Role of Gender in Dairy Cattle Management, Milk Production and Microbial Quality, Among Smallholder Farms in Shashemene, Hawassa, and Yirgalem districts, Ethiopia

MSc Thesis

By

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HAWASSA UNIVERSITY
College of Agriculture

Hawassa, Ethiopia
June, 2025

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A Thesis Submitted to the School of Animal and Range Science

HAWASSA UNIVERSITY
College of Agriculture

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Dairy Science and Technology

Hawassa, Ethiopia
June, 2025

HAWASSA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "**Role of Gender in Dairy Cattle Management, Milk Production, and Microbial Quality Among Smallholder Farms in Shashemene, Hawassa, and Yirgalem districts, Ethiopia**", submitted in partial fulfillment of the requirements for the degree of Master of Science in **Dairy Science and Technology** to the Graduate Program of the **School of Animal and Range Science**, has been carried out by Ms. Elleni Cherinet, ID No. GPDaScR/0004/15, during the academic year 2024/2025 G.C.

The research work has been conducted under my supervision and meets the standards and requirements of the program. Therefore, I hereby recommend that the thesis be accepted and submitted to the **School of Animal and Range Science**.

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DEDICATION

To my dearest mom, **Wegayew Kifle (Wawe)**, my first teacher, my biggest believer, and my constant source of strength. You've always made me feel like your favorite, cared for me with unmatched devotion, and instilled in me the belief that education is the surest path to a better life. For you, learning was never just about school; it was about access, opportunity, dignity, and the power to shape one's future. Even as a child, I could see it in your eyes, words, and sacrifices, the dream you carried to see yourself in me: rising beyond limits, breaking cycles. This journey is as much yours as it is mine, and I dedicate this work to you with all my love and gratitude.

ACKNOWLEDGMENTS

First and foremost, I give all glory, honor, and thanks to **Jesus Christ**, my Lord and Savior, for granting me the strength, wisdom, and perseverance to complete this journey. Without His grace, none of this would have been possible.

I sincerely thank my advisor, **Dr Sintayehu Yigrem (Associate Professor),** for his unwavering support and mentorship. His insights shaped my research proposal, analysis, and results, while his thoughtful feedback and engaging discussions were invaluable. His dedication to excellence fostered my growth, both technically and intellectually, and created an environment where I could thrive. I am deeply grateful for his guidance, trust, and the opportunity to learn.

I also extend my sincere thanks to the faculty and staff of the **School of Animal and Range Science, College of Agriculture, Hawassa University**. I am also thankful for the support of the **LSL II-LCD-C2P ETHIOPIA PROJECT** in helping me secure the financial resources that made this research possible. I will always be grateful for the trust, insight, and guidance they provided and for creating an environment where I could truly learn and flourish.

My appreciation goes to the many individuals who contributed to the fieldwork, including data collectors, laboratory assistants, and local administrators, whose cooperation and efforts during the survey and milk sample collection, and GIS professionals were crucial to the success of this research.

To my beloved mother, Wegayew Kifle, thank you for your support. I am also grateful to my family for their continuous encouragement throughout this journey.
Finally, I thank everyone who supported, encouraged, or contributed to this journey in any way; your presence has made a difference.

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STATEMENT OF AUTHOR

I proudly declare that this thesis is entirely my original work. I've made sure to acknowledge and cite all the sources of information and materials I've used. This thesis hasn't been submitted to any other institution for any academic degree, diploma, or certificate, and I have no plans to submit it anywhere else in the future.

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LIST OF ACRONYMS AND ABBREVIATIONS

APHA	American Public Health Association
AGP-LMDP	Agricultural Growth Project-Livestock Market Development Programme
AHSN	Animal Health Service Netherlands
ANOVA	Analysis of Variance
CAC	Codex Alimentarius Commission
CC	Coliform Count
CCP	Critical Control Points
CSA	Central Statistical Agency
DMRT	Duncan's Multiple Range Test
DPC	Dabhol Power Company
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
HACCP	Hazard Analysis Critical Control Points
ILO	International Labour Organization
ILRI	International Livestock Research Institute
LMICs	Low Middle Income Countries
MoFED	Ministry of Finance and Economic Development
NDO	Netherlands Development Organization
NZAGRC	New Zealand Agricultural Greenhouse Gas Research Centre
SPCA	Standard Plate Count Agar

SRS	Summarized Rating Scale
TBC	Total bacterial count

ABSTRACT

Role of Gender in Dairy Cattle Management, Milk Production, and Microbial Quality, Among Smallholder Farms in Shashemene, Hawassa, and Yirgalem districts, Ethiopia

By Elleni Cherinet

Supervisor: Dr. Sintayehu Yigrem (Associate Prof.)

