for younger farmers. The choices regarding the use of land and investment are often made by elders and/or the male head of the household, influenced by gender and generational factors (Nambi *et al.* 2024). Such dynamics may obstruct the adoption of technologies in commercial dairy farming by youth and women farmers.

Similarly, 3% of respondents rent land, or make use of land owned by community, government or coop. Land renters deal with the most tenure insecurity. Their agreements tend to be short-term and are not guaranteed to be renewed or must pay an increased rent. As a result, they rarely spend on structural improvements or productivity-enhancing technologies like better pastures or irrigation. Ouma *et al*. (2024) and Majalija *et al*. (2020) reported that short-term and limited benefit usage rights of tenants and communal land users in Uganda contribute to low agricultural productivity of these land uses.

According to Figure 4.5, 71% of smallholder dairy farmers in Central Uganda keep improved or exotic breeds, while 29% own indigenous breeds. It implies the use of finer dairy genetics to improve productivity and profitability. The overwhelming popularity of improved breeds highlights that a large number of smallholders have become aware of the economic advantages of high-yielding breeds like the Friesians, Jerseys, and Ayrshires that have higher milk production potential and are well-equipped for semi-intensive systems. Research conducted by Seruma *et al.* (2025), and Nambi *et al* (2024), shows that most of the increase in adoption of improved dairy breeds is a result of government and NGO's artificial insemination (A.I) and breed improvement and better breeding stock availability. As a result, now the farmers can increase better quality and quantity of milk. Afterwards, the household food security is enhanced and poverty is reduced.

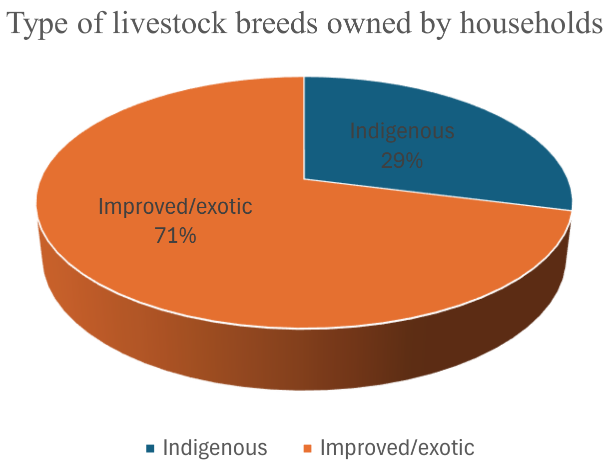


Figure 4.5: Type of livestock breeds owned by smallholder farmers in Central Uganda

Exotic or improved breeds are in high demand nowadays, but their productivity is based on proper feed, and vet care. Many smallholders' dairy farmers have problems like high feed costs, limited access to veterinary services, and disease risk in tropical regions (Ouma *et al.,* 2024). Indigenous breeds are less expensive to care for, but they produce less milk than exotic breeds. Due to this, whether the various system sustain it indigenous and local feeding and health diseases remain farmers' access to input.

About 29% of households have native breeds either because they do not have the means to manage exotic breeds or they want native breed due to their resilience. Indigenous cattle can survive in tough environments. They have resistance to local diseases and can survive on poor quality feeds. This makes them very useful for households that don't want to take risks or that have very few resources. According to Majalija *et al.* (2020), Mugisha *et al*. (2022), indigenous breeds are critical in enhancing the resilience of people's livelihoods, especially for rural communities living in semi-arid dry lands who lack access to advanced management technologies.

Having both breed types at the same time shows how smallholder farmers are trying to diversify their production and risk. The improved breeds are sold for milk and most of the income comes from it. The Indigenous breeds act as a backup during feed shortage or disease outbreak. Moreover, a combination of breeds allows farmer to benefit from the advantages of crossbreeding, such as better milk production and adaptability (Taramuel-Taramuel *et al.,* 2025).

4.1.2 Structure of herd composition among smallholder dairy farmers in Central Uganda

Small-scale farmers' dairy herds in Central Uganda are examined in table 4.1 in terms of composition and productivity. The makeup of a herd affects its size and sustainability of milk production. In turn, this affects the food safety and quality measures that smallholder farmers can adopt. Findings reveal striking discrepancies in herd size and structure of the farmers, pointing to the differences in resource availability, management strategies, and production objectives.

Table 4.1: Herd composition owned by smallholder farmers in Central Uganda

Livestock stock	Mean	Std. dev	Minimum	Maximum
Bulls owned in the last 12 months	0.69	1.04	0	8
Cows owned in the last 12 months	6.98	7.50	1	25
Steers owned in the last 12 months	1.83	4.34	0	15
Male calves owned in the last 12 months	1.48	2.21	0	15
Female calves owned in the last 12 months	2.1	2.58	0	11
Number of cows milked in the last 12 months	3.96	4.62	1	22
Average number of months the cows were milked	7.59	1.54	3	12
Average milk production per day per milked cow (liters)	12.98	10.27	3	70

Milk produced was consumed by the household each day either in the form of liquid milk (litres)	2.14	1.40	0	15

Table 4.1 reveals that households owned an average of 0.69 bulls (SD = 1.04) in the last 12 months. The minimum and maximum number of owned bulls were 0 and 8 respectively. The low mean indicates that bulls are not owned on farm and that majority of the smallholder dairy farmers in Central Uganda depend on shared breeding services or AI. According to the findings of Seruma *et al.* (2025), use of artificial intelligence in the region has significantly increased leading to a reduction in the need for farmers to keep bulls on their farms. Businesses are moving towards AI, a change that will encourage better breeding practices and dairy genetics. However, the daunting presence of some households having up to eight bulls, indicates the existence of semi-commercial breeders or community bull-sharing schemes, which continue to be common within mixed crop-livestock systems (Nakiganda *et al.,* 2024).

The average household has 6.98 cows (SD = 7.50), with a range of 1 to 25. This points towards a high level of skewness where certain farmers own higher yet most retain them for subsistence and local markets. According to Mugisha *et al.* (2022), land ownership, access to credit, and breed types influence differences in herd size. Farmers with upgrades or exotic breeds are more likely to have large herds. Further, they are more likely to adopt formal measures for milk safety. The district level mean of almost seven cows agrees with Nampijja *et al.* (2023) and confirms that smallholder systems dominate the dairy system in Central Uganda.

Steers are raised for meat or draught and not for milk (the average number of steers was 1.83 (SD = 4.34), with the range of 0 to 15). This shows that in Central Uganda, smallholder farmers are more interested in dairy production rather than dual-purpose systems as steers outnumbered cows. Still, some families keep a steer so that they can rotate their herds and earn extra cash. According to Kasozi *et al*. (2023), keeping steers as part of a herd diversifying strategy for smallholder dairy farmers can reduce milk price risks, and hence, is a risk management strategy.

When talking about calves, the average farm has 1.48 male (SD = 2.21) and 2.10 female (SD = 2.58). But the figures vary a lot by farm. A slightly higher number of female calves suggests that the farmer of the cattle herd is retaining females for herd replacement. This is a good sign. However, the high standard deviations suggest inconsistent reproductive ability and possibly calf mortality problems. A calf management system is one of the weakest links in Uganda's dairy systems (Okello *et al.* 2023). Primarily due to the weakness in housing, nutrition, and veterinary care. Higher death rates in calves lower the chances of replacements and growth.

The ratio of female calves (2.10) to the whole herd size implies a replacement level of about 30%, which is consistent with the optimum replacement level for sustaining herd viability in a smallholder system (Namanda *et al.,* 2022). The difference in ownership of calves can be due to breed that is the incremental and improved breed has better calving efficiency than the local breed. Also, the households that adopted the technology to a high degree kept a higher proportion of female calves which means that these farmers were more aware of herd improvement measures which either comes from training or cooperatively (Nassanga *et al.,* 2023).

Regarding the cow numbers and productivity, the average number of cows milked over the past 12 months was 3.96 (SD = 4.62) with a minimum of 1 and a maximum of 22. This is about 57% of the total cows owned per household implying that almost half the herd comprises of either non-lactating or replacement animals. The length of lactation is short in tropical dairy systems, probably due to environmental stress, feed shortage and disease incidence (Seruma *et al.,* 2025). In Central Uganda, pasture and water availability differ by season, this limits milk production throughout the year. And this causes milk production to peak at certain times and taper off at others.

The average annual milking duration for cows was 7.59 months. (SD = 1.54, Range = 3-12 months). Farmers lack feed in dry months indicated by only a few smallholders' dairy producers able to get year-round milking. According to Mugisha *et al.* (2022), constraints on dairy production and the quality of milk occur due to nutritional stress. As a result, the adoption of conservation of feed by adopting silage production and high protein fodder can enhance the period of lactation and increase the overall productivity.

On a daily basis, the households used an average of milk (2.14 liters SD= 1.40) and the consumers range was (0-15 liters). This means that some milk is kept for home use, but maximum milk is sold. The consumption of milk at home is a major contributor to nutritional security, particularly for children and lactating mothers. All in all, the average is relatively low, especially when compared to overall production. This seems to indicate that production for the market dominates. The relatively lower average suggests that households prefer production for income earning rather than for direct dietary consumption.

The study by Nampijja *et al.* (2023) shows that over 80% of the milk produced in Central Uganda is sold informally. Further, a minor portion of the milk is used for home consumption. The marketing strategy has encouraged smallholder dairy farmers in the region to adopt food safety practices. These farmers sell milk through informal channels that do not undergo quality tests or regulation.

As shown in Table 4.1, there are significant differences in the herd sizes and productivity of smallholder dairy farmers in Central Uganda. These differences are due to varying access to resources and management skills. Farmers possessing more animals and the higher yield of milk are more likely to invest in sanitary facilities and comply with food safety standards (Seruma *et al.,* 2025).

On the other hand, smallholders have limited assets. As a result, they may have less incentive or ability to implement essential food safety measures. This includes proper waste disposal, udder sanitization, cooling of the milk. Larger producers can spread the costs of safety measures over more output. Kasozi *et al.* (2023), assert that milk yield and herd size affect economies of scale in food safety compliance.

Smallholder dairy farmers in Central Uganda have a varied herd composition, as shown by the results on the whole. The majority of homes have small herds that average about seven cows each. The quantity of milk produced and cow output is small and available throughout the year. The results suggest that feed management, breeding and veterinary services are the most promising options to enhance productivity and food safety. More access to credit, better genetics and farmer training can boost herd growth and make households more economically and nutricionally robust.

With respect to herd structure, need gender-sensitive and scale-appropriate strategies in dairy development. Our extension services should focus on smallholder friendly messages about improved milk hygiene and better conditions for animals since much of the population maintains near-subsistence herds. In addition, also initiatives that enhance female farmers' access to improved breeds and AI services can help in inclusive as well as sustainable dairy growth. Finally, better ways of milking and storage can help translate the improvement in dairy productivity into safer and high-value dairy products.

4.1.3 Socio-economic characteristics of smallholder farmers based on adoption of food safety measures

According to table 4 .2 above, the socio-economic characteristics of smallholder farmers in Central Uganda indicate an adoption of food safety measures (FSMs). Of the 757 respondents, 16% are low adopters, 43% middle adopters and 41% high adopters. These dairy farmers also differ in terms of their demographic, institutional and farm management traits. As shown in Table 4.2, high adopters are mainly male farmers (28.14%) than female farmers (13.08%).

The chi-square statistic is 2.39 which is not significant but the data shows that somewhat gender affects adoption levels. Male ownership is often presented as a well-known narrative with regard to dairy and decisions on productive resources (Mugisha *et al.,* 2022). In Uganda, for instance, men control productive resources and make livestock investment decisions. It is often men who take the decisions on dairy production and consumption. Women have limited access to assets, extension services, and credit themselves from adopting safety standards (Nampijja et al., 2023). Increased participation of women in dairy cooperatives and training programs is linked to better milk hygiene and safety. (Seruma *et al,* 2025).

Education has a significant association with the adoption of food-safety practices (χ^2 = 48.88***). Smallholder dairy farmers with at least primary education have a higher likelihood to be high adopters (13.08%) compared to non-educated ones (4.62%). This supports Namanda et al. (2022), who found that education improves farmers' understanding of technical advice on milk hygiene and handling. Besides literacy or record-keeping education also raises farmers' responsiveness to training and extension. According to Kasozi *et al.* (2023), educated farmers understand the health risks of cow's milk contamination better. They are more willing to adopt preventive measures such as udder cleaning and the use of aluminum cans for milk storage. This relationship shows just how important adult education and literacy efforts are in dairy communities.

Farmers' access to the information has no impact (χ^2 = 0.25), where high adopters were slightly more likely (9.51%) to indicate they have enough access. The weak link may arise from the narrow range of formal communication channels and excessive reliance on informal farmer networks, which communicate heterogeneous knowledge (Kabunga & Alary, 2023). Dairy extension services and mass media that are credible are known to enhance their adoption through raising awareness of milk-borne diseases and the handling of milk and related products (Waiswa *et al.,* 2022). The weak linkages among smallholder dairy farmers in Central Uganda indicate that current information systems are either poorly organized or inadequately suited to farmers' literacy.

FSMs costs significantly influence the likelihood of adoption (χ^2 = 57.36***). Eighteen point seventy-six per cent of high adopters can manage compliance costs, compared to three point eighty-three per cent of low adopters. Maintenance costs include cleaning materials, equipment maintenance, and veterinary bills. Smallholder dairy farmers are less likely to take protocols seriously when these are perceived as costly (Kasozi *et al.,* 2023). Moreover, views on compliance are highly related (χ^2 = 128.52***).

Based on animal type (Table 4.2), this variable has a strong positive relationship with FSM adoption (χ^2 = 64.94***). Farmers rearing improved or exotic breeds have a higher adoption rate (30.91%) than farmers rearing indigenous breeds (10.30%). When breeds are improved, it is associated with improved productivity and requires more intensive management and implementation of strict hygiene and health regulations (Okello *et al.,* 2023). Farmers who keep crossbreeds or exotic cattle most often operate semi-commercial dairy systems. They are subjected to the quality assurance standards of their processors and cooperatives (Kariuki *et al.,* 2022).

Easily getting loans largely affected adoption of financial services. A greater share of the high adopters (16.78%) had credit facilities than did the low adopters (3.04%). Accessibility to credits boosts the liquidity of farmers allowing them to buy hygienic tools, veterinary drugs and better feed (Nassanga et al 2023). It helps in making investments in infrastructure like sanitary milking sheds and milk storage facilities. This agrees with the study of Seruma *et al.* (2025) that access to rural financial institutions positively influences adoption of quality enhancing technologies in smallholder dairies.

Training and being part of farmer groups, both strongly correlated with higher levels of adoption (χ^2 = 5.32* and χ^2 = 5.59*). 15.19% of high adopters received training while the same percentage were members of dairy groups. Farmer groups play a key role in information-sharing and learning. Groups provide social capital through collective action, which supports access to inputs and to markets that require compliance with food-safety standards (Kabunga & Alary, 2023).

Table 4.2: Cross-tabulation analysis of smallholder dairy farmers' socio-economic characteristics based on the adoption of food safety measures

Variables	Low adopters=116		High adopters=325		High adopters=311		Chi2
Categorical	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	
Gender							
Male	78	10.30	236	31.18	213	28.14	2.39
Female	41	5.42	90	11.89	99	13.08	
Education							
No formal	38	5.02	44	5.81	35	4.62	48.88***
Adult	2	0.26	9	1.19	18	2.38	
Primary	48	6.34	119	15.72	99	13.08	
Secondary	19	2.51	84	11.10	84	11.10	
College	4	0.53	42	5.55	37	4.89	
University	8	1.06	28	3.70	39	5.15	
Access to information							
Yes	30	3.96	79	10.44	72	9.51	0.25
No	89	11.76	247	32.63	240	31.70	
Type of livestock breed							
Indigenous	71	9.38	71	9.38	78	10.30	64.94***
Improved/Exotic	48	6.34	255	33.69	234	30.91	
Access to credit							
Yes	23	3.04	138	18.23	127	16.78	21.16***
No	96	12.68	188	24.83	185	24.44	
Training							

Yes	30	3.96	107	14.13	115	15.19	5.32*
No	89	11.76	219	28.93	197	26.02	
Group membership							
Yes	20	2.64	44	5.81	64	8.45	5.59*
No	99	13.08	282	37.25	248	32.76	
Familiar FSMs							
Yes	72	9.51	221	29.19	218	28.80	3.47
No	47	6.21	105	13.87	94	12.42	
FSMs inspection							
Yes	15	15.72	41	5.42	79	10.44	20.30***
No	104	13.74	285	37.65	233	30.78	
Cost of compliance to food safety							
Yes	90	11.89	233	30.78	142	18.76	57.36***
No	29	3.83	93	12.29	170	22.46	
Compliance perception							
Not applicable	85	11.23	86	11.36	83	10.96	128.52***
Strongly disagree	4	0.53	27	3.57	21	2.77	
Disagree	5	0.66	45	5.94	90	11.89	
Neutral	6	0.79	78	10.30	56	7.40	
Agree	16	2.11	77	10.17	43	5.68	
Very important	3	0.40	13	1.72	19	2.51	

Extension access							
Yes	31	4.10	121	15.98	148	19.55	17.98***
No	88	11.62	205	27.08	164	21.66	
HCCP awareness							
Yes	3	0.40	43	5.68	85	11.23	43.57***
No	116	15.32	283	37.38	227	29.99	
Standard operating procedures (SOPs)							
Yes	52	6.74	259	34.21	255	33.69	75.77***
No	68	8.98	67	8.85	57	7.53	
Milk contamination							
Yes	43	5.68	213	28.14	238	31.44	61.24***
No	76	10.04	113	14.93	74	9.78	
Government role in FSMs							
Supportive	12	1.59	39	5.15	72	9.51	18.41***
Not supportive	107	14.13	287	37.91	240	31.70	
Continuous	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	F-test
Age	49.69	13.34	50.83	14.19	48.65	13.75	0.74
Experience	20.62	15.66	17.04	11.83	14.97	10.88	25.58***

Family size	6.26	2.85	6.82	3.22	6.42	2.78	7.36**
Land size	3.11	2.99	3.39	3.11	2.62	2.61	9.84***
Herd size	9.94	13.98	15.62	18.33	11.62	11.47	68.68***
Cows milked	3.08	4.37	4.44	5.43	3.79	3.65	48.83***
Distance to nearest market	3.26	2.93	7.19	9.48	5.11	7.44	158.18***

Being familiar with safety protocols and being inspected by FSM play a part in positively driving the adoption of Good Manufacturing Practices (GMPs). But the inspection frequency, (χ^2= 20.30***), significantly associates with higher adoption of GMPs and only this is true. The other two variables are insignificant. Frequent checks allow for external oversight of farmers' compliance with hygiene and health standards (Seruma *et al.,* 2025). They can also help ensure the public becomes aware of regulations and motivate compliance through rewards and penalties.

Extension access (χ^2 = 17.98***) and awareness of Hazard Analysis and Critical Control Points (HACCP) (χ^2 = 43.57***) are both strongly associated with being in the high adoption group. Extension services give technical advice and behavioral change through continuous contact (Nakiganda *et al.,* 2024). Farms that know about the principles of HACCP recognizes the risk of contamination and is able to apply preventive measures at the farm. According to Nampijja *et al.* (2023), Ugandan dairy farmers are generally unaware of HACCP. Thus, it is important to integrate food safety module in extension training.

The different levels of adoption of SOPs are strongly and positively related to being in the high FSM adoption category (χ^2 = 75.77***). About a third of the High adopters (33.69%) have implemented SOPs for essential farm activities such as milking, cleaning and animal care. Milk handling is organized, routine and therefore systematic when Standard Operating Procedures are being followed. This will minimize errors and avoid issues. Furthermore, it will avoid contamination (Seruma *et al.,* 2025). Most farmers who adopt SOPs are able to maintain quality, which is necessary for the cooperatives and processors.

The level of adoption is highly significantly related to milk contamination rate and government support which has χ^2 = 61.24***, and χ^2 = 18.41*** respectively. Consumers who adopt food safety measures like standard test kits have fewer cases of milk contamination. Government support such as extension services, training, and supervision increases farmers' ability to comply. However, inspections are often inconsistent because of weak enforcement and lack of resources. With an enhancement of institutional frameworks and fostering of public-private partnerships, compliance could be more sustainable.

Whether farmers are young or old makes little difference to adoption rates as both groups participate in FSMs alike. Nonetheless, dairy farming experience is strongly associated ($\chi^2 = 25.58^{***}$), with low adopters averaging 20.62 years of experience, and high adopters with 14.97 years. This contradiction shows that with more experiences sometimes farmers become 'over confident' and do not want to change the current practices (Namanda *et al.,* 2022).

On the other hand, younger or less-experienced farmers, who have received modern training and are more likely to be part of cooperatives, adopt FSMs more readily. The different level of FSM adoption is highly associated with land size and herd size ($\chi^2 = 9.84^{***}$, 68.68^{***} respectively). Bigger pieces of land and bigger herds adopt more. This happens as bigger assets can more make investments in safety. Furthermore, large herds often require systematized management systems like SOPs and quality assurance systems (Okello *et al.,* 2023).

Number of cows are milked and how far they are from the market is critical. Those who adopt high are likely to milk more cows (average = 4.44) and are found closer to the market (the average distance = 5.11 km) than the medium adopters (7.19 km). Farmers that are closer to the market hide the quality standards of buyers from farther farmers that are farther away from cities. According to Kariuki *et al.* (2022), their marketing usually informal that hides them from pressures.

4.2 Characterizing smallholder dairy farmers level of compliance with food safety measures at the farm-level

In this section, we will look at how smallholder dairy farmers are applying farm-level FSMs. We will see how farmers differ in compliance with four key areas of FSMs identified in Kumar *et al.* (2017). These are milk hygiene, milk storage, the dairy environment, and animal health. Each area contains a number of practices that add up to a total of forty-two measures. There are sixteen measures for milk hygiene, ten for milk storage, eleven for dairy environment and five for animal health. You could say that that the categories identify essential or critical control points that may affect the safety and quality of milk at farm level. They also offer a framework to evaluate farmer compliance and overall food safety performance.

4.2.1 Food safety measures (FSMs) under the component of milk hygiene

Table 4.3 presents the adoption of food safety practices about milk hygiene. The outcomes show different levels of adaptation of FSM relevant to milk hygiene by smallholder dairy farmers in Central Uganda. A score of 60% was found for this area, which shows moderate compliance. This is in line with previous research which shows, among smallholders, knowledge of hygiene practices is increasing but the regular application of practices is not consistent (Mugisha *et al.,* 2022; Seruma *et al.,* 2025).

The proper technique has been used by most of the smallholder dairy farmers (68.4%) of the study area as they milk their cattle away from the stall. Milk that is properly separated has been shown to reduce the bacterial load in milk (Kanyima *et al.,* 2023) According to Ouma *et al.* (2024), about 31.6% of the farmer still milk inside or close to the stalls. This is because of lack of infrastructure such as milking space.

Environmental hygiene practices were up to the mark with 76.2% of respondents having fully drained milking floor; while 83.6 % respondents cleaned it properly every day. It is essential to avoid microbial contamination and prevent breeding of the vectors (Nambi *et al.,* 2024). Cleaning and drainage aid in the reduction of moisture that will help the bacteria flourish (Kasozi *et al.,* 2024). The findings are consistent with those of Nakatumba *et al.* (2023), who reported that although some structural maintenance challenges still exist for some Ugandan dairy farmers, they increasingly recognize the need for clean milking environment for quality milk.

Hand hygiene practices showed notable variation. Although three-fourths (75.8%) of farmers washed their hands with soap and water before milking, only 7.3% used sanitizers and 54% relied on water. This shows that people wash their hands a lot. But they do not use sanitizers which are more effective at killing germs. Mugisha *et al*. (2022) obtained similar results and indicated that Ugandan farmers did not use sanitizer due to access, costs, and lack of technical knowledge regarding the product.

Moreover, 59.8 per cent of farmers dried their hands before milking which is risky with dilution or recontamination of milk. Wet hands can carry microorganisms that can degrade the quality and shelf stability of raw milk (Nambi *et al.,* 2024). The results indicate that standards for proper hand hygiene are only partially and incompletely adhered to, showing the need for enhanced training of farmers on optimal hygiene during milking (Seruma *et al.,* 2025).

Table 4.3: Rate of reported adoption of food-safety practices for milk hygiene

Statements	Responses: n=757	
FSMs under the Component of Milk Hygiene	Yes	No
1. Cattle is/are milked separately from the stall	68.4 (518)	31.6 (239)
2. The floor of the milking area is kept well-drained daily	76.2 (577)	23.8 (180)

3.	The floor of the milking area is cleaned daily	83.6 (633)	16.4 (124)
4.	Hands are washed with only water before milking	54.0 (409)	46.0 (348)
5.	Hands are washed with water and soap before milking	75.8 (574)	24.2 (183)
6.	Hands are dried before milking	59.8 (453)	40.2 (304)
7.	Hands are sanitized before milking	7.3 (55)	92.7 (702)
8.	Utensils are dried before use for milking	84.5 (640)	15.5 (117)
9.	Utensils are cleaned before milking	97.4 (737)	2.6 (20)
10.	Utensils are sanitized before milking	8.1 (61)	91.9 (696)
11.	Utensils are immediately washed after milking	86.0 (651)	14.0 (106)
12.	Milk is withdrawn/thrown after use of medicine	76.0 (575)	24.0 (182)
13.	Udders/teats are cleaned before milking	89.8 (680)	10.2 (77)
14.	Udder/teats are dried before milking	59.2 (448)	40.8 (309)
15.	Udder/teats are sanitized before milking	19.6 (148)	80.4 (609)
16.	Milk is pasteurized and labeled	9.0 (68)	91.0 (689)
	Mean score	60.0 (454)	40.0 (303)

The adherence to hygiene of the equipment was high. Almost all respondents (97.4%) cleaned their utensils before milking and 84.5% dried the utensils before use, showing good awareness of equipment cleanliness. Despite this, only 8.1% of them sanitized their equipment before milking as per the more modern practices. The majority of the respondents (86%) washed their hands immediately after milking. This indicates a strong behaviour, which is likely a result of extension training and cooperative programs. As Ouma *et al.* (2024), state, most farmers acknowledge the importance of cleaning but few can differentiate between cleaning and sanitization which is use of chemicals or heat to destroy residual pathogens.

Animal health hygiene measures were generally well adopted. About 90 percent of farmers cleaned their udders and teats before milking and 60 percent dried them. She only 196% sanitized teats; meaning there was limited use of disinfectant before and after milking. Proper sanitisation of udder is a key defence measure against mastitis. The low adoption rate indicates that these herds could still be harbouring subclinical infections (Kanyima *et al.,* 2023). Using pre- and post-dipping solutions has proven to be a good preventive measure, although it is not often used by smallholders due to cost and lack of extension support (Nakatumba *et al.,* 2023).

The study indicated that the percentage of smallholder dairy farmers that stop milk withdrawal after administering veterinary drugs is 76%. This is a good percentage as it lowers the risk of antimicrobial residues in the food. Still, 24% do not comply with withdrawal periods, thus increasing the public health threat that could jeopardize the safety of milk (Seruma *et al.,* 2025). The findings of this study concur with that of Nambi *et al.* (2024) where a considerable number of smallholders in Uganda are unaware of the antibiotic withdrawal guidelines or simply do not find it economically viable to discard the milk.

Just 9% of respondents pasteurize and label the milk they sell, indicating limited capacity to process milk among smallholder dairy farmers. In a study by Ouma *et al.* (2024), it was discovered that high informal milk markets which refer to the sale of raw milk reduces investment in pasteurizers. While pasteurisation is very effective to ensure microbial safety, its low uptake indicates that there are structural and economic constraints in the dairy value chain (Kasozi *et al.,* 2024)

The results of the study showed that the adopters' level of adoption is vary from high level of adoption of cleaning measures to low level of adoption of sanitization and value–added measures. According to Mugisha *et al.* (2022), smallholder dairy farmers are shifting away from traditional practices for the better management of food safety. Nonetheless, full compliance is limited by inadequate technical support, poor infrastructure, and the overwhelming strength of informal production systems that function outside strict regulatory control (Seruma *et al.,* 2025).

Extension programs should emphasize that besides cleaning, sanitization drying and pasteurization are but more than important. Training must encourage the use of cheap disinfectants, separate milking areas, understanding withdrawal periods. By improving the hygiene of milk, public health will be improved and will make Uganda's dairy sector more competitive on the market and ready for export (Kanyima *et al.,* 2023; Nakatumba *et al.,* 2023).

4.2.2 The small-scale dairy farmers in Central Uganda reported the adoption rate of milk storage food safety practices.

It is important for smallholder dairy farmers to adopt food-safety practices for the storage of milk to maintain microbiological safety, chemical quality and overall standard. In Central Uganda, farmers complied with storage methods to a greater or lesser extent. The data in Table 4.4 suggests that there was an average adoption of 73.5% in adoption. But there are still some shortcomings in terms of using proper containers and preventing adulteration.

Table 4.4: Rate of reported adoption of food-safety practices for milk storage

Statements	Responses: n=757	
FSMs under the Component of Milk Storage	Yes	No
1. Milk from diseased animals is kept separately	83.2 (630)	16.8 (127)
2. Milk from seriously diseased/infected animals is discarded	88.8 (672)	11.2 (85)
3. Milk is stored away from the animal shed	91.4 (692)	8.6 (65)
4. The floor of the milk-storage area is dried regularly	81.5 (617)	18.5 (140)
5. The milk-storage area is swept regularly	77.5 (587)	22.5 (170)
6. The milk-storage area is washed regularly	79.0 (598)	21.0 (159)
7. The milk-storage area is kept free from pests	85.1 (644)	14.9 (113)
8. Milk containers used for bulking are without joints	47.2 (357)	52.8 (400)
9. Milk containers used for bulking are washed regularly	95.9 (726)	4.1 (31)
10. Baking soda/powder is added to milk before selling the milk	5.0 (38)	95.0 (719)
Mean score	73.5 (556)	26.5 (201)

Most of the respondents (83.2%) said they are keeping milk from diseased animals separately and 88.8% said they discard milk from the seriously infected animal. A strong awareness of zoonotic threats and milk-borne pathogens is shown by smallholder dairy farmers. Kang'ethe *et al*. (2023), hold that taking milk from sick animals is one way of reducing the risk of microbial contamination especially of Brucella spp. and Mycobacterium bovis. Following the guidance of the World Health Organization (WHO, 2022), segregation is one of the key hazard control measures recommended in dairy safety management.

The remaining 11.2% of smallholder dairy farmers who do not discard contaminated milk are a risk to public health. Seruma *et al*. (2025) claims that the sale or consumption of contaminated milk by some farmers due to economic pressure highlights the importance of continued education and enforcement of dairy hygiene regulations. Due to lack of regulations and monitoring in Uganda's informal milk sector, such practices can lead to diseases that are spread through food and diminish consumer confidence in Uganda-produced milk (Nalubega *et al.*, 2024).

It shows that 91.4% of smallholder dairy farmers store their milk away from animal sheds. These people dry floors (81.5%), sweep (77.5%) and wash (79.0%) to maintain hygiene. The public perception of cleanliness in milk security is becoming increasingly evident. Studies by Mutua *et al.* (2022), and Niyonzima *et al.* (2024) back this hypothesis, as reducing contamination through a clean environment decreases dust, dung, and airborne bacteria exposure.

Dairy farmers who are smallholders and who are cleaning the utensils and drying the area regularly will get better quality milk with more shelf life and less spoilage. These findings agree with Byaruhanga *et al.* (2023), which found that bacterial load in milk samples from Central Uganda was lower when the facilities for milk storage were routinely sanitized. On the other end of the spectrum, 21–22% of the farmers do not often clean their storage spaces mainly owing to limited access to clean water, low awareness, and lack of labor. Okullo *et al.* (2021) have also reported that poor infrastructure and poor investment in storage systems affect hygiene, particularly farmers who are resource limited, small holder farmers.

A high 85.1% of smallholder dairy farmers kept their milk-storage areas pest free keeping rats, flies, and cockroaches away from milk. Kabonesa *et al.* (2023) for example found that pest management was more common on farms that belong to a cooperative society or a training program in Western Uganda. When people keep their environments clean and free of pest, the risk of microbial cross-contamination during milk handling is reduced. This is according to Mubiru *et al.* (2024), who found that the presence of pests and stored milk with increased bacterial counts are related.

While the pest control methods leave behind toxic residues that one cannot see. Using pesticides or disinfectants in storage areas may endanger milk safety. According to Tuhirirwe *et al*. (2022), training smallholder dairy farmers in safe pest management using mechanical, biological not chemical management. Despite limited resources, 95.9% of respondents regularly washed the milk containers used for bulking indicating a positive hygiene practice at farm level. According to the findings of Seruma *et al*. (2025), the frequency of washing is more important than the material of the container for microbial safety of milk. If not properly dried and sanitized, washing items often will not get rid of all soil. Thus, washing does not always imply clean.

Only 5.0% of smallholder dairy farmers acknowledged adding baking soda or powder in milk before selling, showing a generally good compliance level. Any amount of adulteration may be concerning, as substances like baking soda tend to be added to the food to mask any spoilage or acidity. This is a food safety violation according to food law, and it poses a risk to health. Mukisa *et al.* (2023) report similar challenges in Kampala's milk markets where the main aim of the adulteration is to prolong shelf life or to make it appear more appealing.

Findings in this study on the level of adulteration could be attributed to consumer awareness and improved market supervision by Uganda Dairy Development Authority (DDA) as well has better access on the cold chain system in some areas (Nabwire *et al.,* 2024). On the other hand, the informal sector still faces loopholes in the detection and punishment of adulteration (Sserumaga *et al.,* 2025).

Findings show an overall adoption rate of 73.5% with more smallholder farmers in Central Uganda using better milk storage hygiene practices. Dairy cooperatives, training programs, and NGOs that promote food safety and standards are contributing to the growing demand for milk. The same rates were seen in Kenya and Rwanda where participation in collective marketing groups by smallholder farmers led to better adherence to milk storage (Mugisha *et al.,* 2023).

Still, the persistence of gaps mostly in the use of appropriate containers and systematic sanitation shows further capacity draw. Poor quality containers and irregular washing in the milk value chain led to contamination and loss of income. The authors claim that training, infrastructure financing, and continuous regulation are necessary means to enhance milk safety (Kiyaga *et al.* 2022).

Results suggest that storage related food safety measures can take place only if non-technical, especially socio-economic measures are provided. Staff in dairy processing plants and other related firms have little knowledge about where and how the milk will be sold and consumed (Gonzales, 2027). Customized interventions targeting these socio-economic differences would help with uniform compliance.

4.2.3 Rate of adoption of food-safety practices for hygiene of the surrounding dairy environment among smallholder farmers in Central Uganda

The 62.3% mean compliance rate for environmental hygiene food-safety practices by smallholder dairy farmers in Central Uganda is illustrated by Table 4.5. This section reflects the main findings and implications supported by relevant literature.

Table 4.5: Rate of adoption of food-safety practices for hygiene of surrounding environment/premises

Statements	Responses: n=757	
FSMs under the Component of Dairy Environment	Yes	No

1.	The floor of the stall-feed area is kept well-drained daily	77.1 (584)	22.9 (173)
2.	The floor of the stall-feed area is kept clean daily	81.1 (614)	18.9 (143)
3.	Dung is disposed of immediately after excretion	37.4 (283)	62.6 (474)
4.	Urine is drained immediately after excretion	50.7 (384)	49.3 (373)
5.	Chemicals are used as per instruction	88.1 (667)	11.9 (90)
6.	My workers wear suitable clean clothes	61.7 (467)	38.3 (290)
7.	The nails of my workers are trimmed regularly	84.3 (638)	15.7 (119)
8.	Any cuts/wounds are covered with an appropriate waterproof dressing	75.0 (568)	25.0 (189)
9.	My dairy farm is inspected regularly to ensure the safety of the overall farm	50.3 (381)	49.7 (376)
10.	My farm environment is sprayed with insecticides occasionally	56.5 (428)	43.5 (329)
11.	My farm environment is fumigated every three months	23.0 (174)	77.0 (583)
	Mean score	62.3 (472)	37.7 (285)

Most of the respondents reported that 77.1 per cent drain stall-feed areas well and, 81.1 per cent, daily clean these areas. This shows the knowledge of farmers about the need for clean and dry conditions for animals. As explained by Seruma *et al.* (2025), proper drainage reduces the dampness that harbours bacteria and pathogens like *E. coli* and *Listeria monocytogenes*. Moreover, clean feed spaces reduce feed contamination and lessen the risk of harmful bacteria entering milk through the milking unit.

In a similar study, Nabwire *et al.* (2024), found that extension support improved drainage management and stall hygiene among Ugandan farmers compared to non-technical farmers. Many smallholders' dairy farmers – almost 23 % – do not have proper drainage. This is because they do not have sufficient infrastructure or access to building. Kiyaga *et al.* (2022) noted that the structural problems of smallholder farms still remained a serious obstacle to the acceptance of total environmental sanitation standards.

Proper management of dung and urine is crucial to control odor, flies, and microbial contamination. Nevertheless, only 37.4% of smallholder dairy farmers dispose of dung immediately after excretion, and just over half (50.7%) drain urine promptly. Dung and urine must be managed well to reduce odour flies and pathogenic contamination. Yet, only 37.4

percent of smallholder dairy farmers dispose of dung immediately after its excretion and over half (50.7%) urine discharging. Low adoption rates may be due to the lack of a specific manure disposal system or not having enough labour to clean up daily. Smallholders often use manure as fertilizer, but this leads to stored manure before field application (Kabonesa *et al.* 2023).

But since most smallholder farmers in Central Uganda have low levels of literacy, not all respondents understood the chemical handling guidelines fully. In a study by Mubiru et al. (2024), they mentioned that farmers say they adhere to instructions but some mix disinfectants anyhow or use higher doses, which could be toxic to animals and humans. It is necessary to continuously train farmers on the use of chemicals involving the use of personal protective equipment and dosage measure.

It is necessary to maintain the personal hygiene of dairy workers. In this study, 61.7% of smallholder dairy farmers said workers had clean and appropriate clothing during milking and handling. Also, 84.3% said workers regularly trim their nails. In addition, 75.0% said wounds were covered with waterproof dressings. The high level of compliance with personal hygiene practices indicates that there still exists scope of improvement.

According to Kawuma *et al.* (2023), they indicated that good personal hygiene was associated with low levels of microbes in milk samples from Uganda farms Besides, Mukisa *et al.* (2023) argue that clean clothes, short nails, and covered injuries help avoid direct transfer of germs to milk. About half (50.3%) of smallholder dairy farmers reported regularly inspecting their farms regarding farm inspection and vector control. In addition, 56.5% of farmers occasionally use insecticides. Of those surveyed, only 23.0% fumigated every three months. These figures show moderate participation in monitoring and pest control. As stated by Kabonesa *et al.* (2023), inconsistent inspections and bad pest control can subsequently result in the recontamination by microbe and the spread of diseases. This is commonplace in tropical regions that harbor several pests.

In Uganda, not checking the system often could be because of institutions and logistics. Local veterinary and dairy authorities often suffer from inadequate staffing, which limits routine checks (Nalubega *et al.,* 2024). The results shows that a dairy farm generally face no inspections for years. As a result, the dairy farms become complacent when it comes to hygiene.

Smallholder dairy farmers do not fumigate their cattle largely due to financial and safety reasons. Fumigation is effective but requires trained personnel and special equipment that many smallholders cannot afford. Farmers choose to spray insect now and then, since it is cheaper (56.5%) but not so thorough. Tuhirirwe and others in 2022 warned that the unregulated use of insecticides near storage could cause contamination of milk thus the need for guidelines to farmers on vector control was clear.