This study explores the role of gender in dairy cattle management, milk production, microbial quality, and value addition among smallholder farms in the Shashemene, Hawassa, and Yirgalem districts, Ethiopia. Data were collected from 150 households, where half of the farms had women-led and the other half had male-led farm management. In addition, 80 raw milk samples were analyzed for microbial quality, focusing on Total Plate Count (TPC), coliform counts (CC), and Escherichia coli (E. coli) using standard microbiological methods. Small-scale farms dominated (69.4%), with male-led farm management households accounting for 72.2%. Female-led farm management households managed smaller herds (mean 2.7 cows) and produced less milk daily (mean 6.2 liters) than male-led farm management (mean herd size 4.3 cows; mean milk production 9.5 liters). Observational results showed significant gender differences in 8 of 14 management practices ($p < 0.05$), with Female-led farm management excelling in milking hygiene, milk storage, feed management, and processing despite facing 1.8 times more equipment access challenges. Milk from women-led farms had better microbial quality; Total Plate Count (TPC) was significantly lower (mean $\log_{10}$ CFU/mL 4.2) than male-led farm management (mean 5.1), confirmed by chi-square tests ($p < 0.001$). Logistic regression indicates gender, education, and location as significant predictors of processing engagement (all $p < 0.05$). Female-led farm management was 2.1 times more likely to practice hygiene, and higher education increased modern technique adoption by 2.3 times. These findings highlight women's often-overlooked role in ensuring milk quality and safety and maintaining high standards in dairy production, even under constrained conditions. The study concludes that supporting women through targeted training, improved infrastructure, and access to veterinary services could lead to better milk quality and more equitable outcomes in the dairy sector. These insights provide important guidance for inclusive agricultural development policies and strengthen the case for investing in gender-responsive approaches to enhance Ethiopia's smallholder dairy value chain.

Keywords: Gender roles, Dairy cattle management, Microbial milk quality, Smallholder farms, Milk value addition

1. INTRODUCTION

1.1. Background

In Ethiopia agriculture sector and national economy, the dairy sub-sector play important contributions (Tegegne *et al*., 2013; Hoddinott *et al*., 2014). The dairy sub-sector accounts for 30-35 percent of the national agricultural output and 40 percent of agricultural export value (Edomo H, 2017). Dairy is also a vital source of nutrition and provide important livelihood opportunities for dairy farmers, processors, transporters, retailers and other dairy value chain actors (FAO, 2017). Recent data estimates indicate that there are over 70 million cattle, from which 55.38% are female animals (CSA, 2022).

Dairy production also plays a vital role in economic development and sustainability of several low- and middle-income countries, where it provides critically important contributions to nutrient cycling, plays a crucial role in income generation and poverty alleviation, and serves as a vital source of manure for crop production and cooking fuel and women's empowerment (Adesogan & Dahl, 2020)**.**

Both men and women have a significant contribution to agricultural related activities in the African continent, although the contributions of women are not usually explicitly recognized in official statistics and documents (Kebede T, 2021). Women play a significant role in agricultural productivity, that they contributing about 40–60% of all agricultural related labor (World Bank, 2008). Worldwide, women produce over 50% of the food and it is more than this in developing countries. Women in Africa play a significant role in agriculture but they are more often considered as family assistances on farmland belonging to their husbands who have a correspondingly enhanced status. They are usually have a sole responsible for food processing and also make a major contribution to food storage, transportation and marketing but they seldom control the revenue generated (Kristjanson P., *et al*. 2014). In Ethiopian dairy sector, the role of women is immense from managing the managing dairy cattle up-to managing the products. Women role is typically associated to activities around the home, with little decisions on sale and marketing of milk but not owning big assess (LMD, 2013). Traditionally, the role of women to milk products handling and ownership is not questionable, however, it is not clear if the role of women is bold enough when farms generate more income and become commercial farms it seems to be male-dominated thus limiting women's participation (Njarui *et al*,. 2012). It is assumed that Women are confined at lower-level dairy value chain activity which is routine and daily, which genders' perception supports this role (Michael, 2015). Women are also not allowed to share equally in the proceeds despite their active involvement in most of the farm activities along the dairy value chain. This is because their contribution is not visible by the other stakeholders in the industry (Immaculate N, 2O14).