Findings in this section show an overall mean score of adoption of 62.3 %. This score reveals moderate compliance to environmental hygiene practices among smallholder dairy farmers. These were smallholder dairy farmers in central Uganda. Compared to maintaining milk hygiene (60%) or storage hygiene (73.5%), environmental hygiene is not consistently observed more often than not. Hence, the farmer focuses more on the milk handling procedures which are publicly visible than on further aspects of milk sanitation which are not. This was echoed by Niyonzima *et al.* (2024) who showed that farmers from East Africa prioritized the direct milk handling process rather than the cleaning up of their environment as both processes are equally beneficial for hazards prevention.

The intricate relationship between environmental sanitation, worker hygiene, and waste handling is established by the finding that food safety management is complex. The knowledge and skills of these practices by smallholder dairy farmers signify the influence of their socio-economic resources and institutional supports. Kiyaga *et al*. (2022) highlight that smallholder dairy farmers linked to cooperatives or training programs have much better hygiene practices than their counterparts who operate independently. So, if we can improve farmer networks, upgrade extension services, and build in hygiene checks in co-ops, we can improve safety.

4.2.4 Food safety measures (FSMs) under the component of animal health

The speed at which dairy farmers adopt food-safety measures for the health of animals indicates the quality and safety of milk at source. According to Table 4.6. The mean adoption rate of these measures concerning animal health is at 53.3 per cent compliance level. It shows that animal health management is an important aspect of food safety in the dairy value chain.

Table 4.6: Rate of adoption of food-safety practices for animal health

Statements	Responses: n=757	
FSMs under the Component of Animal Health	Yes	No
1. There are no feaces on the body of my animals	51.5 (390)	48.5 (367)
2. Diseased animals are kept separately	72.8 (551)	27.2 (206)
3. My animals are washed regularly	43.6 (330)	56.4 (427)
4. My animals drink clean water (source is piped public water supply and rainwater)	91.4 (692)	8.6 (65)
5. I practice dry-cow therapy is practiced to prevent mastitis	7.1 (54)	92.9 (703)

	Mean score	53.3 (404)	46.7 (353)

As per the information presented in Table 4.6, 91.4% of the smallholder dairy farmers indicate that their animals drink clean water from the piped public system or rainwater harvesting. It is important for animal health and reduces microbial risks in milk (Seruma *et al.,* 2025).

About 72.8% of smallholder dairy farmers have reported isolating sick animals in order to practice biosecurity so that the animals don't get infected. When sick animals are separated, the chances of cross-contamination are minimized. Diseases such as mastitis and foot-and-mouth disease spread easily through contact and they may also spread through infected feed (Mwangi *et al.,* 2024). On the other hand, those who do not follow this who are 27.2% have increased risks. This can compromise safety of milk and productivity of farms. Improvement of animal segregation should therefore be a top priority to capacity building and extension services.

Table 4.6 indicates that 51.5 percent of smallholder dairy farmers reported that their animals had no feces on their bodies, which shows moderate hygiene. As many as half of the farmers may not do regular cleaning or grooming which may increase the risk of bacterial contamination during milking (Kairu *et al.,* 2022). Animals, as well as their udders, may be capable of contaminating raw milk via faeces. It can affect quality and marketability. The results suggest that farmers need to be made aware regarding routine cleaning of the animals and stall management.

Only 43.6 percent of smallholder dairy farmers in Central Uganda report washing their animals on a regular basis. This suggests that a good number of these farmers do not see routine washing of animals as essential for the safety of the milk produced. Odhiambo *et al.* (2023) suspects that limited access to water, labor constraints and low awareness of hygiene practices leads to this. Regular washing of animals could help reduce the microbial load in milk being offered in the formal market.

The dry-cow therapy has the lowest adoption rate of only 7.1%. A leading cause of milk rejection in Kenya is mastitis (Njoroge *et al.,* 2024). One of the most effective preventive measures against mastitis is dry-cow therapy. This is a significant finding. The low rate could be due to a lack of extension service of veterinary agency, low awareness level or high cost of veterinary input by extending it to veterinary training farmers may also get more expert help.

The average score of 53.3% signifies that smallholder dairy farmers undertake some basic food safety practices aimed at animal health. However, there are still gaps in hygiene and preventive measures and veterinary guidance. The greater willingness to provide clean water and isolate sick animals suggests greater awareness of hygiene essentials. Still, washing infrequently and limited use of dry-cow therapy shows the need for extension only.

Several scholars have revealed that improving animal health practices leads to an increase in milk safety and reduced spoilage losses. It also helps in enhancing consumer confidence in the milk and dairy products (Seruma *et al.,* 2025; Njoroge *et al*., 2024). Teaching farmers, increased veterinary service and regular inspections of farm improve milk safety, resulting in better market outcomes for the smallholder dairy farmers of Uganda.

4.2.5 Adoption of hazard analysis critical control point (HACCP) principles and standard operating procedure at the farm

Smallholder dairy farmers in Central Uganda not consistently receiving HACCP principles by procedures in place at the stages of the food safety management system. As shown in Table 4.7, 58% of farmers realize that there exists a hazard in their production processes while less progress to CCP, limit setting and monitoring. Not all smallholder dairy farmers have adopted HACCP progressively (Seruma *et al.,* 2025). This uneven adoption indicates that HACCP is still only partially and fragmented integrated into smallholder dairy systems. This has mainly been caused by limited technical skills to apply the approach, lack of training, and a shortfall of institutional support (Seruma *et al.,* 2025).

Table 4.7: Adoption of hazard analysis critical control point (HACCP) principles

Steps in HACCP integration	Frequency (Yes)	Percentage (%)	Frequency (No)	Percentage (%)
Identify hazards (Listing of all hazards associated with, each step and consider any control measures ‘to eliminate or minimize hazards)	397	58.0	287	42.0
Establishment of critical control points (CCP)	321	47.0	362	53.0
Establishment of critical limits for each CCP	226	32.9	460	67.1
Establishment of a monitoring system for each CCP	205	29.9	481	70.1
Establishment of corrective actions	277	40.4	408	59.6
Establishment of verification procedures	168	24.6	514	75.4

Establishment of record-keeping and documentation	430	68.8	255	37.2
Implementation of the HACCP plan	189	27.6	495	72.4
Review of the HACCP plan	163	23.8	521	76.2

The first and most common HACCP step is hazard identification, which is reported to be done by 58% of smallholder dairy farmers. Involves identifying all the possible biological, chemical and physical hazards at every stage of milk processing and specifying controls to eliminate or minimize them. The somewhat high level of participation means that smallholder dairy farmers are somewhat aware of milk safety risks. This is mostly due to the training programs and community extension that emphasize hygiene and disease prevention (Mugisha *et al.,* 2022).

Ouma *et al.* (2024), indicated that numerous farmers perceive mastitis, antibiotic residues and milking errors as hazards. They mainly use standard procedures and not formal hazard assessment tools. This lack of awareness shows that smallholders do not widely adopt formal food safety frameworks, like the one above, in an informal milk trading situation where enforcement of legislation is also limited (Kanyima *et al.,* 2023).

On the other hand, mere 47% of farmers reported the setup of Critical Control Points (CCPs). These are points in production where controls are installed to keep hazards from occurring or eliminate them. Limited technical understanding of the organized movement suggested by HACCP was the low rate of adoption. As seen with Kasozi *et a.l* (2024), the identification of CCPs requires scientific reasoning and verification based on records which is often beyond the capacity of smallholder farmers who work informally.

Smallholder dairy farmers do not have facilities to cool milk, or stainless-steel equipment, or testing kits to manage these monitoring control points effectively. These challenges resonate with findings by Nambi *et al.* (2024), who found farmers express preference for clean milking environment and healthy animals, but rarely record their practices as part of documented control system. That's why hazard identification is fairly common; formal identification and management of CCPs are still somewhat limited for smallholder dairy farmers.

A small percentage of smallholder dairy farmers, only 32.9%, established critical limits for each CCP, indicating a limited capacity for determining acceptable safety thresholds. Product safety is determined by critical limits that can be evaluated for temperature, time or level of microorganisms. As pointed out by Seruma *et al.* (2025), since testing facilities or laboratories for smallholder farmers to quantify those are limited, they mostly rely on sensory evaluations such as smell, colour and texture for milk quality.

This subjective assessment leads to an increased risk of contaminated milk being marketed. Similarly, Ouma *et al.* (2024) observed that the feedback from buyers or middlemen was relied upon by numerous smallholders to assess milk quality; this further complicated the enforcement of standards. The fact that compliance with this HACCP step has been poor points to the technological and resource constraints to scientific control during informal dairy production.

In Central Uganda, only 29.9% smallholder dairy farmers have a monitoring system for each CCP suggesting less continuous monitoring. We must closely monitor analytical results to identify deviations and preempt food safety problems. A structured monitoring system is lacking most of the time. This shows the prevalence of knowledge gaps and infrastructural challenges. Mugisha *et al.* (2022), found that smallholder farmers do not maintain records of daily activities such as milking times, treatments and cleaning. It is difficult to trace or verify variations from Control with no records.

Most operations are done manually, and there are not many trained personnel available. Smallholder dairy farmers often find it difficult to afford verification tolls like temperature loggers and microbial testing, undercut the affordability. As a result, Nakatumba *et al.* (2023) observe that the monitoring failures are the main difficulty encountered with the application of HACCP in Africa's informal dairy sector which makes hazard control reactive rather than preventive.

It is notable that forty-point four percent of smallholder dairy farmers have put corrective actions in place. We can regain control of contaminated milk and other substances with action. We can call the call actions which can remove hazards or disinfect equipment. Farmers' involvement at this stage indicates their reactions are often in response to spoilage or disease incidents after the fact rather than preventative measures (Seruma *et al*., 2025).

Kanyima *et al.* (2023), noted that usually corrective action is started after detection of contamination through sensory change and consumer complaint. This reactive strategy is contrary to HACCP's preventive strategy Nevertheless, the fact that more smallholder dairy farmers take corrective measures than verification procedures (24.6%) indicates that smallholders prefer to react to visible problems over abstract procedural controls.

Only 24.6% of respondents adopted verification procedures, which confirm the HACCP system is working as intended. Smallholder farmers rarely have access to systematic documentation, laboratory testing, and expert review for such procedures (Nambi *et al.,* 2024).

Kasozi *et al.* (2024) indicate that for verification to succeed, regulatory oversight is vital and the institutional connections within the milk sector must be reinforced. In many rural areas, the absence of such linkages explains low verification rates. Also, the limited role of veterinary officers and milk inspector due to logistical problems hampers verification process (Ouma *et al.,* 2024). Thus, the implementation of HACCP by smallholder dairy farmers in Central Uganda has not been significantly verified such that it raises food safety compliance concerns along the value chain.

Nevertheless, 68.8 percent of smallholder dairy farmers mentioned that they keep records and documentations the second-highest compliance level after Hazard Identification. This excellent performance may result from more attention given by cooperatives and milk collection centre to vital record-keeping in milk delivery, animal-health and payments. Seruma *et al*. (2025) said that many dairy groups in central Uganda recorded the volume of milk delivered, the time of delivery, and the names of contributing farmers which indirectly aided HACCP documentation and was basically like a HACCP documentation system. The quality and reliability of these records remain variable. Mugisha and their team reveal that without a protocol or templates as well as training, these records may not reliably prove food safety control measures. The increased use of documentation suggests that opportunities exist for strengthening existing HACCP systems via team training and electronic record-keeping.

Only 27.6% of respondents said they implemented the HACCP plan which indicates that even the initial idea did not lead to the overall full adoption. To apply this, integrate all previous steps into daily operation of the farm. The low uptake shows that HACCP is still mostly a theoretical concept and not a useful management tool by smallholder dairy farmers, (Kanyima *et al.,* 2023). Farmers do not submit for a multitude of reasons like lack of incentive and education. Smallholders prefer productivity and immediate income over long-term safety systems when market enforcement is weak (Nambi *et al.* 2024). Policy instruments that link HACCP compliance with social value largely relate to access to better markets and/or certification programs.

Only 23.8 per cent of the smallholder dairy farmers reported to do regular reviews of the HACCP plan which was the least frequent step. Routine review is necessary for a plan to remain effective as production environments and/or hazards change, or regulations are modified. Few smallholder dairy farmers have a management system suitable for climate variations as only few participate in review activities. According to Seruma *et al.* (2025), smallholder dairy farmers seldom update their practices unless driven to do so by disease outbreaks or an external inspection. Kasozi *et al.* (2024) also explain that, in the absence of a regular review, HACCP will become out-of-date, limiting the ability of HACCP systems to manage new and emerging risks such as of arising from AMR or climate change.

The result of the findings indicates that while some aspects of HACCP such as hazard identification and record keeping are implemented but other important procedural and verification steps are carried out inadequately. This trend is similar to a partial use that could be seen in other low- and middle-income countries (Ouma *et al.,* 2024). The findings indicate that smallholder farmers have some understanding of food safety risks. However, their lack the institutional, financial and technical support to implement HACCP systems in a full-scale manner.

In order to boost adoption, an appropriate mixed strategy involving better farmer training, affordable monitoring tools, and cooperation verification will be required. Mugisha *et al.* (2022) claim that context-adaptive HACCP to smallholders require simplifies procedures while maintaining their essential preventive principles.

Smallholder dairy farmers in Central Uganda are aware of HACCP. However, those principles are not implemented consistently in their operations. To ensure the safety of milk, we need more than just awareness campaigns. There should be capacity-building, incentives for complying with regulations as well policies to incorporate HACCP into smallholder production. Improving partnerships with cooperatives and extension services can progressively align smallholder dairy systems with international food safety standards while reducing public health risks and enhancing competitiveness of smallholder dairy system in the marketplace (Seruma *et al.,* 2025; Nakatumba *et al.,* 2023).

4.2.6 Adoption of standard operating procedures in ensuring milk safety

The use of the Hazard Analysis Critical Control Points (HACCP) in dairy products to ensure process and quality control is shown in Table 4.7. A main part of this method is Standard Operating Procedures. All HACCP plans require to have SOPs documented and reviewed from time to time for consistent quality of milk. In addition, SOPs allow less variation when different workers do the same job using different methods at the farm. So, the study looked to see how often farmers use SOPs on their dairy farm. According to the depicted information in figure 5, 75 percent of the smallholder dairy farmers admitted to complying with SOPs. Whereas, 25 percent of them admitted to not complying with it. Further analysis indicated most of the SOPs were informal or unwritten, and local farmers had based on their experience.

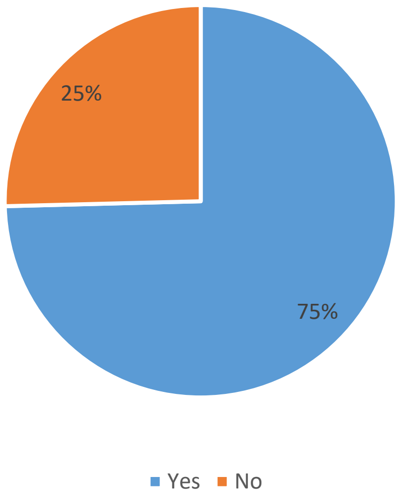


Figure 1: Adoption of standard operating procedures (SOPs) to ensure milk safety

Table 4.8 illustrates the different types of SOPs used by smallholder dairy farmers of Central Uganda. The findings indicate differing levels of SOP adoption. Most of them (70.5%) have system-based SOPs on feeding, milking, animal health, reproduction and manure disposal. Fifty-eight point one per cent belong to procedure-based SOPs like sanitizing milking preparation and clean-up. Further, four-four-point five per cent adhere to step-by-step operations SOPs like wearing gloves, hot water with soap, etc. These findings indicate that milk safety standards were partially put in place. This is similar to reports showing that broad systems are employed by smallholders but do not comply with specific procedural provisions (Mugisha *et al.,* 2022).

Table 4.8: Adoption of standard operating procedures in ensuring milk safety

SOPs	Yes		No	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Systems, e.g., feeding, milking, health, reproduction, waste/manure management.	534	70.5	223	29.5
Procedures, e.g., sanitizing, milking preparation, milking, cleanup.	440	58.1	317	41.9
Steps, e.g., wearing fresh gloves, using a bucket, filling the bucket with hot water, add soap, etc.	337	44.5	420	55.5

As shown in table 4.8, most of the smallholder dairy farmers of Central Uganda are increasingly using system-based standard operating procedures (SOPs). Farmers understand that daily and repetitive actions are essential to maintain the health and hygiene of the herd to enhance the quality of milk (Nambi *et al.,* 2024). The findings of a high adoption rate of 70.5% suggested that the extension training was effective in promoting herd-based practices like adequate and consistent feeding, house sanitation and manure management (Ouma *et al.,* 2024).

The moderate use of procedure-based standard operating procedures (SOPs) (58.1%) is indicative of being at the fence stage. Smallholder dairy farmers are aware of hygiene routines but they have not yet adopted them. According to Kasozi *et al*. (2024), cleaning and sanitizing are essential in ensuring safety of milk, especially at milking time. If you don't follow all these measures, microbial pathogens can remain on equipment and udder surfaces. That negatively affects raw milk quality and shelf life.

In addition, the lack of access to cleaning agents, water scarcity, and insufficient vet or extension officer oversight might cause inadequate execution of these practices (Kanyima *et al.*, 2023). This finding is in line with Nakatumba *et al.* (2023) who found that although most farmers in Central Uganda are aware of the significance of hygienic milking, few practice all recommended procedural standards owing to time and cost constraints.

Step-based SOPs had the lowest adoption, with 44.5%, indicating problems farmers are facing to implement detailed procedures in smallholder dairy farming. Wearing clean gloves, washing equipment with hot water and soap, and sanitizing utensils in that order are some of the basic yet important tasks which were not always followed as they should have been. Such attributes suggest behavioral and resource challenges typical for smallholder farmers (Seruma *et al.,* 2025). Some processes are not controlled as practitioners rely more on informal learning than on written SOPs. Lack of PPE and informal supervision reduces compliance to the steps provided (Nambi *et al*., 2024).

The results suggest that beyond training, capacity building needs to also be about implementation. Farmer cooperatives and quality assurance initiatives play an essential role in reinforcing routine standards and offering shared resources like disinfectants and other sanitation supplies (Mugisha *et al.,* 2022). More backing of the institutes with enhanced peer learning and demonstration farms will improve mobilization of the milking community for adherence to details SOPs. Further, it can help improve milk safety at the source itself.

4.3 Descriptive analysis of smallholder dairy farmers' intention toward milk-safety behaviors

This part analyzes smallholder dairy farmers' intentions regarding milk safety behavior descriptively. The variables addressed in this research are attitude towards milk safety practices (ATT), subjective norms (SN), perceived behavioral control (PBC), and behavior intention (BI).

4.3.1 Attitude toward milk safety practices

The study of this attitude construct is important because it shows the personal beliefs and value decisions of smallholder dairy farmers regarding the importance of specific milk hygiene practices. The specific milk hygiene practices relate to the handling and production of milk Table 4.9. The various means in this section demonstrate a supportive attitude toward hygienic behaviors which enhance the safety of milk.

Table 4.9: Descriptive statistics for smallholder dairy farmers' attitudes toward milk-safety practices

Attitude statements	Mean	Std. Deviation
1. For me washing udder before milking is important for milk safety	4.51	0.727
2. Using clean containers/utensils is important for milk safety	4.66	0.595
3. For me washing my hands always in a particular container/facility is not important.	2.53	1.232
4. For me, following the proper handwashing steps is not important to milk safety.	2.43	1.242
5. For me to wash my hands before and after milking, I consider it very important for milk safety.	4.59	0.688
6. When I fall ill of any sickness, it is not important to seek immediate medical help.	2.42	1.215
7. For me keeping sick animals isolated is very important for milk safety	4.05	0.947
8. Milking wearing clean clothes all the time is very important for milk safety	3.95	1.030

Note: (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Table 4.9 showed that the second most common opinion was that “Using clean containers/utensils is important for milk safety” respondents agreed to that to an average of (M = 4.66, SD = 0.595). Many small-scale dairy farmers agreed that it is important for safety and quality to keep containers clean. People’s views on the matter do not differ much as shown by the standard deviation being low. Hence, this belief is quite widely-held and ingrained. Most milk contamination occurs when milking utensils aren’t clean. Therefore, the positive attitude means that interventions to enhance the cleanliness of milking equipment would be welcomed by Central Uganda smallholder dairy farmers.

Likewise, a high average score was recorded for “I wash udder before milking for milk safety” (M = 4.51 SD = 0.727) and “I consider it very important to wash my hands before and after milking for milk safety” (M = 4.59 SD = 0.688) by most respondents. This finding indicates that most smallholder dairy farmers in Central Uganda recognize the importance of personal and animal hygiene to the quality of raw milk. The consistently high scores across the items suggest that these smallholder dairy farmers have positive affective and cognitive beliefs on these preventive actions. The low standard deviations also demonstrate little variation in responses and thus indicate that washing practices are universally recognized as essential rituals in milking.

The average scores for the statements “Keeping sick animals isolated is very important for milk safety (M = 4.05 SD= 0.947” and “Milking wearing clean clothes all the time is very important for milk safety (M = 3.95 SD = 1.030)” was quite moderate which shows the respondents were generally agreeable but they are lower than the scores for washing hands and udder. It appears that while smallholder dairy farmers do have some understanding of the concept of hygiene, their consistent behaviour is more indicative of routine visible practices, like washing, rather than more general management practices like isolation of sick animals or regular washing of clothes. The higher standard deviations indicate that there was a lot more variability because the farmers may not have had access to protective clothing, shared milking places with other animals, and did not have adequate veterinary advice on the means of preventing zoonotic risk.

Likewise, the means for the negative statements were low. Specifically, “For me, following the correct steps of washing my hands does not matter when it comes to the safety of the milk” recorded a mean of 2.43 (SD=1.242). Further, “For me, always washing my hands in a particular container/facility does not matter” recorded a mean of 2.53 (SD=1.232). Smallholder dairy farmers in Central Uganda generally have a positive attitude towards handling milk hygienically. This is in conflict with the negative wordings. The low average scores and moderate standard deviations indicate that most respondents do not agree to do away with hand hygiene.

The statement "When I fall ill of any sickness, I don't need immediate medical treatment" (M = 2.42, SD = 1.215) had a low average. This suggests that most of smallholder dairy farmers do recognize the importance of getting medical treatment as it becomes necessary. This shows that human health is concerned with the safety of the milk, especially when it comes to zoonoses as well as human-animal transmission of diseases. Most people believe seeking medical help is socially acceptable, but some remain indifferent or negative. This is not surprising, as there may be economic, cultural, or accessibility obstacles (SD> 1.0).

To sum up, smallholder dairy farmers in Central Uganda have a generally favorable outlook about safety according to attitude domain. The notably high ratings given to the items 'use of clean containers/utensils', 'washing the udder before milking', and 'washing hands before and after milking' suggests that these farmers hold favourable views on hygiene, consistent with the attitude construct in TPB. In agricultural and dairy contexts, a positive attitude towards food safety and hygiene is often the best predictor of intention and behaviour. As an illustration, the study by Ledo *et al.* (2021), based on the Theory of Planned Behavior (TPB), of a training intervention in formative dairy chains found enhanced attitudinal beliefs associated with greater adoption of milk safety practices.

The importance of attitude has highlighted by their work in behaviour change initiatives. Furthermore, Jingyi *et al.* (2025) found that attitudes significantly explain the variance in intentions to adopt animal health practices. The consistently high levels of attitudinal scores articulated in this paper lend support to the argument, both within the context and TPB evidence generally, that smallholder dairy farmers tend to favour milk-safety practices. A positive attitude forms a base for behavioural conformity. But, their statements on clothing hygiene and isolating sick animals differ, indicating that the behavioural gaps are driven more by constraints than attitude.

4.3.2 Subjective norms

The subjective norm construct assessed perceived social expectations and normative pressures from significant others, including customers, supervisors, and community members, influencing smallholder dairy farmers' milk-handling behavior. As shown in Table 4.10, the means across this dimension generally range between 3.68 and 4.54, suggesting moderately to highly positive social influences on compliance with milk-safety practices.

Table 4.10: Descriptive statistics for subjective norms regarding milk-handling behavior

Subjective norm statements	Mean	Std. Deviation
1. My customers whom I value will disapprove if I don't wash my hands properly	3.95	0.978
2. It is required of me to wash my hands before milking	4.54	0.703
3. The people I supply milk will disapprove if I don't wear clean clothes before handling milk.	3.71	1.099
4. People who are important to me think that I should wash udder of cows before milking	4.07	0.952
5. People whom I respect (i.e., customers) will disapprove if I do not stay away from milking when I am sick	3.68	1.076
6. I am expected of me to stay away from milking when I am sick	3.83	1.044
7. My customers expect me to bulk milk in clean milking containers/utensils	4.40	0.858

Note: (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

The average score of respondents on the statement "It is required of me to wash my hands before milking" was the highest (M = 4.54, SD = 0.703) as per Table 4.10. The strong agreement suggests that smallholder dairy farmers in Central Uganda view handwashing not only as a private practice but also a socially and professionally acceptable practice. The lack of much variation shows that the expectations are well known across the dairy community probably through government regulations, training programs, or inspections.

Further, high mean 4.40 (SD .858) for the statement "My customers expect me to bulk milk in clean milking containers/utensils" reflected high social pressure for sanitary handling of milk. Dairy business in Central Uganda seems to take note of customers. This positive normative incentive could enhance adherence to hygiene, as reputation and trust incentivize customers and service providers alike.

The items "People important to me think I should wash the udder of cows before milking" (M = 4.07, SD = 0.952) and "My valued customers will disapprove if I don't wash my hands properly" (M = 3.95, SD = 0.978) scored moderately high. Smallholder dairy farmers in Central Uganda experience social disapproval if they fail to undertake critical hygiene practices. Individuals and reputable figures are taken as important references. This reinforces the market-oriented nature of hygiene compliance. Clients' ongoing patronage and good reputation provide the motivation to behave.

The statements on illness-related behavior, "People whom I respect will disapprove if I do not stay away from milking when I am sick" (M = 3.68; SD = 1.076) and "I am expected to stay away from milking when I am sick" (M = 3.83; SD = 1.044) received lower means. While these still tend to be similar, the lower averages as compared to two other items suggest lower social norms enforcing absenteeism due to health. The outcomes suggest that for smallholder or informal dairy farms, the economic need to work despite illness may be greater than social disapproval. Moreover, the high standard deviations suggest that there are a lot of differences between respondents who might possible be due to not knowing the health-to-milk contamination pathway. Maybe the respondent has substitute labour at the farm level.

The statement, "The people I supply milk to will disapprove if I don't wear clean clothes before handling milk," had the lowest mean in this construct at M=3.71 (SD=1.099) which indicates a moderate degree of normative influence on personal cleanliness among smallholder dairy farmers of central Uganda. While there seems to be an agreement, the high level of variability suggests that in informal dairy systems the oversight of clients on clothing hygiene is minimal. In contrast to other checks such as container cleanliness, clothing condition is not in sight or easily detectable.

In general, the results obtained on subjective norm clearly indicate that social and market-related expectations have a significant impact on certain hygienic behaviour, for example, handwashing and sanitizing containers. However, the same doesn't go for personal health and dress codes. Dairy farmers in Central Uganda are likely to change visible traits of their cattle such as the cleanliness of containers and other traits that are visible to others as opposed to invisible private traits that are resource dependent.

This pattern is in accordance with the TPB literature which recognizes normative influences as more relevant for travels that are more visible. In dairy value chains, it is market actors or cooperatives or extension agents who often monitor activities like cleaning a container or handwashing; this is done more than failing to exhibit self-exclusion when ill. According to Ledo *et al.* (2021), perceived social pressure from stakeholders like customers and extension agents are significantly predictive of intentions for personal hygiene and udder care in dairy systems.

Variations in smallholder dairy farmer norms in Central Uganda may vary due to differences in exposure to enforcement (such as through strict or informal buyers); variations in community norms; or different social networks. Research conducted on the Theory of

Planned Behavior (TPB) shows that the effect of social normative is dependent on the referent groups' influence and power as well as the acceptability of the groups. When an area is under economic pressure, disapproval from others might not be effective (Jingyi *et al.,* 2025). What this shows is that institutional measures like buyer audits, peer accountability, and the like can backfill weaker areas of norms like illness avoidance and clothing hygiene. As a result, greater community monitoring, peer oversight, and buyer standards could enhance adherence to hygiene norms.

4.3.3 Perceived behavioural control (PBC)

The perceived behavioral control constructs represent smallholder dairy farmers' sense of autonomy and capability to perform recommended milk-safety behaviors despite potential obstacles. This construct generally received low average scores, mostly ranging from 1.92 to 2.74, suggesting limited perceived agency among smallholder dairy farmers in Central Uganda in fully adopting hygienic practices without external assistance (Table 4.11).

Table 4.11: Descriptive statistics for perceived behavioural control over milk-safety practices

Perceived behavioural control statements	Mean	Std. Deviation
1. It is entirely up to me to wear clean clothes all the time when milking	2.71	1.301
2. Washing my hands before and after milking is completely up to me.	2.54	1.412
3. Not having support from others would make it more difficult for me to wash my hands properly.	1.92	1.062
4. It is entirely up to me to wash my hands from dedicated handwashing containers.	2.70	1.230
5. It is completely up to me to stay away from milking when I fall sick of diarrhoea, cholera or sneezing.	2.59	1.529
6. Not having support from government to acquire protective clothes would make it difficult for me to wear clean protective clothes when milking.	2.26	1.204
7. Not having support when sick would make it difficult for me to stay away from milking.	2.74	1.276

Note: (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

As shown in Table 4.11, the lowest mean value was recorded for the statement "Not having support from others would make it more difficult for me to wash my hands properly"

(M = 1.92, SD = 1.062). The low mean, within the scale context, suggests that smallholder dairy farmers in Central Uganda tend to disagree with the statement, indicating they do not necessarily rely on others to wash their hands. However, when considering all items together, this result may reflect a mixed view: farmers recognize the importance of support networks but also see some independence in simple hygiene practices.

The findings indicate about a third of the items have low to moderately low mean scores showing smallholder dairy farmers in Central Uganda have the tendency to believe they have less control over their activity. To demonstrate this, the following statements scored similarly "It is entirely up to me to wear clean clothes all the time when milking" (M = 2.71, SD = 1.301) and "It is entirely up to me to wash my hands from dedicated handwashing containers" (M = 2.70, SD = 1.230) shows that respondents are limited by external barriers, be it financial, infrastructure or social. Farmers may not have full control over the use of agrochemicals because they do not have access to water, protection clothes or proper washing, especially on rural and resource-poor farms.

A different but related statement about the same level of responsibility – "I totally can avoid milking when I'm sick with diarrhoea or cholera or sneezing" gave similar results (M = 2.59, SD = 1.529). There is a large variance with a standard deviation of 1.529. This indicates that self-efficacy is influenced by different circumstances. We find, for example, that those smallholder dairy farmers who can delegate milking duties will do so. On the other hand, those who must labour on, despite being ill, usually have no choice due to a lack of alternatives or because of financial need.

The phrase "Not having support from government to buy protective clothes will make it hard for me to wear clean protective clothes when milking" (M = 2.26, SD = 1.204) shows dependence on external support. These show how smallholder dairy farmers face systemic challenges in Central Uganda that are not resolved by personal effort alone. With the low mean, the farmers mostly agree that government or cooperative help is needed for full compliance.

Last in the list was the statement "Not having support when sick would make it difficult for me to stay away from milking" (M=2.74, SD=1.276) which shows the dependency narrative. The average percent score of 58 with a moderate variability of 27 percent reflects the fact that although some smallholder farmers felt empowered to make decisions to protect their health, others were confronted by different structural barriers including lack of replacement labour, and income insecurity that undermined their sense of control.

The PBC scores suggest that smallholder dairy farmers in Central Uganda understand and appreciate milk-safety behaviours (as evident in the Attitude section), but often lack the environment and resources to perform these behaviours on their own. Having the intention is not deemed sufficient unless the person believes he is capable.

According to these findings the application of Theory of Planned Behavior or TPB in farming and public health has shown that the perceived behavioural control (PBC) often becomes the main bottleneck between intention and action. Intention is one thing. Putting it into action is another. If the factor doesn't exist which stops one from taking action, one may put intention into action. Researchers PBC studied and its effects. There are studies that show that the influence of PBC to attitude and PBC to subjective norm. The influence studied and shows that due to PBC there are little or no changes to the variable studied that is due to PBC Hagger *et al*. (2022). So, programs that encourage the constant handwashing of soapy water should concentrate on infrastructural and institutional enablers. For instance, they require access to handwashing infrastructure, subsidized personal protective equipment, and community health services to elicit and solidify positive behaviours.

4.3.4 Behavioural intention

Within the TPB framework, behavioral intention is the most direct predictor of actual behavior, serving as a mediator for the influence of attitude, subjective norm, and perceived behavioral control (Ajzen, 1991). As shown in Table 4.12, the average scores (M = 3.15–4.18) indicate that smallholder dairy farmers generally intend to ensure milk safety by adopting hygienic practices. The farmers strongly believe that handwashing (M = 4.18) and wearing clean clothes (M = 4.10) are within their personal control, which shows a strong level of intrinsic motivation.

However, slightly lower scores on items emphasizing lack of external support (M = 3.15–3.33) indicate moderate dependency on institutional or social assistance, especially when ill or lacking resources for protective clothing. Standard deviations (0.84–1.11) show moderate variability, suggesting that while most smallholder farmers in Central Uganda maintain consistent intentions, external factors (economic, infrastructural, or social) may influence actual behavior.

Table 4.12: Descriptive statistics for farmers' intention toward hygienic milk-handling practices

Intention statements	Mean	Std. Deviation
1. Washing my hands before and after milking is completely up to me.	4.18	0.84

2. Not having support from others would make it more difficult for me to wash my hands properly.	3.22	1.03
3. It is entirely up to me to wash my hands from dedicated handwashing containers.	4.05	0.92
4. It is completely up to me to stay away from milking when I fall sick of diarrhoea, cholera or sneezing.	3.89	1.08
5. Not having support when sick would make it difficult for me to stay away from milking.	3.15	1.11
6. It is entirely up to me to wear clean clothes all the time when milking.	4.10	0.87
7. Not having support from government to acquire protective clothes would make it difficult for me to wear clean protective clothes when milking.	3.33	1.02

Note: (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Smallholder dairy farmers in Central Uganda are willing to adopt hygienic practices for handling milk if structural limitations can be addressed. This shows strong intention; however, they will be useful environmental support to turn intentions into action on a regular basis. Our findings are similar to that of Mucinhato *et al.* (2021) who used an extended TPB to study household food-handling behaviours. They report that intention significantly mediated the effect of attitudes, norms and control beliefs on reported behaviours.

Rezaei *et al.* (2023), in an on-farm food safety study found that intention was a significant predictor of safe practices. The authors noted that the relationship from PBC to intention was strong. The results are consistent with theory of planned behavior literature. The average score for smallholder dairy farmers' behavioural intentions is high. This means that smallholder dairy farmers in Central Uganda are aware, socially-pressured and psychologically-committed to safe milk handling practices.

4.4 Measurement model for latent constructs of structural equation modelling

The measurement model evaluation is the foundation of structural equation modeling (SEM), which is used for studying the reliability, consistency, and discriminant validity of the latent constructs (Hair *et al.,* 2021) The validity and reliability of the latent constructs that express farmers' behavioral determinants of food safety and hygiene-control practices were examined through measurement model. According to Table 4.13, the measurement model gives the following results.

The farmers' Performance of Food Safety and Hygiene (PFSH) is measured using latent variables Perceived Behavioural Control (PBC), Attitude (ATT), Subjective norm (SN) and Behavioural Intention (BI). The measurement model in SEM is very much necessary when the indicators will measure the concepts being proposed by the TPB.

The factor loadings (β), standard error (SE), confidence interval, and level of significance (z and p values) of all the observed variables were assessed. All the loadings were significant $p < 0.001$ (Table 4.13). This demonstrates that each item loaded significantly onto the relevant latent factor. This shows that the measurement model is adequate, and the selected indicators represent the respective behavioral constructs.

Table 4.13: Measurement model results for attitude, subjective norm, perceived behavioural control, and behavioural intention

Latent Construct	Observed Variable	Estimate	SE	95% CI Lower	95% CI Upper	β (Standardized)	Z	P
Perceived behavioural control (PBC)	PBC6	1.000	0.000	1.000	1.000	0.467	—	—
	PBC1	−1.360	0.137	−1.629	−1.091	−0.635	−9.91	< 0.001
	PBC2	−0.651	0.099	−0.844	−0.457	−0.304	−6.60	< 0.001
	PBC3	−1.145	0.109	−1.358	−0.932	−0.535	−10.54	< 0.001
	PBC4	1.750	0.165	1.426	2.073	0.817	10.58	< 0.001
	PBC7	−0.656	0.101	−0.854	−0.458	−0.306	−6.50	< 0.001

	PBC5	−0.738	0.099	−0.932	−0.543	−0.345	−7.43	< 0.001
Attitude (ATT)	ATT6	1.000	0.000	1.000	1.000	0.426	—	—
	ATT7	1.067	0.129	0.815	1.319	0.455	8.29	< 0.001
	ATT3	1.282	0.131	1.026	1.538	0.547	9.82	< 0.001
	ATT2	1.345	0.134	1.082	1.607	0.573	10.03	< 0.001
	ATT1	1.178	0.130	0.922	1.434	0.502	9.03	< 0.001
	ATT4	1.145	0.123	0.904	1.385	0.488	9.34	< 0.001
	ATT5	1.412	0.135	1.148	1.677	0.602	10.46	< 0.001
	ATT8	1.337	0.128	1.085	1.588	0.570	10.42	< 0.001
Subjective Norm (SN)	SN1	1.000	0.000	1.000	1.000	0.341	—	—
	SN2	1.120	0.177	0.774	1.467	0.382	6.34	< 0.001

	SN5	1.569	0.189	1.198	1.940	0.535	8.29	< 0.001
	SN7	1.109	0.182	0.752	1.466	0.378	6.09	< 0.001
	SN3	1.877	0.212	1.461	2.293	0.640	8.84	< 0.001
	SN4	1.808	0.230	1.359	2.258	0.617	7.88	< 0.001
	SN6	1.233	0.157	0.924	1.541	0.421	7.84	< 0.001
Behavioural Intention (BI)	BI Index	1.000	0.000	1.000	1.000	1.000	—	—

4.4.1 Perceived behavioral control (PBC)

PBC is how easy or difficult smallholder dairy farmers perceive it to implement food safety and hygiene practices on the farm. This gauge their self-efficacy, access to resources, and mitigating barriers to adopting protective behaviours. This model utilizes seven observed variables (PBC1–PBC7) to measure the construct.

The PBC items standardized loadings (β) ranged from -0.635 to 0.817, and all paths were statistically significant ($p < 0.001$). This means that every measured variable added value to the PBC construct. PBC4 had the strongest impact on the smallholder dairy farmers perceived behavioral control as it has the highest loading of $\beta = 0.817$ and also shows a high significance of $z = 10.58$, $p < .001$. Conversely, PBC2, PBC5 and PBC7 had negative loadings that were lower but significant. The following statements were negative and reverse-coded to measure smallholder farmers' behavioral attributes for FSM. Even though they had negative signs, they had statistical significance and therefore provided meaningful information about the latent variable after taking orientation into account.

The stability and statistical power of the loadings reflected that the items measuring perceived behavioral control were reliable and measured different aspects of smallholder dairy farmers' confidence and ability to implement safety and hygiene practices. Accessing the tools for mechanization, understanding their safe handling, ability to purchase hygiene items, and perceived constraints in time and labour; were other aspects. Smallholder dairy farmers' perceptions of control differ, as evidenced by the identification of both positive and negative loadings. Some people think constraints are a big deal while others think they are easy to get over. Psychometrically, high coefficients for all indicators show strong convergent validity and represent the construct well.

PBC indicators' standard errors (SE) are on the small side, ranging between 0.0986 and 0.1653. Hence, SE estimates are precise. The estimates are robust since the 95 percentile confidence intervals of all indicators do not include zero. To illustrate, PBC3's interval (–1.358, –0.932) was narrow and stable, indicating a reliable measurement across samples. This is in agreement with the Theory of Planned Behavior whereby perceived behavioural control significantly determines intention or action. In other words, people tend to perform an action when they feel able and ready.