Milk from healthy udder contains few bacteria (not more than $5x10^5$ bacteria/ml), but it picks up many bacteria from the time it leaves the teat of the cow until it is consumed (O'Conner, 1995). Gender roles should be taken into account at every step in the value chain in order to reduce food safety risks. Training farmers on hygienic milk production and handling, including microbiological testing and examination of livestock, can help reduce food safety risks (Lore *et al.,* 2006) but the training needs to recognize that women and female children are the primary processors of milk and milk products and cleaners of milking equipment (Colverson, 2019; FAO, 2012).

Despite a substantial potential, the Ethiopian dairy sector is not well developed that is characterized by a large gap between actual and potential contribution to national economy and the welfare of rural people in Ethiopia (Yilma *et al*., 2001; Hoddinott *et al.*, 2014; FAO, 2017). This emanates from the major constraints to the development of livestock sector in general and dairy sector in particular includes shortage and fluctuation in quality and quantity of feed, poor breeding program, poor management practices, diseases, poor market infrastructure, poor service delivery, policy and institutional arrangements (ILRI/IPMS, 2005). Value chain development is key to achieve increased production and improved livelihoods of the rural poor, especially women. A value chain refers to all the sequence of production and marketing steps of a product ranging from primary production, processing, and distribution up to the retail sale till it reaches the final consumer (Kaplinsky and Morris, 2001). Value chains offer tremendous opportunities to women through better market linkages and employment opportunities. At the same time, the way these value chains operate can affect women negatively (Njuki *et al.,* 2012). And there is no clear evidence, to what existent they manage and own resources, to what existent they contribute to the quality and safety of products and how they decide on the volume of milk that goes to the family and market. The decision process on milk and milk products utilization's are not clear. Several reports show how much they are involved in dairy farm management, such as feeding, watering, milking, animals reared close to home. This study aims to achieve a dual purpose: firstly, to provide a comprehensive understanding of the diverse roles women undertake in the Shashemene, Hawassa, and Yirgalem districts**,** value chain, and secondly, to evaluate the role of women microbiological quality of milk at different stages of production, processing, and distribution. As we delve into this investigation, our overarching goal is to contribute valuable insights that not only acknowledge the indispensable contributions of women but also inform strategies for enhancing the value addition and microbiological quality of dairy products within the Hawassa milk shed.

1.2 Statement of the Problem

Women play a significant role in animal husbandry and dairy production (FAO, 2017). In many smallholder's cattle-raising enterprises, their contributions vary based on region, culture, and social class. However, their roles are often underrecognized, as is the value of their local knowledge and expertise (Immaculate, 2014). Historically, women participating in the livestock value chain have been confined to lower levels and have faced greater inequalities in the upper segments, where economic benefits are distributed (Njuki, 2011).

Although women engage in a wide range of dairy-related tasks such as weeding fields, feeding and watering cows, milking, and cleaning animal sheds they continue to experience disparities in access to resources and participation in decision-making processes (Njarui et al., 2012). In addition, women play a crucial but often overlooked role in ensuring milk safety, particularly in Ethiopia, where traditional practices and limited support systems can pose challenges to quality assurance (Garsow et al., 2021). Their access to opportunities in the dairy sector is shaped by intersecting social norms, institutional structures, and gender relations (Rietveld et al., 2019). As Okali and Sumberg (2012) note, global, regional, and local economic processes, alongside cultural expectations and social relations, determine the type of work available to women and young people in the livestock sector.

Despite their contributions, little empirical research has systematically assessed how gender dynamics influence key outcomes such as milk production efficiency, microbial quality, and value addition in the dairy value chain. This gap is especially relevant in smallholder farming systems like those in the Shashemene, Hawassa, and Yirgalem districts of Ethiopia, where dairy serves both nutritional and economic functions. Without clear evidence on how gender roles and inequalities affect dairy management and milk safety, policies and interventions risk reinforcing existing disparities rather than promoting inclusive development.

1.3 Research Questions

1. What are the gender-specific roles and practices across the dairy value chain, particularly in production, processing, and marketing, among smallholder farmers in the Hawassa Milk Shed?
2. How do gender-based differences in farm management, hygiene, and milk handling affect the microbial quality of milk and opportunities for value addition in dairy production?

1.4 Research Objectives

1.4.1 General Objective

To explore and analyze gender-based differences in dairy cattle management, milk production, microbial quality, and value addition on smallholder farms in the Shashemene, Hawassa, and Yirgalem districts, with a focus on understanding and enhancing women's contributions to the sector.

1.4.2 Specific Objectives

- Assess, describe, and compare roles of gender in dairy farm management practices
- Assess the role of gender in milk handling practices and quantity, and compare microbiological quality of milk among women-led and men-led dairy farms.
- Analyze the role of gender and other socio-economic factors on the milk value additions among smallholder dairy farms.

1.5 Research Hypotheses

Based on the literature and research objectives, the following hypotheses are proposed:

Null Hypothesis (H_0): There is no significant difference in milk microbiological quality, milk production, farm management practices, and value addition activities between female-led farm management and male-led farm management dairy farms in the Hawassa Milk Shed, Ethiopia.

Alternative Hypothesis (H_1): There is a significant difference in milk microbiological quality, milk production, and farm management practices between female-led farm management and male-led farm management dairy farms in the Hawassa Milk Shed, Ethiopia.

2. LITERATURE REVIEW

2.1. Overview of Dairy Production in Ethiopia

Dairy farming is one of the livestock production systems practiced almost all over the world, including Ethiopia, involving a vast number of small, medium, or large-sized, subsistence or market-oriented farms. Based on climate, land holding, and integrated with crop production, dairy production can be: pastoralism, highland smallholder, urban and peri-urban, and intensive dairy farming systems are recognized in Ethiopia. A large number of small, medium, and large farms that are focused on either market-oriented farming or subsistence farming are involved in the dairy industry, which is one of the livestock production systems used almost everywhere in the world, including Ethiopia. Ethiopia recognizes pastoralism, highland smallholder, urban and peri-urban, and intensive dairy farming systems as viable dairy production methods based on climate, land holding, and integration with crop production (Guadu and Abebaw, 2016).

Ethiopia holds large potential for dairy development due to its large livestock population, favorable climate for improved, high-yielding animal breeds, and the relatively disease-free environment for livestock (Mohammed *et al.,* 2004). Milk production in Ethiopia takes place within four main dairy production systems: medium-scale commercial, small-scale commercial, rural mixed crop-livestock dairy system and pastoral/agro-pastoral. The latter two systems are classified as rural dairy production systems. The highlands are also the regions with market-oriented milk production (FAO & NZAGRC, 2017). There are about 11.4 million livestock-producing households in Ethiopia (CSA, 2013). In Ethiopia, dairy production is one of the livestock production systems. The diverse livestock species like cattle, camel, goats account as the major sources of milk producers (MOARD, 2004). Out of the total milk produced, cattle produce 83% of it. Moreover, of the total milk produced by cattle indigenous breeds contribute 97%. Dairying is practiced all over the country and is classified as pastoral, agro-pastoral, crop-livestock, urban, and peri-urban production systems. The production systems involve a vast number of small, medium, and large-scale operation and defined by its location, agroecology, production objectives, access to inputs and services, scale of production and management, market orientations, and resource uses (Tegegne *et al.,* 2013). Depending on the production zone, cattle are the dominant species in 70% to 90% of livestock-producing households, depending on the production zone, and thus dominate smallholder income generation and milk production in all production zones. In addition, smallholder farmers represent about 85% of the population and are responsible for 98% of the milk production (FAO & New Zealand Agricultural Greenhouse Gas Research Centre, 2017). The aforementioned research tells us dairying is well known in Ethiopia.

2.2. Characteristics of Dairy Value Chain in Ethiopia

Dairy value chain analysis refers to different stages where the dairy products pass from farm to consumer (FAO, 2007). There are different levels of value chains identified like input supply, production, marketing, processing, and consumption (Brhane and Weldegiorgis, 2019). Value chain is the overall activities that are necessary to create, produce, and add value to end products or services. Value chains include different levels of production like producing raw materials, processing, distribution, marketing, provision of services/products, and disposing of it after-use (Kaplinsky and Morris, 2000). The value chain includes various actors such as input suppliers, farmers, collectors, cooperatives, processors, and consumers (Adane, 2020). The dairy production systems in Ethiopia are classified based on factors such as climate, production intensity, land holding, and market orientation (Brhane 2019, Adane 2020, Gebremariam 2019, Beyene 2015). Smallholder farmers play a significant role in milk production, but face challenges such as poor genetics, limited access to animal feed, and poor management practices (Adane, 2020). Financial analysis shows that dairy production and marketing can be profitable and create value added (Adane, 2020).