As shown in Table 4.13, the definition of PBC construct was clear in this measurement model. How farmers perceive their control & capacity affects whether farmers are likely to adopt food safety & hygiene practices. The significant factor loadings on perception suggests a possibility of quantification and that it is distinct from acceptance or subjective norm.

4.4.2 Attitude (ATT) toward food safety and hygiene practices

Attitudes refer to the general evaluation by smallholder dairy farmers of the food safety and hygiene practices in a positive or negative way. As per Theory of Planned Behavior, attitude is a central motivator that influences intentions and ultimately behaviours. This concept was assessed based on eight indicators (ATT1–ATT8), which refer to farmers perceived values, importance, and outcomes of safety and hygiene measures.

According to Table 4.13, the loadings for all attitude measures were positive and significant ($p < .001$), with β values ranging from 0.426 to 0.602. The most significant predictor of the latent construct was ATT5 ($\beta = 0.602$, $z = 10.46$, $p < .001$). This sounds as if it is something that facilitates quality and/or access to the market. The loading for ATT6 was at the lowest level with a value of 0.426, which is still acceptable for reflective measurement models.

The loadings are important and strong, suggesting smallholder dairy farmers have complex but generally positive attitudes toward food safety and hygiene. Since all items have moderate to high loadings, it can be stated that they uniquely represent the main concept (beliefs, feelings and intended actions) in their own way. Thus, there is strong evidence for the convergent validity of the attitude measurement.

The standard errors were small and stable ranging from 0.1226 to 0.1351 indicating that the estimates are stable and measurement error is a problem. All confidence intervals of the indicators at 95% were completely above zero. This confirmed the strength of the relationship and eliminated random chances. For examples, ATT3 indicates that the estimate is between 1.026 and 1.538 with high confidence.

From the behavior's perspective, the results of a strong commercial loading and significant loading imply that smallholder dairy farmers generally have good attitude towards adopting food safety and hygiene practices. Farmers view these measures as vital to improve quality, gain consumer confidence and increase income by accessing better markets. The strength of this construct is consistent with theory, which asserts that more positive attitudes will elicit higher behavioral intentions and greater use of safety management measures. The attitude construct showed that evaluations of safety and hygiene practices made by smallholder dairy farmers are well-formed and inter-individual consistent. According to the TPB, attitudes play an important role in predicting behaviour.

4.4.3 Subjective norm (SN)

Farmers experience social pressure to either adopt or ignore food safety and hygiene practices, which is referred to as subjective norm. Social pressure keeps the farmers in mind with the expectations of the actors that matter to them. The social pressure is reflected in their market engagement. This concept will be measured using seven indicatorsSN1SN7 (see Table 4.13) in this model.

The standardized loadings for subjective norm for these smallholder farmers in Central Uganda were between 0.341 and 0.64 and significant at $p < 0.001$. The SN3 had the highest loading ($\beta = 0.64$, $z = 8.84$, $p < .001$), followed by SN4 ($\beta = 0.617$) and SN5 ($\beta = 0.535$). According to these items, there is a strong normative influence from the local cooperative society, agricultural officer and fellow farmers. The lower loadings (for example, SN1 = 0.341) seem to illustrate weaker social influences or statements about general versus specific social expectations. The measurement of subjective norm was confirmed to be valid and reliable as all indicators significantly contributed to the construct.

At 0.1573 to 0.2295, the standard errors of the subjective norm indicators were moderate to stable, and acceptable. None of the confidence intervals for these indicators contained zero, confirming their statistical significance. As an example, SN3 had a confidence interval of 1.461 to 2.293, indicating a strong stable link between the measures observed and the construct underlying.

The moderate level of loadings indicates that even though social influence affects smallholder dairy farmers in Central Uganda to adopt food safety practices, it does vary. These differences could arise from differences in community structure, peer relationships or the strength of extension and cooperative networks. Farmers who take part in strong cooperatives or producer groups are likely to face most normative pressure to comply with safety standards, while more isolated farmers largely rely on intrinsic drive instead of collective norms.

According to theory, the subjective norm in this study worked as expected within the Theory of Planned Behaviour, as it reflected perceived expectations by key referent groups and linked them to intentions to behave. As all indicators stressed out, the social environment and peer influence significantly impact smallholder dairy farmers' choices to implement safety and hygiene practices. Positive indicator loading shows that higher social approval or encouragement causes one to likely adopt the FSM.

4.4.4 Behavioural intention (BI)

The single index, referred to as BIindex, was used to operationalize the construct behavioural intention (BI), which was the performance or level of adoption of the specific food safety and hygiene control practices by farmers (Table 4.13). No other indicators were used to assess the measurement reliability since it is represented by a single observed variable with a fixed loading of one. Regardless, the BIindex as a formative or composite indicator functioned as an outcome variable that summarised the extent to which smallholder dairy farmers in Central Uganda adopted relevant safety and hygiene measures. Examples of these safety and hygiene measures are proper handling, storage, waste management, use of clean water and equipment.

If $\beta = 1$ for the fixed loading, it means that BIindex perfectly represents the latent construct by definition. This is because it is the only observed measure. In the SEM model context, this index was the dependent latent variable impacted by the farmers' behavioral constructs which included PBC, Attitude, and Subjective Norm. The assessment of the BIindex is simple, but its reliability depends on internal consistency of the items summed to form the BIindex. The index reliably reflected the outcome behavior that was the target of the study, based on its theoretical basis and the strength of the previous constructs.

By representing BI as a latent construct, psychological and social factors in the model were able to cause behavior. Understanding how farmers' perceptions and attitudes, along with social pressure, leads to tangible improvements in safety and hygiene compliance was instrumental. Using BI has made SEM easier to comprehend and provided a more concrete measure of performance according to behavior modeling.

4.4.5 Statistical robustness and model validity

In addition of the different constructs, the data also looked at the overall measurement quality validity reliability. All indicators of all constructs were significant, supporting convergence validity. The degree to which these multiple indicators have the same measurement and are correlated is a high level of assurance. Generally, when loading above 0.4 with significance, convergent validity is affirmed.

To test the overall validity and reliability of the constructs' measurement model, confirmatory factor analysis was performed. As demonstrated in Table 4.14, this encompassed internal consistency, convergent validity, and discriminant validity. The tests were done to show whether the constructs converge to mean one thing or not (Hair *et al.,* 2017).

The study questionnaire was tested for reliability at the overall level and at the level of each latent variable, SmartPLS 3.0 was used to test the reliability coefficients as shown in Table 4.14. The results showed that the total cronbach's alpha was 0.76 while latent variables showed Cronbach's alpha varying from 0.73 to 0.81, above the threshold of 0.7. The overall composite reliability (CR) was 0.81, while the composite reliability (CR) of latent variables ranged from 0.77 to 0.87 which was above 0.7. Hence, the constructs of the study questionnaire showed high reliability.

The study assessed the validity of the constructs through a thorough evaluation of content and structural validity. Content validity was determined to be good as the questionnaire was sent to subject experts and supervisor of the University for Comments which helped the researcher improve the questionnaire. They carried out a pretest of the questionnaire on 40 randomly selected smallholder dairy farmers in the Kampala District who responded to the questions in 25-40 minutes.

The KMO was used to assess the structural validity, where the overall KMO was 0.77 and the latent variable KMO was between 0.72 and 0.83 which is greater than 0.7. Moreover, the average variance extracted (AVE) range of 0.51 to 0.53 exceeded the threshold of 0.5. The results indicate that study constructs fulfilled the requirements for validity to be used for the study (Hair *et al.,* 2017).

Table 4.14: Results of reliability and validity tests

Constructs	Cronbach α	CR	KMO	AVE
PBC	0.81	0.87	0.83	0.53
ATT	0.75	0.78	0.72	0.52
SN	0.73	0.77	0.75	0.51

The discriminant validity of the constructs was assessed by the HTMT index of study. The values from the analysis of the reflective measure, as summarized in Table 4.15, ranged from 0.527 to 0.751, which is less than 0.85 (Henseler *et al.,* 2015). This confirms that the criteria for discriminant validity are met and the questionnaire passed the test of validity. The successful convergent and discriminant validity tests indicate that the data are valid and reliable for SmartPLS-SEM hypothesis testing.

Table 4.15: Discriminant validity test amongst constructs (Heterotrait-monotrait (HTMT) ratio of correlations)

Constructs	PBC	ATT	SN
PBC	1		
ATT	0.602	1	
SN	0.527	0.751	1

Note: PBC=Perceived behavioral control, ATT= Attitude SN=Subjective norm

Most estimates' confidence intervals are sufficiently narrow and standard errors small enough to indicate precise measurement and little sampling variation. Also, we see that the signs of the coefficients meet the expectation of the theory. Specifically, positively loaded items reflect positive perceptions or supportive attitudes. While, negatively loaded items show negative frames or barriers. The pattern suggests the coding was correct and the construct differentiated and identified appropriately.

The analysis shows that all the thresholds were met based on data for composite reliability (CR), average variance extracted (AVE), and discriminant validity statistics. Convergent validity was strong, as indicated by standardized loadings that showed the constructs explained most variance in the indicators. Furthermore, the cross-loadings showing no insignificant items further conferred discriminant validity. These items showed how the constructs might be related but show they are still distinct dimensions of the smallholder dairy farmers' behaviour.

The study's measurement model results confirmed that Theory of Planned Behaviour is a suitable and useful model to investigate the adoption of food safety and hygiene practices in Central Uganda smallholder dairy farmers. The three main constructs (attitude, subjective norm, perceived behavioral control) were well-defined, reliable and consistent with theory. The farmer behavior mentioned in their documents can be understand through this psychological approach as these constructs have strong significant and very strong association with respective indicators.

The study found out that farmers perceive positively on food safety and hygiene, and it is beneficial in terms of award. They think that social expectations probably play a normative role in what they adopt but a limited one. Most importantly, personal perceived power behaviours is important, as it stresses the practical skills and resources available to apply safety standards.

From a theoretical perspective, the structural pathways among validated constructs were evaluated using these constructs. According to Hair *et al.* (2017), once the measurement model is confirmed, the structural model is used to determine the direct and indirect effects of the behavioural factors towards the adoption performance of the farmers. The measurement model that has been tested is reliable. As a result, we can confidently interpret structural relationships that are based on accurately measured latent variables.

All the items were significant. This means the questionnaire used to measure the above constructs is psychometrically sound and can be used in future studies or for regional scale use Researchers acknowledged that this is an important step towards understanding the behavioral aspects that promote food safety adoption, especially in developing countries where we lack data on the behaviour of the consumer and food industry.

The outcomes of the measurement model yield a statistically sound and theoretically consistent framework that explains the behavioral factors of smallholder dairy farmers with respect to food safety and hygiene practices. All constructs prove to be statistically significance thus, prove that they are valid and reliable TPB. Remarkably high item loadings were observed for PBC as it plays a predominant role in enhancing farmers' ability and confidence to implement milk-safety measures. The ability to access resources, facilities and support determines the behaviour exhibited by the person or population.

The results shows that attitude construct show a moderate loading. It means the smallholder dairy farmers do believe that hygiene and safety of food matter a great deal for quality and income enhancement. In contrast, Subjective Norm demonstrated the largest variation in loadings amongst the different items showcasing the diversity of social expectation and peer influence of smallholder dairy farmers of Central Uganda. Healthy social behaviour does not signify uniform social pressure. Support and social pressure differ by context. Operationalizing normative pressure may involve analyzing material and social pressures.

The postulated construct of behavioural intention (BI), measured as a single index, performed effectively as a measure of the behavioural outcome, revealing how smallholder dairy farmers converted their positive attitudes, perceived control and social expectations into hygienic behaviour. The measurement accuracy across all constructs was found to be high.

This was established by low standard errors and short confidence intervals, confirming the presence of internal consistency and robustness of parameter estimates. In addition, the size and direction of the coefficients aligned with the theoretical predictions of the TPB, lending support to the model.

The measurement model is defined and empirically valid, thus providing an adequate basis for the next structural analysis. The connection between the constructs is supported with their statistical independence suggesting that in conceptual terms they can refer to a multi-dimensional representation of farmers' behaviour on food safety and hygiene practices. The loading of all observed variables to their respective latent variables indicates that the measurement system was reliable and valid.

The perceived behavioural control was the most influential and stable factor. This highlights the fact that smallholder dairy farmers need to be confident and have access to resources and situational skills for the enactment of behaviours. Food safety is highly valued personally and attitudes are always positive. During the same period, while subjective norms were significant, their level of significance varied depending on the case. The behavioral intention (BI) construct captures what these psychological elements mean for behavior.

4.4.6 Variances and covariances for measurement model

The variances and covariances in the model indicate how well the observed indicators emulate their latent variables and predict behavioral variables. This part explains the variance and covariance results from SmartPLS measurement model output (Table 4.16) focusing on internal consistency, convergent validity, and relations among the constructs. This interpretation examines the size and significance of estimates, offering empirical insights into the robustness of the TPB-based model in explaining smallholder dairy farmers' adoption of food safety and hygiene practices.

Table 4.16: Variances and covariances for attitude, subjective norm, perceived behavioural control, and behavioural intention

Variable 1	Variable 2	Estimate	SE	95% CI Lower	95% CI Upper	β (Standardized)	z	p
Perceived behavioural control (PBC)	PBC6	0.782	0.000	0.782	0.782	0.782	—	—
	PBC1	0.596	0.000	0.596	0.596	0.596	—	—
	PBC2	0.908	0.000	0.908	0.908	0.908	—	—
	PBC3	0.714	0.000	0.714	0.714	0.714	—	—
	PBC4	0.332	0.000	0.332	0.332	0.332	—	—
	PBC7	0.906	0.000	0.906	0.906	0.906	—	—
	PBC5	0.881	0.000	0.881	0.881	0.881	—	—
Attitude (ATT)	ATT6	0.818	0.000	0.818	0.818	0.818	—	—
	ATT7	0.793	0.000	0.793	0.793	0.793	—	—
	ATT3	0.701	0.000	0.701	0.701	0.701	—	—
	ATT2	0.671	0.000	0.671	0.671	0.671	—	—
	ATT1	0.748	0.000	0.748	0.748	0.748	—	—
	ATT4	0.762	0.000	0.762	0.762	0.762	—	—
	ATT5	0.637	0.000	0.637	0.637	0.637	—	—
	ATT8	0.675	0.000	0.675	0.675	0.675	—	—
Subjective norm (SN)	SN1	0.884	0.000	0.884	0.884	0.884	—	—
	SN2	0.854	0.000	0.854	0.854	0.854	—	—
	SN5	0.714	0.000	0.714	0.714	0.714	—	—
	SN7	0.857	0.000	0.857	0.857	0.857	—	—
	SN3	0.590	0.000	0.590	0.590	0.590	—	—
	SN4	0.619	0.000	0.619	0.619	0.619	—	—
	SN6	0.823	0.000	0.823	0.823	0.823	—	—

Behavioural intention (BI / FSM adoption)	BIindex	0.000	0.000	0.000	0.000	0.000	—	—
	BIindex	189.411	14.028	161.916	216.905	0.821	13.50	< 0.001
Latent covariances	Perceived ↔ Attitude	−0.0918	0.013	−0.118	−0.066	−0.461	−6.84	< .001
	Perceived ↔ Norm	−0.0538	0.010	−0.074	−0.034	−0.338	−5.19	<0.001
	Attitude ↔ Norm	0.1307	0.019	0.094	0.168	0.898	6.96	< 0.001
Construct variances	Perceived	0.2183	0.0357	0.148	0.288	1.000	6.12	< 0.001
	Attitude	0.1819	0.0314	0.120	0.243	1.000	5.80	< 0.001
	Norm	0.1164	0.0260	0.065	0.167	1.000	4.48	< 0.001

The measurement model converted the main concepts of the Theory of Planned Behaviour (TPB) into latent variables represented by several observed indicators. The hidden variables represent the diverse elements affecting farmers' food safety and sanitation behaviors. Perceived Behavioral Control (PBC) is measured by 7 indicators (PBC1-PBC7). These indicators define how easy or difficult are the implementation of safety and hygiene measures as perceived by the farmer. Further it also takes into account the access to and availability of facilities, resources and support. In terms of overall views and personal valuation as beneficial and worthwhile of smallholders' milk-safety practices, attitude is evaluated with eight indicators. At least seven items denoted subjective norms (SN1-SN7). All represent social pressure from peers, customers, extension officers and regulator to adhere to hygiene standards.

Behavioural Intention, (BI) was a concrete measure of actual safety and hygiene performance. It shows to what extent farmers adopt and implement food-safety control measures. As can be seen from the Table 4.16, the model provides the estimated variances (i.e. diagonal elements) and covariances (that is off-diagonal elements) among such estimates with their standard errors (SE), confidence intervals (CIs) and significance levels (p-values). All of these statistical measures proved that the constructs are different yet related enough to support the hypothesized relationships in this study, thus supporting the theoretical and measurement validity of the TPB model.

4.4.6.1 Variance in perceived behavioral control (PBC)

As shown in Table 4.16 the PBC construct has high Internal Consistency. The variances of its indicators are between 0.3317 (PBC4) and 0.9076 (PBC2). The results were high, above 0.70, that is, the latent construct explains most of the observed because measurement error variance. In particular, the variances of PBC2, PBC5, PBC6, and PBC7 are all greater than 0.88, thereby confirming their validity as a measure of control beliefs.

The modest variance (0.3317) of PBC4 suggests that this indicator contributes less to the construct, reflecting the fact that farmers may be able to access equipment and knowledge, or benefit from institutional support. The average variance extracted (AVE) for PBC was satisfactory and confirmed good convergent validity. The result shows that the construct reliably captures perceived differences in control among smallholder dairy farmers regarding food safety behaviours adoption.

4.4.6.2 Variance in attitude (ATT)

According to Table 4.16, the attitude indicators had values ranging from 0.6372 (ATT5) to 0.8181 (ATT6) indicating a high degree of internal consistency. Variation in scores did not differ in a meaningful way; in other words, smallholder dairy farmers' assessments of safety and hygiene practices whether positive or negative were found to be reliably measured. The bigger variance of ATT6 (0.8181) and ATT7 (0.7930) indicates it is primarily the underlying attitude that drives the attitudinal responses of the respondents and not an error. The finding shows smallholder dairy farmers' views about practices such as seeing hygiene as a plus for quality milk and entry into the market were consistent and measurable. The small differences across ATT indicators support their convergent validity as they all captured the same ATT without fail.

4.4.6.3 Variance in subjective norm (SN)

The variances of the indicators of subjective norm construct range between 0.5901 and 0.8836. Different levels of perceived influence on different smallholder dairy farmers in Central Uganda. The high values of SN1, SN2, and SN7(0.8568–0.8836) indicate that these items reliably capture perceived peer or community pressure regarding safety and hygiene standards compliance.

The lower SN3 (0.5901) and SN4 (0.6193) variances indicate these items captured less accurate measures of social pressure. This may be due to smallholder dairy farmers' inconsistencies in engagement with cooperative leaders and extension officers. Even with variations, the overall variance pattern still showed strong consistency. According to earlier TPB studies, social influences on behavioural control were often different within different social networks and production systems, which our results support (Ajzen, 2020; Hair et al., 2021).

4.4.6.4 Variance in behavioural intention constructs

The index of BI was fixed to exhibit 0 variance as a reference variable. While BI had a high estimate of variance (189.4105, SE = 14.0279, $p < 0.001$). The large difference implies that there are considerable disparities in the adoption of the farmers. So, the farmers are heterogeneous in the use of food safety and hygiene practices. This finding confirms that the measure is stable and reliable, as seen with the large z-value (13.50) and tight confidence interval (161.9163−216.9047). In short, the high variances in PBC, ATT, SN, and BI constructs indicate that their corresponding latent variables are significantly reflected in their observed indicators. All of the constructs had a good reliability which enabled us to run the model.