2.3. Women's Involvement in Milk Production, Processing, and Marketing

2.3.1 Milk production

Women are playing a pivotal role both in agriculture and dairying (Manthekar & Nigade, 2018). The involvement of women in milk production in Ethiopia is a complex issue influenced by market dynamics and gender relations. Women were largely involved in obtaining feed, giving it to the animals, watering them, tending to the ill and young ones, cleaning the animal shelter, milking the animals, and helping to sell the products made from them (Obosha, 2020). Women tend to be responsible for activities carried out at or near the home, activities required for the day-to-day care of animals, and storing, processing, and adding value to livestock products, while men are more often responsible for activities outside the home. This is evident from observations and analysis in several published reports (Aregu *et al.*, 2010; AGP-LMDP, 2013; Benyene, 2015). This corresponds to the findings of this study, where women tended to be predominantly involved in the day-to-day management of dairy cattle as well as the home-processing of milk into butter and cheese (Beyene, 2015).

The dairy production sector is one in which female participation is high, with a range of potential benefits for women in terms of income, employment, and empowerment (Maestre *et al.,* 2018, Boros and McLeod 2015; Safi 2016). Women play an integral role in Ethiopia's dairy value chain, though their contributions are often overlooked and undervalued. At the production level, women are primarily responsible for feeding, milking, and cleaning cows, in addition to processing the milk into products like butter, cheese, and yogurt Garsow *et al.,* 2022; Beyene 2015; Beyene 2016; Desalegne 2016; Tingirtu 2019; Yuya 2018; Tadesse 2016). Women were involved in a wide range of different work tasks, mainly in cattle barns and at home (Kallioniemi and Kymäläinen, 2012).

Women are crucial to the management of cattle, as they are involved in the production, processing, and selling of milk, even though not all of them are in charge of the milk and its product sales (FAO, 1999). Women mostly participated in gathering feed and providing feed to the livestock, watering, taking care of the sick and young animals, contribute to cleaning the animal shelter, milking, and contributing to sale of the livestock products (Obosha, 2020). It was found that women are mainly responsible for barn cleaning, milk selling, processing, and feeding, whereas male undertakes shed construction, feed storing, and animal health treatments (Workneh & Galmessa, 2011). The findings clearly showing women's involvement dairy sector is high and their involvement is greatly significance for the sector.

2.3.1 Processing

Management practices were mainly carried out by women including feeding, cleaning, watering, and milking (Zahra *et al.,* 2014). Women play a critical role in the storage of dairy products in Ethiopia, with 89% and 100% found to be responsible for these activities in the Walmera and Kersa Woredas, respectively (Colverson, 2019). Women processed sheep and goat milk into butter using traditional labor-intensive methods. Women smoke milk and butter containers with herbs and olive tree leaves to increase the shelf life of the butter (Zahra *et al.,* 2014)(Zahra *et al.,* 2014). Value-addition technologies targeting women should be relevant, accessible, and affordable (Odero-Wanga *et al.,* 2009).

2.3.2 Marketing

Traditional/informal milk markets have played a key role in dairy development in Ethiopia. Informal, small-scale markets control over 90% of marketed milk in the country. Producers sell their milk to anyone whom they come across every day. Dairy cooperatives and the formation of milk groups give producers guaranteed access to market and sell their milk (Seifu and Doluschitz, 2014). Even though the proportion of milk channeled through the formal markets is still small, since 1991 the supply of milk and other dairy products from non-state actors (private and cooperative dairy firms) has increased, (SNV, 2008). FAO (2010) acknowledged that dairy production and marketing are of areas where both men and women are involved, however, we need to remark on the gender biases that remain prevalent in the dairy sector. This suggests that women's involvement in the market can lead to greater economic independence and decision-making authority. Hebo (2014) further explored the impact of evolving markets on gender relations, noting that the commercialization of milk is challenging traditional gender roles in milk production and distribution.

Women make essential contributions to the agricultural and rural economies in all developing countries. Evidence suggests that women tend to lose income and control as a product moves from the farm to the market (Belete, 2019). In the collection process, males were principally assigned to milk transportation, whereas milk reception, selling, and quality control activities were mainly given to females (Misganaw & Dagnew, 2022). They have far more rights over livestock products (milk, butter, cheese, ghee, hides, and skins) than they do over the live animals themselves (Njuki *et al.,* 2013). These studies highlight the need for further research and policy interventions to support women's participation in the milk market while addressing the potential risks to their traditional roles and responsibilities.

2.4. Female Dairy Cooperatives and Their Impact on Quality Milk Production

Women entrepreneurship is the process where women take lead and organize a business or industry and provide employment opportunities to others. It may be defined as a woman or group of women who initiate, organize, and run business enterprises (D. Ravinder, & S. Prathap, 2016)(D.Ravinder, 2016). Research on female dairy cooperatives in Ethiopia has highlighted their potential to improve milk quality and safety. Cooperatives can indeed play an important role in poverty alleviation among dairy producers. In addition, similar to what has been reported by Fischer and Qaim (2012) and Abebaw and Haile (2013). And Fikadu (2019) emphasizes the need for targeted interventions to enhance female-led farm management households' membership in these cooperatives. Garsow (2021) further emphasizes the importance of gender-sensitive interventions in ensuring the safety of milk and milk products, particularly in the context of female involvement in the dairy value chain.

Women actively participate in small-scale milk production and informal processing, and have opportunities to control the income from both or to influence its use (FAO, 2017). The FAO (2011) publication provides guidelines for practitioners on promoting gender equity in dairy value chains. It emphasizes the need to involve women in decision-making processes, provide training and capacity-building opportunities, and ensure equal access to resources and benefits. These strategies can contribute to improved milk quality. Milk cooperatives realized that women's participation in Dairy Cooperatives can help rural women become self-confident and self-reliant and can run Dairy Cooperatives more efficiently at the same time, it will create income and employment as a result, women became empowered through this milk cooperative (Roopa, 2017).

2.5. Challenges Faced by Women in the Dairy Business

Men and women are involved in dairy value chains, but in different ways, and they face different constraints (FAO, 2017). As Sintayehu Y. *et al.,* (2008) described the major constraints for dairy development in the area included availability and costs of feeds, shortage of farmland, discouraging marketing systems, waste disposal problems, lack of improved dairy animals, poor extension and animal health services, and knowledge gap on improved dairy production, processing and marketing. Like different African countries, Ethiopian women traditionally have been subject to socio-cultural and economic discrimination that resulted in fewer economic and social opportunities than men (Kebede T. 2021). Women in the dairy value chain in Ethiopia face numerous challenges, including limited decision-making power and access to resources (Beyene, 2015). And Women are also constrained with lower levels of human capital (Mulema *et al.,* 2017), They are also at a higher risk of exposure to food safety hazards due to their primary role in milk production (Garsow *et al.*, 2021). These challenges are further exacerbated by gender-related factors such as poor technical skills, limited access to markets and financial services, and social expectations (Obosha, 2020). Despite this growing momentum, women around the world still face discrimination and gender barriers that prevent them from unleashing their full economic potential (ILO, 2014).

Gender-based constraints are factors that inhibit men's or women's access to resources, behaviors, participation, time use, mobility, rights, and exercise of power based on their gender identity (Rubin, 2010). And women reported some unique challenges, not faced by male traders, related to milk transportation (traveling to source the milk from producers and transporting it to the sales point) female participants reported that women are less likely to own motorbikes or even know how to ride a bicycle. Similarly, adherence to transportation requirements of using metal cans poses a specific challenge for women, as women consider metal cans too big and heavy for them. Also, given that most household responsibilities fall disproportionately on women, they have less available time to travel to source milk (Alonso *et al.,* 2018). A major barrier to women's access is gender biases within households, communities, and cooperatives themselves that favor educated male household heads and land owners over resource-poor women (Woldu *et al.*, 2013). Women are affected by resource scarcity more than men as they are characterized by a higher level of insecurity concerning livestock and access to other rights and resources (Gallina A, 2016). Tadesse (2016) found that while men dominate dairy production, women provide much of the labor, spending twice as much time as men on household and farm tasks. Addressing these issues is crucial for the empowerment of women in the dairy value chain and the improvement of their livelihoods.