4.4.7 Covariance analysis among constructs

4.4.7.1 Covariance between perceived behavioral control and attitude

According to table 4.16, the (PBC) and ATT ($\beta = -0.0918$, SE = 0.0134, $z = -6.84$, $p < 0.001$) have a negative covariance. It shows that farmers who find it more difficult or face more constraints to use the safety and hygiene measures tend to have a less positive attitude towards them. When dairy farmers do not have equipment, time, or training to do food safety procedures, they will not view those procedures as favourable. This finding supports the TPB theory which states that even though attitude and perceived control are two separate constructs in the theory, high perceived barriers can mitigate the development of positive behavioral attitudes (Ajzen, 2020). The large z-score and small 95% CI (–0.1181 to –0.0655) indicate that this covariance is significant, showing that there is a systematic relationship across the sample.

4.4.7.2 Covariance between perceived behavioral control and subjective norm

A negative and significant association exists between PBC and SN ($\beta = -0.0538$, SE = 0.0104, $z = -5.19$, $p < 0.001$), showing that as farmers find the safety hazard measure hard to implement, they receive less social encouragement or normative pressure to implement the measure. Some smallholder dairy farmers perceive safety practices as burdensome so they may disengage from community norms or downplay the significance of social expectations from outside the community. The association was negative, which demonstrates the complicated interaction between control and social influence. Social norms may matter less when smallholder dairy farmers feel structurally or economically constrained and so do not perceive the value of compliance. The results underscore the necessity of fortified extension support systems and community-owned initiatives for addressing perceived constraints.

4.4.7.3 Covariance between attitude and subjective norm

As seen in Table 4.16, attitude and subjective norm are positively correlated as demonstrated by $\beta = 0.1307$, SE = 0.0188, $z = 6.96$, $p < 0.001$. This significant relationship confirms that favorable attitudes toward food safety are strongly connected to higher social support and normative expectations. In essence, smallholder dairy farmers who perceived greater encouragement from peers and institutions were more inclined to view adopting hygiene control practices positively.

This finding aligns with prior TPB-based studies where social approval acted as reinforcement for favorable attitudes (Fishbein & Ajzen, 2011; Henseler *et al.,* 2015). The relatively high standardized coefficient (0.898) and confidence interval (0.0939–0.1675) indicated a meaningful and consistent relationship. It reflected that the cultural and community-based nature of dairy production, where shared norms and cooperative behavior strongly influence attitudes toward safety compliance.

4.4.8 Model-fitness test

The goodness of fit indices for the measurement model was tested using SRMR, RMSEA, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Bentler-Bonett Normed Fit Index (NFI), Bollen's Relative Fit Index (RFI), and Goodness of Fit Index (GFI), and all the indices fulfilled the accepted values as indicated in Table 4.17. Therefore, all the indices met the criteria, indicating that the model had good fit (Schreiber *et al.,* 2006; Bagheri *et al.,* 2019).

Table 4.17: Model fit indices for SEM

Fit indices	Model Value	Accepted value
SRMR	0.012	RMR ≤ 0.05
RMSEA	0.081	< 0.10
Comparative Fit Index (CFI)	0.923	> 0.90
Tucker-Lewis Index (TLI)	0.931	> 0.90
Bentler-Bonett Normed Fit Index (NFI)	0.912	> 0.90
Bollen's Relative Fit Index (RFI)	0.943	> 0.90
Goodness of Fit Index (GFI)	0.949	≥ 0.90

4.4.9 Structural model (direct effect between farmers' behaviors and performance of safety- and hygiene-control practices)

This section shifts from validating measurement properties to analyzing the structural (causal) relationships among latent constructs in the proposed Theory of Planned Behavior (TPB) model. Specifically, the analysis was conducted to determine how perceived behavioral control (PBC), attitude (ATT), and subjective norm (SN) influence FSM adoption among dairy farmers. The estimated parameters (unstandardized coefficients, standard errors, confidence intervals, standardized path coefficients, z-statistics, and p-values) offered insights into the strength, direction, and significance of each hypothesized path.

Table 4.18 shows the results of the structural model, highlighting the influence of various factors on farmers' adoption of safety and hygiene practices. Firstly, PBC ($\beta = 0.121$, p=0.06) and ATT ($\beta = 0.883$, p=0.01) have a significant positive effect on adopting safety and hygiene practices, which supports H1 and H2 respectively. However, the relationship between subjective norms and the adoption of safety and hygiene practices was negative ($\beta = -0.533$, p=0.02), leading to the rejection of H3.

Table 4.18: Results of test on hypothesis of drivers of dairy farmers' behaviors relating to performance of safety- and hygiene-control practices

Path relationship/Hypothesis	Std. Beta (β)	SE	Z	p-values	Decision
PBC ⇒ FSM adoption	0.121	2.05	1.92	0 .06*	Supported
ATT ⇒ FSM adoption	0.883	8.62	3.65	0.01***	Supported
SN ⇒ FSM adoption	-0.533	9.91	-2.39	0.02**	Not Supported

***p<0.01, **p<0.05, *p<0.10

The second specific objective of this study was to assess the impact of cognitive behavior based on the Theory of Planned Behavior constructs (perceived behavioral control, attitude, and subjective norms) on the adoption of safety and hygiene practices among smallholder dairy farmers in Central Uganda. The influence of each dimension on adopting safety and hygiene practices was represented by hypotheses H1, H2, and H3, respectively. The statistical results show a direct, significant relationship—both positive and negative—between each TPB construct and the adoption of safety and hygiene practices.

4.4.9.1 The effect of perceived behavioral control on adopting safety- and hygiene-control practices (H_1)

Perceived behavioral control significantly influences the adoption of safety and hygiene practices. The positive and significant relationship between PBC and the adoption of FSM practices indicates that farmers are more likely to adopt these practices if they believe they have the necessary skills and ability to do so. PBC plays a crucial role in affecting smallholder dairy farmers' adoption of safety and hygiene practices, and the more control they perceive over their actions, the more likely they are to engage in farm-level food safety practices due to increased motivation and confidence (Yin *et al*., 2022). Nevertheless, when smallholder dairy farmers do not possess the required knowledge, skills, and resources, their PBC may reduce. These findings align with those of Hossain *et al*. (2021) and Tama *et al.* (2021), who found that PBC positively affects smallholder farmers' adoption of agricultural practices.

4.4.9.2 The effect of attitude on adopting safety- and hygiene-control practices (H_2)

Among the cognitive factors measured in this study, attitude stands out as the most influential aspect affecting smallholder farmers' adoption of safety- and hygiene-control practices (highest β coefficient of 0.883). The positive relationship between attitude and FSMs indicates that farmers with a positive perception of FSMs are more likely to adopt them. This finding aligns with Rezaei *et al.* (2018), who found that farmers with a positive attitude toward on-farm food-safety practices increased their capacity to adopt these practices. Therefore, to boost the adoption of FSMs at the farm level in the Ugandan dairy sector, smallholder dairy farmers need to have a positive attitude toward food-safety practices. In other words, farmers must believe that adopting these practices will improve their farms' performance in terms of the quality and safety standards of their dairy products and, ultimately, their profits.

4.4.9.3 The effect of subjective norms on adopting safety and hygiene control practices (H_3)

Subjective norms have a significant negative impact on the adoption of safety and hygiene practices. This suggests that social pressure from important people in respondents' lives does not motivate them to adopt FSMs at the farm. In fact, increased social pressure actually decreases FSM adoption. This finding contradicts Ulhaq *et al.* (2020), who stated that subjective norm is a strong predictor of the intention to adopt farming practices. It also contradicts Gowda *et al.* (2021), who found that family members, friends, relatives, progressive farmers, and agricultural experts significantly influence farmers' willingness to use pesticides.

According to Hofstede (2011), a collective culture features strong, lasting relationships among its members and a shared responsibility for others' welfare, which creates social pressure on decision-makers. The impact of SN is not significant among Ugandan farmers because most of them have an individualist culture, leading them to work independently and making collectivism or group behavior less relevant in adopting SHCP at the farm level. The finding shows that as smallholder dairy farmers become more commercially driven, they stop relying on external friends and family for influence in decision-making; instead, they turn inward to their personal perceptions of the behavior and their perceived ability to implement it.

4.5 Drivers of compliance with food safety measures among smallholder dairy farmers in Central Uganda

4.5.1 Multicollinearity tests

The Variance Inflation Factor (VIF) test was employed to assess multicollinearity among the explanatory variables in the ordered probit model. The results in Table 4.19 show that the mean VIF value was 1.85, well below the typical cutoff of 5, indicating no significant multicollinearity issues. Although "herd size" (VIF = 8.43) and "cows milked" (VIF = 7.22) had higher VIF values than other variables, they remained below the critical threshold of 10, suggesting only moderate correlation that does not severely distort parameter estimates. All other variables had VIF values between 1.06 and 1.93, reflecting low correlation among them.

Table 4.19: Variance Inflation Factor (VIF) results for explanatory variables used in the ordered probit model

Variable	VIF	1/VIF
Herd size	8.43	0.1187
Cows milked	7.22	0.1385
Land size	1.93	0.5169
Farming experience	1.53	0.6541
Training	1.38	0.7240

Credit access	1.35	0.7395
Extension access	1.33	0.7497
Cost of compliance to food safety	1.31	0.7632
Age	1.30	0.7674
Standard operating procedures (SOPs)	1.29	0.7731
Information access on FSMs	1.27	0.7888
Family size	1.24	0.8037
Level of education	1.24	0.8063
Compliance perception	1.24	0.8066
Type of livestock breed	1.23	0.8115
Distance to nearest market	1.21	0.8278
Group membership	1.20	0.8358
HACCP awareness	1.19	0.8384
Government role in FSMs	1.18	0.8464
Milk contamination	1.18	0.8465
Familiar FSMs	1.15	0.8713
FSMs inspection	1.13	0.8833
Gender	1.06	0.9444
Mean VIF	1.85	

4.5.2 Determinants of compliance with FSMs

Table 4.20 shows the results of the ordered probit model estimates on the factors influencing compliance with food safety among smallholder dairy farmers. The chi-squared statistic for the ordered probit models is statistically significant (Wald chi^2 (17) = 93.44, P = 0.0000), indicating that the joint test of all slope coefficients being zero is rejected, which suggests the model fits well. As mentioned earlier, the ordered probit model presented in Table 4.20 could not be clearly interpreted. Therefore, the marginal effects for each category of adopters were re-estimated (Table 4.20).

The coefficients had clear interpretations based on the likelihood of falling into a specific adoption category. A positive coefficient in a particular category indicates that it increases the probability of being in that category, while a negative one implies it reduces this probability. Since the study was mainly focused on significant variables that lead to a higher-adoption class, the analysis concentrated on interpreting the results from the high-adoption category.

The findings suggest that increasing education level of smallholder dairy farmers lead to a decline in the likelihood of being in low or medium FSMs by 1.93% and 2.89% respectively, if the education level increases high FSMs adoption likelihood increase by 4.82%. The education level of the household head crucially determines their awareness, knowledge and skill about the FSM. As smallholder dairy farmers get more education, they will become more aware of the benefits of adopting food safety and are more likely to be a high adopter. This finding is similar with Kumar *et al.* (2011), which identified that the education level of the household head significantly and positively affected the adoption of the various food-safety practices.

On the contrary, we find that each additional year of experience in dairy-farming reduces the probability of being in the high-adoption group by about 0.52% On the contrary, the likelihood of entering both the low and the middle adopter categories increases by nearly 0.21% and 0.31% respectively. There is a negative link between dairy farming experience and FSM adoption. This means that dairy farmers with more farming experience are less likely to adopt FSMs than those with less experience. It may happen that experienced farmers are confident in their management strategies and prefer to continue with the known practice instead of trying new FSMs. This is in line with Kumar *et al.* (2020), who found that the experience of dairy farmers negatively influenced the adoption of FSM in India.

Likewise, the increase in size of the land decreases the probability of being higher adopters of FSMs by about 2.7% while increases the probability of being low and middle adopters by 1.08% and 1.62% respectively. As the farm size of a farmer increases, he diversifies his production and takes up other activities like crop production. Smallholder farmers with more land might spend less time and labor on cow husbandry. This limits their inclination and ability to adopt FSMs due to enterprise specialization not being available, affecting their refusal to use FSMs. This finding suggests the opposite of Kumar *et al.* (2017), and Ma *et al*. (2018), which observed a positive effect of farm size on the adoption of milk-safety measures.

The improved or exotic breeding type of livestock was found to have a positive and significant association (at 1% level) with low and high adoption of FSM. But it negatively associates with the middle adoption of ESR but not significant association. It coded as a dummy type variable 1= improved or exotic; 0=indigenous. This suggests that owning improved/exotic cow breeds increases the likelihood of adopting FSMs. The results show that the marginal effect of the livestock breed type for high adopters is 0.1439, indicating that ownership of improved/exotic breeds raises FSM adoption by 14.39%. A plausible explanation is that improved/exotic breeds tend to have higher milk-yielding potential than indigenous breeds, partly due to their longer lactation periods. However, these breeds are less resistant to diseases. Therefore, farmers owning these livestock breeds are likely to adopt FSMs to maximize the productivity of their dairy cows (Nyokabi *et al.,* 2024).

Table 4.20: Results of ordered probit model and its marginal effects

	Ordered probit		Marginal effects					
			Low adopters		Medium adopters		High adopters	
Variables	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.
Age	0.0030	0.0059	-0.0003	0.0006	-0.0004	0.0008	0.0007	0.0014
Gender	-0.1890	0.1669	0.0172	0.0148	0.0275	0.0251	-0.0447	0.0398
Level of education	0.2056***	0.0592	-0.0193***	0.0057	-0.0289***	0.0088	0.0482***	0.0139
Farming experience	-0.0221***	0.0075	0.0021***	0.0007	0.0031***	0.0011	-0.0052***	0.0018
Family size	-0.0018	0.0277	0.0002	0.0026	0.0003	0.0039	-0.0004	0.0065
Information access on FSMs	-0.2744	0.1955	0.0273	0.0206	0.0358	0.0237	-0.0631	0.0439
Land size	-0.1152***	0.0350	0.0108***	0.0034	0.0162***	0.0052	-0.0270***	0.0082
Type of livestock breed	0.6414***	0.1798	0.0675***	0.0215	-0.0764***	0.0190	0.1439***	0.0381
Herd size	-0.0284**	0.0137	0.0027**	0.0013	0.0040**	0.0020	-0.0067**	0.0032

Cows milked	0.0969**	0.0423	-0.0091**	0.0040	-0.0136**	0.0061	0.0227**	0.0099
Distance to nearest market	0.0128	0.0097	-0.0012	0.0009	-0.0018	0.0014	0.0030	0.0023
Credit access	0.0190	0.1785	-0.0018	0.0167	-0.0027	0.0252	0.0045	0.0419
Training	-0.0136	0.1839	0.0013	0.0173	0.0019	0.0258	-0.0032	0.0431
Group membership	-0.2402	0.2209	0.0240	0.0236	0.0311	0.0261	-0.0551	0.0494
Familiar FSMs	0.2806*	0.1693	-0.0274	0.0173	-0.0375*	0.0216	0.0649*	0.0386
FSMs inspection	0.3375	0.2430	-0.0291	0.0193	-0.0518	0.0404	0.0809	0.0593
Cost of compliance to food safety	-1.0797***	0.1790	0.0941***	0.0159	0.1605***	0.0299	-0.2546***	0.0414
Compliance perception	0.1670***	0.0508	-0.0157***	0.0049	-0.0235***	0.0075	0.0392***	0.0119
Extension access	0.1899	0.1749	-0.0176	0.0160	-0.0271	0.0255	0.0447	0.0413
HACCP awareness	0.7683***	0.2259	-0.0597***	0.0149	-0.1271***	0.0422	0.1867***	0.0555
Standard operating procedures (SOPs)	0.7326***	0.1950	-0.0798***	0.0248	-0.0820***	0.0182	0.1618***	0.0398

Milk contamination	0.8259***	0.1686	-0.0866***	0.0203	-0.0984***	0.0193	0.1850***	0.0356
Government role in FSMs	0.4596**	0.2274	-0.0003**	0.0006	-0.0726*	0.0396	0.1109**	0.0559

***p<0.01, **p<0.05, *p<0.10

Slightly different from the breed type, herd size showed a positive and significant effect on low and middle adoption of FSMs at a 5% significance level, while it had a negative effect on high adoption, also at a 5% significance level. The marginal effects indicate that an increase in herd size reduces the likelihood of high FSM adoption by 0.67%. This suggests that as herd size increases, smallholder dairy farmers tend to adopt FSMs less. Farmers with smaller herds are more likely to ensure proper milk hygiene, storage hygiene, general hygiene practices, and animal health management on their farms than those with larger herds.

A large herd size directly impacts their production management, and due to the cost of adhering to FSMs, smallholder dairy farmers with larger herds are less likely to strictly adopt FSMs than those with smaller herds. The current finding is in contrast to Kumar *et al*. (2017), who found that having an addition of an animal in the farm is associated with a 0.88 percent increase in the adoption of food safety practices.

As the number of cows milked increased, the probability of being in the higher-adopter class increased by 2.27%. Larger herds produce larger quantities of milk. This raises the necessity of food safety measures, namely increased storage, milk storage hygiene and animal health measures. This finding is consistent with Nyokabi *et al.* (2024), which reported that an increase in lactating cattle number encourage greater adoption of hygienic milk storage FSM.

Variable familiarity with FSMs (dummy variable, 1=yes; 0=no) was positive, significant at the 1% level for high adopters' group, and negative for middle adopters. More knowledge of food safety among smallholder dairy farmers leads to a greater probability of adoption of food safety practices. If farmers know more about the FSMs, then becoming a higher adopter has a higher probability by 6.49% according to the marginal effect. This means that frequent awareness about the benefits of FSMs could lead to their adoption by smallholder dairy farmers. A study by Aysha *et al.* (2024) shows farmers who knew and recognized FSMs adopted these measures on their farms.

At 1% significance, compliance costs (a binary measure where a value of 1 indicates a cost exists in FSMs compliance whereas a value of 0 indicates the opposite) decreased the chance of being in the higher FSM-adopter category by 25.46%. In short, an increase in compliance cost discourages the uptake of FSMs. The finding is in line with Yang *et al.*'s (2019) finding that average compliance cost which is higher contribute to lower adoption of milk-safety measures.

The FSMs higher-adopter category experienced a strong positive and significant awareness impact from Hazard Analysis and Critical Control Points (HACCP). This means that compared to smallholder farmers who are unaware of HACCP principles on dairy production, smallholder farmers who were aware of HACCP were likely to be in the category of high adopters. The execution of increased HACCP awareness raises the probability of being a higher adopter by 18.67%. HACCP is an essential part of food safety management that enables smallholder dairy farmers to identify and control physical, chemical and biological hazards along the dairy value chain. The results of this study are similar to the results of Yang *et al.* (2019). These authors found that respondents that were familiar with the HACCP system had higher knowledge of and adoption of FSMs compared to those not familiar with HACCP.

Like HACCP awareness, having a significant and positive coefficient of compliance perception and having standard operating procedures were found at 1% for FSMs' higher-adopter class. This means that if the smallholder farmers have a positive perception of food safety measures and possess conforming operating procedures to manage their dairy enterprises, the chances that they will adopt FSM increases. Smallholder dairy farmers make the decision of whether to use FSMs for their produce. If a smallholder dairy farmer believes that producing safe, quality products is the right thing to do, they comply with standard practices associated with food-safety measures. In addition, if a smallholder farmer possesses efficient SOPs, they will be more likely to adhere to them and consistently produce quality milk that is market-compliant (Nikola *et al*., 2024). Canales *et al*. (2022) and Yeboah *et al.* (2023), had similar findings with respect to the positive perception of food safety among handlers being associated with the increased adoption of food-safety practices.

Having a good perception of the FSMs and FSM standard-operating procedures (SOPs), and an increase in milk contamination at farm positively influenced the chances of being a higher adopter for smallholder dairy farmers. Lack of infrastructure such as inappropriate storage facilities, lack of separate milking area, dirty milking areas and utensils, not cleaning udder/teats before milking are causes of milk contamination due to low adoption of milking hygiene measures. If they get contamination in the milk, they cannot sell the milk (also loss) so to sell their milk, they will use those practices that reduce contamination or improve safety of milk. Higher milk contamination increases the chance of being a higher adopter by the marginal effects, which stands at 18.5% at 1% level of statistical significance. According to the findings, Nyokabi *et al*. (2024), also established that unhygienic handling practices increased the likelihood of contaminated milk on dairy farms.