2.6. The Socio-economic Impact of Women's Participation in the Dairy sector

Dairy farming provides economic and social benefits to farmers and their wider communities (FAO, 2011). In the food systems of smallholder farmers, dairy production holds significant role. They have a huge contribution to smallholders as income generation and poverty alleviation, food and nutrition security in the country (T. Mihret *et al.,* 2017 and Andeweg K. *et al.,* 2020). Lenjiso *et al* (2015) argued that household milk market participation has the potential to improve household food and nutritional security in Ethiopia.

Dairy production is particularly important to rural women, providing them with income and a means to meet social obligations (FAO, 2017). The participation of women in the dairy sector in Ethiopia has significant socio-economic implications. Lenjiso (2016) found that women's involvement in the smallholder milk market led to a shift in income control from women to men, but also increased women's bargaining power within the household. This suggests that while women may have less control over income, their participation in the market can still enhance their overall influence. Abebe and Galmessa (2011) highlighted the gendered division of labor in dairy production, with women primarily responsible for tasks such as milk selling and processing. However, men tend to have greater control over income from live animal sales. Garsow *et al.,* (2021) emphasized the crucial role of women in ensuring the safety of milk and milk products, particularly in the context of potential food safety risks.

Women are powerful agents of change and continue to make increasing and significant contributions to sustainable development, despite existing structural and socio-cultural barriers (Markham, 2013). Small-scale dairy production is considered beneficial to more women and children. Sales dairy product provides regular income for women that help to diversify their diets and children (FAO, 2011). Value chain development aims at improving the livelihoods of poor families and enhances the potential of women to provide for their families, it is important to understand access to and control of resources and the benefits from various productive assets (Zahra *et al.,* 2014). Small-scale dairy production is considered beneficial to more women and children. Sales dairy product provides regular income for women that help to diversify their diets and children (FAO, 2011).

The dairy sector fulfills many important roles: milk and dairy products are a rich source of essential nutrients (e.g., protein, calcium, vitamin B12 and riboflavin), especially for young children and pregnant women and is one of the most affordable nutritious products. Moreover, dairy value chains are a primary source of livelihoods for rural populations and women in particular. In East Africa, milk is one of the few resources that is usually under the control of women, both as a food product for the family and a source of earnings from its sales. This is central to the link between dairy production, consumption and nutrition, because women are also generally in charge of household nutrition, are the main preserves of food cultures, and some studies have suggested they tend to prioritize expenditures in high-quality and high-nutrition foods more than their male counterparts (Rogers, 1996; Smith *et al.,* 2003; UNICEF, 2011).

A shift in focus towards establishing women's cooperatives and self-help groups, it is argued, could assist more women in becoming empowered to become business leaders themselves, to obtain positions where they can access productive resources, and ultimately, work towards creating tangible improvements in mitigation practices in the dairy sector in the long run (Gallina A, 2016). If more income is to be generated from women owned micro enterprises in the dairy sector to improve the status of women and their families, it is imperative that government policies and programme effectively address issues that affect women's participation in this sector (Odero-Wanga *et al.,* 2009). Women on female contact farms were observed spending dairy income on food for the household and children's schooling more often than their counterparts on male contact farms (Mullins *et al.,* 1996). Women often devote more time and resources under their control towards improving household concerns related to food security as compared to men and their involvement (Quisumbing *et al.,* 1995). Ensuring that women's contributions to food systems are recognized by their families, communities, policymakers, and society more broadly and that women can make strategic choices about their involvement in food systems has benefits for all of society. Women's empowerment can improve agricultural productivity, household food security and dietary quality, and maternal and child nutrition (Malapit *et al,,* 2020).

2.7. Overview of Milk Quality Standards and Regulations

The safety and quality of milk and dairy products in Ethiopia are a major concern, with the majority of products falling below standard requirements (Gemechu, 2017). This is due to poor hygienic practices, water adulteration, and the use of adulterants such as water (Zebib and Zewudu, 2020). The handling and processing of milk also lack proper hygienic conditions, further compromising the quality of the products (Bereda *et al.*, 2014). The existing food laws and regulations in Ethiopia are outdated and not comprehensive, particularly in the inspection of food sources and street foods (Temesgen, 2015).