The government helped smallholder dairy farmers use FSMs, so their adoption rates improved. The government is crucial in developing the conditions for smallholder farmers and building capacities. Also, through legislation on food safety and standards, it enables smallholder dairy farmers to adopt FSMs on the farms. The government's role in FSMs influenced the probability of being in the high-adopter group by 11.09%. According to Karabasil *et al*. (2017), governments, producers and consumers need to work together to manage food safety in order to achieve the most effective result.

Zhang *et al.* (2021), in China showed a negative association between food-safety performance and government intervention which does not agree with the findings of this study. The government's orientation is different from one country to another, depending on the dominant political ideology and economic system in place. This means that with a developing country like Uganda, the government needs to have policies and an enabling environment to allow smallholder dairy farmers to adopt FSMs. In other words, it gave authority to the government to help smallholder farmers comply with food safety requirements through training, inspection, and enforcement. Moreover, it also helps to minimize the rent-seeking behaviour related to FSM compliance.

4.6 Effect of food-safety measures on profitability of smallholder dairy farms in Central Uganda

4.6.1 Gross margin analysis

The table 4.21 shows the results. The average amount of milk produced in a house was 2994.37litres of milk produced. The high standard deviation was 2661.13 litres indicated that a great number of the farmers produced more or less this value. Differences in herd size, breed selection, feeding system & management practices is source of this variation. Some farmers raise improved breeds such as Friesians and Ayrshires for higher milk yield while indigenous breeds are also popular. This corroborates findings from Uganda which identified that smallholder milk yields were erratic and varied as a result of genetic, nutritional, and management factors. (Seruma *et al.,* 2025; Mugisha *et al.,* 2022). Inaccessibility of extension services, veterinary, and input combination can result in unequal access to milk production and profitability (Onishi *et al.,* 2025).

Table 4.21: Gross margin analysis of dairy enterprises in Central Uganda

Variable	Mean	Standard deviation
Total milk (litres) produced	2994.37	2661.13
Total milk (litres) consumed	485.51	329.58
Milk sold (litres)	2508.86	2494.312
Total variable cost (UGX)	4,983,177	4323127
Milk revenue (UGX)	4,310,367	4904804
Gross margin (UGX)	2,709,368	7234259
Gross margin per cow (UGX)	975,078.30	2770084

According to the data, farmers consume 485.51 liters of milk a year for household purposes with a standard deviation of 329.58 liters. The data shows almost 16% of entire milk production comes from sheep and underscoring sheep rearing's dual commercial and nutritional role. Milk is an important source of dietary protein, calcium and micronutrients, especially for children and members of at-risk households. In the smallholder dairy systems of East Africa, households experience similar consumption patterns for nutrition and income as they juggle food security and market participation (Kanyima *et al.,* 2023). The fact that the amount of milk people consume varies significantly is due to their different household size, income and access to other food items.

The average, with a standard deviation, of the amount of milk sold after meeting the household consumption needs is 2,508.86 liters, 2,494.31 liters, respectively. This shows that 84 percent of total milk production is marketed indicating the commercial nature of the dairy farms of the study area. The wide variance however suggests marked differences in market participation whereby some farmers have set up established supply channels through cooperatives or processors while others sell intermittently to local traders or neighbors. If you want to market your product, you need to choose a good location that is closer to collection centre and have facilities for transport and cooling. Supports of the research conducted in East Africa proximity to an urban market and participation in a dairy cooperative has a significant role in commercialization and profitability of smallholder (Kariuki *et al.,* 2022; Majalija *et al.,* 2020). Thus, cold chain infrastructure and market linkages needs to be strengthened for quality milk marketing.

According to the estimates, the average total variable cost (TVC) was UGX 4,983,177 with a deviation of 4,323,127 of the respondents, indicating huge variability in the cost of production. Key expense components are feed, veterinary drugs, breeding services, labour and transport. Usually, feed costs are often over 60% of total costs and this is generally the largest (Onishi *et al.* 2015). Some farmers rely on natural grazing and crop residues while others heavily invest in buying concentrates and improved feeding charges, this indicates high variability in practices. The differences highlight the intensive farming system and the extensive farming system. In addition, smallholder profit margins are under pressure following an increase in input price, especially commercial feed. This is consistent with the findings of Seruma *et al.* (2025) and that of Nambi *et al.* (2024), who found feed and veterinary input costs are key barrier to Ugandan dairy. Pursuing strategies to minimize the volatility of input prices and encourage the utilization of locally available feed resources can improve cost efficiency.

The average revenue from milk was UGX 4,310,367 and a high standard deviation of UGX 4,904,804 revealed that there was significant income disparity among the farmers. For some, the sale of milk incurs profits above variable costs. Other farm groupings are unable to meet this cost. There are changes in prices of milk due to seasons and regions. Commodity prices rise in the dry season due to scarcity. In the rainy season, prices fall as a result of oversupply. The dairy sector of Uganda is made up of informal milk markets which limit price stability and bargaining power of smallholders (Majalija *et al*., 2020). Many farmers who sell to informal channels do not get paid on time and receive lower prices than those who sell to formal processors. Cooperative marketing and farmer participation in formal supply chains should be strengthened in order to stabilize income and improve profitability.

The total revenue minus the total variable costs gives gross margin. The mean or average gross margin was UGX 2,709,368 although the standard deviation was very high at UGX 7,234,259. The average is positive which means dairy farming is profitable in general. However, the large variation means that it varies from farmer to farmer. While some obtain high profits due to better herd management, economy of scale and assured market access, some incur high losses due to inefficiencies, and high cost.

The average gross margin per cow on an enterprise scale was UGX 975,078.30 (SD = 2,770,084). This picture shows how individual animals in a farm are efficient & profitable. The efficiency and profit vary with breed quality, feeding, and health management. The big variation suggests that while some cows, especially improved crossbreds, yield significant returns, others, likely indigenous breeds or underfed cows, yield meager profit. According to Mugisha *et al.* (2022) and Ouma *et al.* (2024), genetic improvement and optimal nutrition play a pivotal role in enhancing per-cow productivity and profitability of the herd. When you enhance breeding services, feed formulation, and veterinary services, you can significantly increase gross margins at both the cow level and the herd level.

4.6.2 Gross margin by adoption level of food-safety measures

Table 4.22 gives results on gross margin and gross margin per cow based on the level of the adoption of FSMs by smallholder dairy farmers in Uganda. The adoption can be classified into three types; low (< 50%), moderate (50-70%) and high (> 70%) Farmers who did not adopt FSM had an average gross margin of -4,333,500 UGX. The mean gross margin per cow was -2,766,125 UGX. On average, these farmers lose money and do not cover their variable production costs from their sales of milk. Low adopters easily fall back on old crop varieties, poor feeding strategies, and other animal health strategies, which limit productivity and profit.

Farmers in moderate adoption of the same practices had a gross margin of 2,876,880 UGX and a gross margin per cow of 884,724 UGX. The farmers who adopt some of the expensive best practices even if they do not adopt the best practices entirely increase their profit by about UGX 8,000 per farm per year. The study implies that according to the technological adoption model, only partial adoption gives moderate benefits as farmers look at their risk and resource allocation. Moreover, a rise in gross margin could reflect learning impacts. Extension services are helping other, more moderate adopters develop their management skills and technical knowledge.

Farmers who made full use of farmer soil management practices (FSMs) generate an annual mean gross margin of 3,197,345 UGX (3,197.34 USD). The mean gross margin per cow was 1,397,328 UGX (1,397.33 USD) annually. The level of adoption of FSM by farmers considerably correlates with their profitability. Farmers who have adopted technology on a large scale enjoy higher profits than moderate adopters. The average gross margin per cow for highly adopting cow farmers is greater than 60 percent than moderate adopters. Enhanced profitability indicates economies of scale. With increased adoption level, more efficient use of resources can also be expected.

Table 4.22: Mean gross margin and profitability trend by level of adoption

Adoption level	Mean GM (UGX)	Mean GM per cow (UGX)
Low	–4,333,500	–2,766,125
Moderate	2,876,880	884,724
High	3,197,345	1,397,328

4.6.3 Model specification test

Before estimating the average treatment effect (ATE) of adopting food-safety measures on dairy farm profitability, several specification tests were performed, including the Brant test.

Additionally, the model's goodness-of-fit test in Table 4.23 shows that the ordered logit model significantly explains the impact of adopting FSMs on profitability and the included explanatory variables (Wald Chi2(14) = 0.000). The parallel lines assumption of the ordered logit model was tested using the Brant test. The results indicate that all explanatory variables meet this assumption (Table 4.23). Since the Brant test confirms the parallel lines assumption, the ordered probit model is appropriate for analyzing smallholder dairy farmers' adoption of food-safety measures.

Table 4.23: Test of the parallel regression assumption for the ordered logit model of food-safety measure adoption among dairy farmers

Variables	Chi^2	$p>Chi^2$	Degree of freedom
All	33.52	0.862	14
Age	0.49	0.486	1
Sex of household head	4.73	0.335	1
Education	11.92	0.234	1
Family size	0.24	0.624	1
Total milk produced	5.92	0215	1
Farming experience	3.16	0.715	1
Dairy training	0.06	0.804	1
Total lactating cows	2.09	0.148	1
Milk price	1.22	0.270	1
Distance to nearest market	10.66	0.651	1
Credit access	6.03	0.114	1
Cooperative membership	2.66	0.103	1
Extension service access	0.02	0.888	1
Access to milk safety information	0.05	0.817	1

Note: A significant test statistic provides evidence that the parallel regression assumption has been violated.

4.6.4 Effects of food safety measures on the profitability of dairy farms - first stage of ordered logit ESR

According to Table 4.24, the education level of smallholder dairy farmers has a significant positive effect on farm profitability. Better educated farmers know more and tend to implement more food safety which leads to better quality milk production. When you do these things, it reduces health risks connected to unclean milk and improves overall quality. From the above milk processed is growing so as modest buyers more attractive and more market opportunities and more high pricing. Also, educated farmers can respond better to the market as they are aware of the happenings related to this. Hence, they can take advantage of the growing demand for safe and quality dairy products. As a result, it can further help them in increasing their profits. The results agree with Korale-Gedara *et al*. (2023), and Kumar *et al.* (2020), who reported that farmers having higher education and supplementary training generate safer milk, sell it more efficiently, and earn higher profits.

The farming experience of smallholder dairy farmers has been related to less profitability on their dairy farms. Older farmers with experience are likely to stick to old-fashioned methods of milking. Thus, experience, or age, was found harmful. Sadly, these old enough practices might not match contemporary FSMs, which improve the quality and quantity of milk. Given the years of successful use, seasoned farmers' resistance to adopting new FSMs may stem from a reluctance to try something new that is different from what they already use.

But their reluctance to innovate and adopt new techniques hinders dairy farmers' capacity to improve milk quality, which in turn curtails their ability to charge higher prices. The study is in line with Molla (2024), who established that those with more experience in dairy farming may hesitate in adopting FMSs, affecting profits negatively. In contrast, Adigun *et al.* (2023), assert that a higher farm experience of farmers results in the growing proclivity to adopt FSMs and higher profit.

As per the findings, milk price shows a strong positive significant association with profitability. Farmers that can get better prices for their milk are more likely to adopt food safety measures (FSMs) and get higher profits. By improving the safety and quality of the milk, they directly help to get a better price for it. The milk usually fetches better prices, especially for safety and quality conscious buyer like dairy cooperative, processors or urban consumers. As such, the use of FSM will gain farmers better market and more profit.

Availability of credit increases the profit of dairy farms. Farmers can invest in the upgraded facilities and practices necessary to implement FSMs with this, resulting in greater profits. For example, credit could finance new milking machines and better storage facilities for milk. It could also be used for better animal health care, which helps improve the quality of milk. Through credit, farmers can expand the size of their operations, increase the volume of output and lower the risks of finances associated with the new method. This higher capacity also increases milk quality while enhancing overall productivity and profits.

The gainful use of extension service was also strongly associated with gains in profit of milking enterprises. Thus, technical support is crucial in persuading the farmers to adopt FSMs which have an increase profit. Farmers can gain valuable knowledge and expertise from these services in order to adopt food-safety practices that enhance profits. Also, it is training on dairy farm management practices.

Table 4.24: Ordered logistic regression results on the effects of food safety measures on the profitability of the smallholder dairy farmers' enterprises

Variables	Coefficient	Std. errs.	P>z
Age	-0.041	0.161	0.798
Sex of household head	0.003	0.005	0.633
Education	0.199	0.058	0.001***
Family size	0.010	0.026	0.697
Total milk produced	0.000	0.000	0.097*
Farming experience	-0.021	0.008	0.006***
Dairy training	0.030	0.171	0.860
Total lactating cows	-0.022	0.019	0.258
Milk price	0.001	0.000	0.000***
Distance to nearest market	0.008	0.006	0.217
Credit borrowed	0.286	0.159	0.073*
Cooperative membership	0.097	0.217	0.657
Number of extension visits	0.561	0.156	0.000***
Access to milk-safety information	-0.117	0.187	0.532

Note: Std. errs = Standard Errors

4.6.5 Second stage analysis of average treatment effects of adoption of food safety measures on profitability

Table 4.25 displays estimate for the Average Treatment Effects (ATE) of profitability for smallholder dairy farmers adopting various measures of food safety (FSM). The levels can be low, medium, or high based on the profitability outcomes measured, respectively, through the ATE, ATT, and ATU for each category of adoption.

Table 4.25: Average treatment effects on effects of food safety measures on profitability

	Adoption Category	ATE

Outcome	Sample	Treatment	Medium		Low			
			Mean	Std. error	Mean	Std error	Mean	Std. error
Profitability	Medium	ATT	1620.345	93.335	1405.378	177.4854	214.967**	77.6207
	Low	ATU	958.937	145.668	-1197.939	338.0412	-219.002**	33.3549
			High		Low			
	High	ATT	2567.382	205.4515	2154.728	291.775	412.6619***	21.782
	Low	ATU	1311.186	284.243	1132.745	338.041	178.441***	338.053

The average profit per farmer of smallholder dairy farmers in the medium-adoption group was 1,620.35; 1,405.38 in the low-adoption group. The profit gap is 214.97 ($p < 0.05$) indicating that medium-adoption farmers earned significantly more than low-adoption farmers. Small-scale dairy farmers with low adoption levels would have made a profit (958.94) according to the ATU than the medium adoption group. This means if low adoption farmers were to adopt FSMs at a medium rate, they could have substantial profits, with -219.00 ($p < 0.01$).

In the high-adoption category, ATT average profitability equaled 2,567.38, meaning widespread adoption of FSMs significantly increases profitability. Farmers from the low-adoption group exhibited an average profitability of 2,154.73. If low adopters of FSMs adopt "at a high level", profitability of ATU would be 1,311.19. On the other hand, the profitability of the untreated group was lower at 1132.75, with a significant difference of 178.44 ($p<0.001$). Adopting high levels of FSM can increase profits by a lot.

Farmers who adopt farm-saved seeds quite widely get better quality milk, less spoilage which improves farms' hygiene condition and access to high-end market which pays higher for FSM compliant seeds. Farmers have less health problems with livestock as their animal health and hygiene management improves, resulting in increased productivity and reduced cost of disease treatment. On the other hand, the low adopters might not be able to obtain these benefits. This may lead to a low quality of milk. Further, there will also be a high chance of wastage. Also, there would be a little access to premium market. If farmers do not follow FSMs strictly, their milk will not meet the safety requirements which will restrict them from charging a higher price or selling to formal markets which have stricter quality standards.

Implementing food-safety measures raises the profitability of smallholder dairy farmers, the findings show. Farmers who adopt medium and high-level practices earn significantly higher profits than those at lower levels. The biggest improvement takes place when you go from a low to a high adoption of FSMs, an important implication for fully implementing FSMs for maximum economic benefit. The distinctions between ATT and ATU show that farmers who adopt FSMs, at higher levels, earn more profits, while farmers, either do not adopt or adopt at low levels, miss out on profits.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

In this chapter, the key findings of the study are summarized along with recommendations based on the findings. Further the chapter highlights the key areas for future research which are in alignment with the objectives and findings of the study.

5.1 Conclusions

i. The total uptake of on-farm milk-safety measures was 62.88%. Of these practices, milk storage had the highest adoption (73.5%) whereas animal health practices had the lowest adoption (53.3%), less than 10% of respondents adopted essential practices such as cleansing of hands and utensils before milking and pasteurization. Farmers generally adopted the HACCP principles in an informal manner. This indicates the need for formal training and capacity-building.

ii. Implementing food safety measures will ensure the quality of dairy products and the theory of planned behaviour. Smallholder dairy farmers' adoption of food-safety practices is influenced by perceived behavioural control, attitude, and social norm factors.

iii. There are numerous factors that determine the adoption of Food Safety Measures (FSMs). These common factors include education level, livestock breed, herd size, knowledge of FSMs, and knowledge of Hazard Analysis Critical Control Point (HACCP) and government support. Farming experience, large land area, and high compliance cost are, however, negative factors. Most farmers fall into middle- or high-adoption categories.

iv. By increasing milk quality and giving access to high-end markets, food-safety measures raise profit. Farmers with formal education and better FSMs earn higher profits and more experienced farmers are generally less adaptable to new practices. When farmers have access to credit and extension services, they adopt better agricultural practices and technologies; and they earn higher incomes. It's important to follow milk-safety practices to get better prices.

5.2 Recommendations

i. Enhance food safety training through continuous training and demonstration programs for smallholder dairy farmers to increase their knowledge and practice of milk hygiene, storage and HACCP standards.
ii. You can create incentive programs such as milk prices based on quality, certification and recognition awards to encourage compliance with food safety standards and entry into premium markets.
iii. Make credit, extension services, technical assistance and other inputs affordable and easily accessible to farmers. It encourages investment in development of farm assets, and sustainable safety practices.
iv. Improve policy and institutional support through collaboration between government, private sector and development partners. Creating an enabling environment with supportive government policies and legal frameworks will enhance the food safety law, and build capacity across sectors.

5.3 Areas for further studies

The main focus of the study was that which entailed the preferences of smallholder dairy farmers in adopting Food Safety Measures. This presents a methodological limitation. Stated-preference techniques rely on self-reporting by farmers about their intentions and views rather than their actual behaviour. Because of this, the replies may not accurately represent the decisions and trade-offs faced by farmers in the real world in implementing FSMs. Despite this, the measurement models showed excellent validity and reliability, indicating that the constructs effectively measured the farmers' attitude, subjective norm, perceived behaviour control and behaviour intention.

Future research should take revealed-preference approaches based on real-world choices like actual investments decisions or milk sales or even participation in certification programs for more objective insights into behavioral adoption. Evidence from the studies can be used for corroboration of stated-preference evidence of how farmers' intentions translate into actual adoption behaviour across socio-economic and policy environments. Moreover, Future research should also be directed towards other areas in order to develop evidence-based policies.

i. Taking help from digital tools – Explore the use of digital technologies like mobile applications, e-extension platforms and automation of monitoring to facilitate the adoption, monitoring and compliance of food safety measures in smallholder dairy systems.

ii. Carry out long-term impact studies on use of FSM to know its influence on farm profitability, productivity and milk quality over several production cycles, thus showing their sustainability.

iii. Gender and social inclusion: Assess how gender modifies the adoption of FSMs, with particular emphasis on women, their hindrances and contribution to food safety management on smallholder dairy farms.

iv. When looking at facility service modularization (FSMs), it is important to understand the cost and benefits of this project. Looking at cost and benefit analysis, cost factors, regulatory environment and market incentives, smallholders can participate more in an effective manner for a more profitable outcome.

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APPENDICES

APPENDIX I: Questionnaire for smallholder farmers

EGERTON UNIVERSITY

EFFECT OF ADOPTION OF FOOD SAFETY MEASURES (FSMS) ON PRODUCTIVITY AND PROFITS OF DAIRY FARMERS IN CENTRAL UGANDA

(This information is strictly confidential and is to be used for statistical and academic purposes only.)

Introduction

My name is Andrew Seruma, a student at Egerton University pursuing a PhD degree in Agribusiness Management. This survey is aimed at determining the effect of adoption of food safety measures (FSMs) on productivity and profits of dairy farmers in Central Uganda. This questionnaire is meant for academic purposes only and information obtained therein will be treated with utmost confidentiality. I take this opportunity to request for your time to run through this interview. Thank you.

Instructions: Tick [√] in the appropriate cell or give the answer in the space provided.

SECTION A: HOUSEHOLD IDENTIFICATION

	CODE	NAME
1. QUESTIONNAIRE NUMBER		☐ ☐
2. COUNTY		……………………………………………………………….
3. SUB-COUNTY		……………………………………………………………….
4. WARD		……………………………………………………………….
5. VILLAGE		……………………………………………………………….

6. NAME OF HOUSEHOLD HEAD ……………………………………………………….….
7. NAME OF INTERVIEWER ……………………………………………………….….
8. INTERVIEWER ID ……………………………………………………….….
9. DATE ……………………………………………………….….
10. STARTING TIME ……………………………………………………….….
11. FINISHING TIME ……………………………………………………….….

Section A: Demographic characteristics

A1: Provide the following details about the household head

Gender 1 = Male 2 = Female	Age (years)	Highest education level (years)	Three primary livelihood sources starting with the main source **(CODE B)**
[___]	[__ _]	[___]	First [___] Second [___] Third [___]

CODE A: Education Level

1=No formal education 2= Adult education 3= Primary education 4= Secondary education 5= College education 6= University education

CODE B: Livelihood

1 = Livestock keeping 2= Crop production 3= Permanent employment 4= Business 5= Temporary employment 6= Remittances

A2: Provide the following details about the household size

Number of adults that usually live in the household	**Number of children in household**	**Total household size**
Male...…Females……. Total=…………	Males……..Females…….	Total =……..

SECTION B: LIVESTOCK HUSBANDRY

B1. Experience in dairy farming …………………. years

B2. Type of breed kept by the smallholder farmer…………..

1= Pure 2 = Cross 3 = Local

B3. What is the land size under dairy production……………………….. acres?

B4. Milk production parameters in the agrienterprises

B5. Type of land tenure: …………

1=Owned with title deed 2=Owned without title deed 3= Rented 4=Owned by parents 5=Communal/ government/ cooperative

B6. Milk production parameters in the agrienterprises

Ownership		**Milk**							**Animal purchased**			**Animal sold**		
B6.1. Stock of livestock owned in the last 12 months?	**B6.2.** Type of livestock does this household currently own?	**B6.3.** How many cows were milked in the last	**B6.4.** How many months on average, were the co	**B6.5.** What was the average milk production per day per	**B6.6.** During this period, how much of the milk pro	**B6.7.** During this period, how many litres of liq	**B6.8.** Where did you sell most of the milk and processed dairy products?	**B6.9**How much did you sell per litre?	**B6.10**. Have you purchased any livestock in the past 12 mo	**B6.11**. How many livestock have you purchased alive in	**B6.12**. What was the total value of the livestock pur	**B6.13.** Have you sold any livestock in the	**B6.14.** How many livestock have you sold	**B6.15.** What was the total value of

		12 months?	ws milked for?	milked cow during this period?	duced was consumed by your household each day either in the form of liquid milk?	uid milk did you sell per day?			nths?	the past 12 months?	chased in the last 12 months?	past 12 months?	in the past 12 months?	sales?
1. Bulls=	1= Indigenous 2=Imp	Number	Months	Litres	Litres/day	Litres/day	1=Cooperative	UGX	1= Yes 0= No	Number	UGX	1= Yes 0= No	Number	UGX

2. Cows= 3. Steers= 4. Heifers = 5. Male calves= 6. Female calves=	roved/ Exotic						2=Middlemen 3=Retailers							
CODES														

B7. Variable costs incurred (Labour, feeds and water)

B7.1. a) Did you hire any labor to help you with the livestock in the past 12 months? 1) Yes ☐ ☐ **o skip to B7.2]**

b) What was the total cost of this labor for livestock in the past 12 months?

UGX.....................................

B7.2. a) Did you purchase any feed / fodder for your livestock in the past 12 months? 1) Yes ☐ ☐ **o skip to B7.3]**

b) How much has this household paid to feed the livestock in the past 12 months? **UGX**………………….

B7.3. a) Has this household ever paid to water in the livestock in the past 12 months? 1) Yes ☐ ☐ **o skip to B7.4]**

b) How much has this household paid to access the main water sources for the livestock in the past 12 months **UGX**……………………...

B7.4. a) Has this household ever paid for animal health services livestock in the past 12 months? 1) Yes 0) No **[If no skip to C1]**

b) How much has this household paid to animal health services for the livestock in the past 12 months **UGX**……………………...

Section C: Market access

C1. Are the buyers'/market participants concerned about food safety measures when purchasing milk?

☐ Yes ☐ No

C2. Have you ever received any complaints from your customers? ☐ Yes ☐ No

If Yes, which ones?

1.________________________

2.________________________

3.________________________

C2. What is the means of transport do you use to the output market?

i) Walking ii) Bicycle/motorbike iii) Vehicle iv) Other (specify)……

C4. What is the distance to the nearest shopping centre/market and how much do you spend if you travel by matatu?

i. Distance………………km
ii. Transportation cost Ugx……………….
iii. Walking time……………minutes

C5. What is the state of the road to the market?

1= Tarmac ☐ 2= Murrum ☐ 3= Other (specify)…………

Section D: Social Capital

D1. Are you a member of any group?

☐ Yes ☐ No

If '**Yes**', which type(s) of group?

1. Self Help group ☐ 2. Cooperative Society ☐ 3. Welfare g☐p

4. Farmer group ☐ 5. Other (Specify) ……………………………

D2. Has membership to this group influenced your decision to utilize milk safety practices?

1 Yes No

Explain……………………………………………………………………………………….

……………………………………………………………………………………………….

D3. a) Do you have trusted buyers that you sell milk to?

 Yes No

b) If yes, how many trusted buyers of milk do you have?......................

<u>Section E: Institutional Factors</u>

E1. Do you have access to credit? Yes No

E2. If yes, how much many have you borrowed to use in daity production………………**UGX**

E3. Where do you access credit?

1) Government 2) NGOs 3) Formal financial institution

4) Relative 5) others, specify_____________________

E4. Did you receive **extension services** related to dairy farming last year?

 Yes No

E5. How many times in the last one year and from which extension providers?

Number of times in a year…………. Extension agent **(CODE D)** …………………

E6. Has your farm been inspected by the officers of Uganda Dairy Board?

 Yes No

<u>CODE D Extension agents:</u>

1= Government extension workers [ ] 2= private extension workers [ ] 3=NGOs/ developmental agencies [ ] 4= Others (*specify*)………………………………………

E7. Have you ever received any training in dairy farming?

 Yes No

E8. If yes, did it influence your decision practice milk production?

 Yes No

Explain………………………………………………………………………………………

……………………………………………………………………………….

<u>Section F: Food-Safety Practices Adopted by Smallholder Dairy Farmers</u>

F1. Have you ever received any information in food safety measures in dairy farming?

 Yes No

F2. If yes, did it influence your decision to adopt food safety measures in milk production?

 Yes No

Explain………………………………………………………………………………

…………………………………………………………………………….

F3. Below are some statements on the four food safety measures adopted by dairy farmers. Kindly tick either Yes or No, with regards to which you are practicing. **Yes =Adopted** and **No=Not adopted**.

F3.1. FSMs under the Component of Milk Hygiene	**Yes**	**No**
6. Cattle is/are milked separately from the stall		
7. The floor of milking area is kept well drained daily		
8. Floor of milking area cleaned daily		
9. Hands are washed with only water before milking		
10. Hands are washed with water and soap before milking		
11. Hands are dried before milking		
12. Hands are sanitized before milking		
13. Utensils are dried before using for milking		
14. Utensils are cleaned before milking		
15. Utensils are sanitized before milking		
16. Utensils are immediately washed after milking		
17. Milk is withdrawn/thrown after use of medicine		
18. Udders/teats are cleaned before milking		
19. Udder/teats are dried before milking		
20. Udder/teats are sanitized before milking		
21. Milk is pasteurized and labeled		

F3.2. FSMs under the Component of Milk Storage	**Yes**	**No**
11. Milk from diseased animal is kept separately		
12. Milk from seriously diseased/infected animals is discarded		
13. Milk is stored separately from the animal shed		
14. Floor of milk storage area is dried regularly		
15. The milk storage area is swept regularly		
16. The milk storage area is washed regularly		

17. The milk storage area is kept free from the pest		
18. Milk containers used for bulking are without joint		
19. Milk containers used for bulking are washed regularly		
20. Powder/Baking soda is mixed before selling milk		

F.3.3. FSMs under the Component of Dairy Environment	**Yes**	**No**
12. Floor of stall feed area is kept well drained daily		
13. Floor of stall feed area is kept clean daily		
14. Dung is disposed immediately after excretion		
15. Urine is drained immediately after excretion		
16. Chemicals are used as per instruction		
17. Workers wear suitable clean clothes		
18. Nails are trimmed regularly		
19. Cuts/Wounds are covered with an appropriate waterproof dressing		
20. Dairy farm is inspected regularly to ensure safety of overall farm		
21. Sprays environment with insecticides occasionally		
22. Fumigates environment every three months		

F.3.4. FSMs under the Component of Animal Health	**Yes**	**No**
22. There are no feces in the animal body		
23. Diseased animals are kept separately		
24. Animals are washed regularly		
25. Animals drink clean water (source is piped public water supply and rainwater)		
26. Dry cow therapy is practiced to prevent mastitis		

F4. Which type of support would you need with regards to on-farm safety and hygiene control practices? (tick the ones that apply)

1. Cooling facilities
2. Milking containers
3. Hand washing facilities
4. Hand cleaning and disinfection material
5. Floor cleaning and disinfection material

6. Feed inspection
7. Storage facilities
8. Improved feeds
9. Udder cleaning and disinfection material
10. Veterinary service
11. Disease treatment
12. Disease prevention
13. Pest control
14. Trainings in food safety practices

Section G: Drivers of Food Safety Compliance

G1. Are you familiar with food safety regulations and standards in your region? (*milk safety information*)

 Yes No

G2. Does the milk you produce undergo food-safety inspection?

 Yes No

G3. Have you ever faced any challenges in achieving food-safety compliance?

 Yes No

If Yes, please describe them?...

G4. What are some of the primary factors that drive your compliance with food-safety measures? (Select all that apply)

 Legal and regulatory requirements
 Customer demand for safe products
 Brand reputation and customer loyalty
 Internal policies and guidelines
 Risk of litigation and penalties
 Competitors' practices
 Certification requirements (e.g., ISO 22000, HACCP)
 Other (please specify): ___________

G5. How do you perceive the role of government agencies and regulatory bodies in promoting food safety compliance?

 Supportive Not supportive

G6. Are there any costs associated with compliance to food safety and quality standards?

 Yes No

G7. If Yes above, please state the costs incurred in implementing food safety and quality standards?

…………………………………………………………………………………………………
……………...

G8. Has the cost of complying with food safety and quality standards affected your decision to adopt these standards for your agricultural products?

□ Very important □ Agree □ Neutral □ Disagree □ Strongly disagree

□ Not Applicable (if the respondent is not involved in commercial agriculture)

Section H: Adoption of Hazard Analysis Critical Control Point (HACCP) principles

H1. Do you have a standard operating procedure (SOPs) in ensuring milk safety?

□ Yes □ No

H2. If yes to H1, do you have SOPs with regards to:

SOPs	Yes	No
Systems e.g. feeding, milking, health, reproduction, waste/manure management.		
Procedures e.g. sanitizing, milking preparation, milking, cleanup.		
Steps e.g. put on fresh gloves, get bucket, fill with hot water, add soap etc.		

H3. To ensure milk safety, you need to adopt HACCP principles in your dairy production operations. Do you know the HACCP principles?

□ Yes □ No

H4. If yes to H3, do you undertake the following steps: ***Note: The enumerators need to explain to the farmers what each key step mean before eliciting information)***

Steps in HACCP integration	Yes	No
Identify hazards (Listing of all hazards associated with, each step and consideration of any control measures ‘to eliminate or minimize hazards)		
Establishment of critical control points (CCP)		
Establishment of critical limits for each CCP		
Establishment of a monitoring system for each CCP		

Establishment of corrective actions		
Establishment of verification procedures		
Establishment of record keeping and documentation		
Implementation of the HACCP plan		
Review of the HACCP plan		

H5. If no to H4, the HACCP principle follows the following steps:

Preliminary Steps	Principles
1. Assemble the HACCP team.	1. Conduct a hazard analysis. Prepare a list of steps in the process where significant hazards occur and describe the preventive measures.
2. Describe the food and the method of its distribution.	2. Determine Critical Control Points (CCP's)/Identify the CCPs in the process.
3. Identify the intended use and consumers of the food.	3. Establish critical limits for preventive measures associated with each identified CCP.
4. Develop a flow diagram which describes the process.	4. Establish CCP monitoring requirements.
5. Verify the flow diagram.	5. Establish corrective action to be taken when monitoring indicates that there is a deviation from an established critical limit.
	6. Establish procedures for verification that the HACCP system is working correctly.
	7. Establish effective record-keeping procedures that document the HACCP system.

H6. Would you be willing to adopt these principles in your milk production?

 Yes No

H7. Have your ever experienced milk contamination in your farm?

 Yes No

H8. If yes to H7, how is milk contaminated in your farm *(causes of milk contamination)?*

……………………………………………………………………………………………

………………………………………….

H9. How do you prevent milk contamination?

…………………………………………………………………………………………………
……………………………………………………………………….

H10. In your own opinion, what are some of the benefits of adopting food safety measures in dairy farming?

…………………………………………………………………………………………
…………………………………………………………………………………………

Section I. Farmers behavior and farmer behavioral attribute

In your opinion, state your level of agreement or disagreement to the following statements regarding farmers' behaviours to perform safety and hygiene control practices. (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Behavioral attributes	**1**	**2**	**3**	**4**	**5**
Attitude					
1. For me to wash my hands before and after milking, I consider it very important for milk safety.					
2. For me, following the proper handwashing steps is not important to milk safety.					
3. For me washing my hands always in a particular container/facility is not important.					
4. When I fall ill of any sickness, it is not important to seek immediate medical help.					
5. For me keeping sick animals isolated is very important for milk safety					
6. For me washing udder before milking is important for milk safety					
7. Using clean containers/utensils is important for milk safety					
8. Milking wearing clean clothes all the time is very important for milk safety.					
Subjective norms					
1. My customers whom I value will disapprove if I don't wash my hands properly					
2. It is required of me to wash my hands before milking					

3. People whom I respect (i.e., customers) will disapprove if I do not stay away from milking when I am sick					
4. I am expected of me to stay away from milking when I am sick					
5. The people I supply milk will disapprove if I don't wear clean clothes before handling milk.					
6. My customers expect me to bulk milk in clean milking containers/utensils					
7. People who are important to me think that I should wash udder of cows before milking					
Perceived behavioral control					
1. Washing my hands before and after milking is completely up to me.					
2. Not having support from others would make it more difficult for me to wash my hands properly.					
3. It is entirely up to me to wash my hands from dedicated handwashing containers.					
4. It is completely up to me to stay away from milking when I fall sick of diarrhoea, cholera or sneezing.					
5. Not having support when sick would make it difficult for me to stay away from milking.					
6. It is entirely up to me to wear clean clothes all the time when milking.					
7. Not having support from government to acquire protective clothes would make it difficult for me to wear clean protective clothes when milking.					
Intentions					
1. Washing my hands before and after milking is completely up to me.					
2. Not having support from others would make it more difficult for me to wash my hands properly.					
3. It is entirely up to me to wash my hands from dedicated handwashing containers.					

4. It is completely up to me to stay away from milking when I fall sick of diarrhoea, cholera or sneezing.					
5. Not having support when sick would make it difficult for me to stay away from milking.					
6. It is entirely up to me to wear clean clothes all the time when milking.					
7. Not having support from government to acquire protective clothes would make it difficult for me to wear clean protective clothes when milking.					

Thank You So Much for Your Cooperation`

APPENDIX III: Ethical Approval

EGERTON UNIVERSITY

TEL: (051) 2217808
FAX: 051-2217942

P. O. BOX 536
EGERTON

EGERTON UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICS REVIEW COMMITTEE

EU/RE/DIR/009
Approval No. EUISERC/APP/352/2024 ***16th July 2024***

Andrew Kizito Seruma
Address: Kampala, Uganda
Telephone: +256 752 180255
E-mail: serumaandrew@gmail.com

Dear Andrew,

RE: ETHICAL APPROVAL: DRIVERS OF FOOD SAFETY MEASURES (FSMs) COMPLIANCE AND ITS EFFECTS ON PROFITABILITY OF SMALLHOLDER DAIRY FARMERS IN CENTRAL UGANDA

This is to inform you that the ***Egerton University Institutional Scientific and Ethics Review Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUISERC/APP/352/2024***. The approval period is ***16th July 2024 – 17th July 2025***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Institutional Scientific and Ethics Review Committee***.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Institutional Scientific and Ethics Review Committee*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Egerton University Institutional Scientific and Ethics Review Committee*** within 72 hours.
v. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

"Transforming Lives through Quality Education"

APPENDIX IV: Publications

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Factors Influencing Adherence to Food Safety Measures Among Smallholder Dairy Farmers in Central Uganda

Andrew Seruma[1], George Owuor[1] & Dickson Okello[1]

[1] Department of Agricultural Economics and Agribusiness Management, Egerton University, Njoro, Kenya

Correspondence: Andrew Seruma, Department of Agricultural Economics and Agribusiness Management, Egerton University, P.O. Box 536, Njoro, Kenya. E-mail: serumaandrew@gmail.com

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Abstract

Promoting compliance with food safety measures among smallholder dairy farmers is critical for public health, market access, and the overall profitability and sustainability of the dairy sector. However, smallholder dairy farmers face challenges related to the implementation of food safety measures (FSMs) on their farms. To devise interventions to overcome these challenges, it is necessary to identify and understand the drivers of compliance with food safety measures among smallholder dairy farmers in Central Uganda. Therefore, this study investigated the factors influencing food safety compliance among smallholder dairy farmers in Central Uganda. Data were collected from 757 randomly selected smallholder dairy farmers using face-to-face interviews. The farmers were classified as low, middle, and high adopters of FSMs. The study employed an ordered Probit model to identify the determinants of compliance with FSMs. The results indicate that significant variables positively influencing the probability of being in the higher adopter class include level of formal education, type of

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Research

Adoption of on-farm food safety measures among smallholder dairy farmers in Central Uganda

Andrew Kizito Seruma[1] · George Owuor[1] · Dickson Okello[1]

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Abstract

Uganda's dairy sector suffers significant economic losses from disease outbreaks and milk contamination, undermining farmer incomes and public health. This study evaluates the adoption of food safety measures (FSMs) among 757 smallholder dairy farmers in Central Uganda, the country's leading milk-producing region, using semi-structured questionnaires, which were administered through interviews. FSMs were categorized into milk hygiene, storage, environmental hygiene, and animal health, revealing an overall adoption rate of 62.88%. While milk storage practices showed the highest compliance (73.5%), critical gaps persisted in sanitization (8.1% for utensils), mastitis prevention (7.1% dry cow therapy adoption), and full implementation of Hazard Analysis Critical Control Point (HACCP) principles (27.6%). The findings indicate that the majority of the farmers prioritized visible hygiene practices (97.4% cleaned utensils) over scientifically vital controls, creating a hygiene paradox that leaves milk vulnerable to pathogens like *Salmonella*, *Listeria monocytogenes*, and *Escherichia coli*. Although 75% used Standard Operating Procedures (SOPs), most relied on unwritten, experience-based protocols rather than formal documentation. The findings underscore urgent policy actions: (1) targeted training to