Quality has become a major driving force in many production enterprises. In the classical context, the quality concept addresses the product only. Quality as a subjective entity comprises both technical and technological characteristics, as well as emotional and ethical aspects. Many definitions of quality can be found in literature, each trying to address quality from one or more of the forenamed points of view. Most important is that a product should fulfil the demands put forward by the consumers and is attractive enough to be bought (Evans and Lindsay, 1996). In dairy production, milk is a product with a long history of product quality testing, particularly with respect to, for example, cleanness, hygiene, microbiological contamination, somatic cell counts, and antimicrobial residues. Most of the regular quality failures in this area are caused by managerial faults, followed by cow problems (AHSN, 1981; Kivaria *et al.*, 2004). As milk leaves the cow, it is dominated by lactic acid bacteria. However, during storage pathogenic bacteria introduced from the environment can cause spoilage of raw milk (Merwan *et al.*, 2018). Implementation of good hygiene and production practices and assessment of interventions targeting the reduction of contamination in the dairy supply chain is needed to inform coordinated efforts focused on improvement of dairy food safety in Ethiopia (Keba *et al*,. 2020).

In Ethiopia, in most cases, milk is produced and marketed without quality control measures (Yilma and Faye, 2006). The nature of milk and its chemical composition renders it one of the ideal culture media for microbial growth and multiplication (Woldemariam and Asres, 2017). The safety of dairy products with respect to food-borne diseases is a great concern around the world. This is especially true in developing countries where production of milk and various dairy products take place under rather unsanitary conditions and poor production practices (Abebe *et al.*, 2014).

The microbial load of milk is a significant factor in determining its quality and safety. It indicates the hygienic level exercised during milking including cleanliness of the milking utensils, storage condition, and transportation as well as the cleanliness of the udder of the individual animal (Yilma and Faye, 2006). In most dairy industrialized countries, milk quality is defined by the level of somatic cells count (SCC) and the microbial load of milk in the pre-pasteurized bulk tank. These are the key components of international regulation put in place for milk quality, udder health and the prevalence of clinical and sub-clinical mastitis in dairy herds (Fatine *et al.*, 2012). The most contentious microbial and residues that occur in milk are bacteria and antimicrobial drugs respectively (Girma *et al.,* 2014). The residual amount of drugs consumed through animal origin food not necessarily toxic, except when exceeds a certain limit i.e. MRL (Gupta, 2019). High levels of SCC and microbial load indicate poor milk quality due to the fact that it contains reduced curd firmness and increased fat and casein loss in whey. Moreover, reduction of milk shelf life, poor farm hygiene, antibiotic residues and the presence of pathogenic organisms and toxins increase the microbial load of the milk. Problems of public health associated with consumption of raw milk and traditional dairy products obtained from raw milk are common in the developing countries (Makita *et al.,* 2012). Chemical contamination may occur at any point of the various stages of processing, packaging, transportation and storage of food (Rather *et al.*, 2017).

2.7.1 Quality regulation

Quality control measures have been advanced to provide better tools for the evaluation of different quality parameters of milk at different stages of the production (Merwan *et al.*, 2018). Governments, all over the world, have put in place various mechanisms for protecting their citizens from food borne illnesses to ensure the socio-economic development of their country. Milk quality standards have been regulated by the respective Food and Drug Administration in the countries. As a result, the EU and USA legislation's have been used as a common measure of milk quality standards. More or less in Ethiopia the application of milk quality standard and regulation is comparable world-wide. Regulation in the area of food quality and safety protection has been one the features of regulatory mechanisms established for problems that are difficult to be identified by consumers using their sense of sight, smell, taste or touch when selecting or consuming foods (CAC, 2007). The safety and quality of milk and dairy products in Ethiopia must be guaranteed, and these findings emphasize the need for stronger standards and laws in the dairy sector.

2.7.2 Milk quality grading

The microbial load of milk is a major factor in determining its quality. It indicates the hygienic level exercised during milking, that is, cleanliness of the milking utensils, condition of storage, manner of transport as well as the cleanliness of the udder of the individual animal (Spreer E (1998) and Gandiya F (2001). Quality control tests are vital to support activities for hygiene and food standards to meet regulatory and customer demand (Burke *et al.,* 2018). In the United States, Grade A milk (fluid grade milk), top quality milk, refers to milk produced in the farms where sufficiently sanitary conditions have been fulfilled to qualify for fluid (beverage) consumption. Grade B milk is referred to as manufacturing grade milk that does not meet the fluid grade standards and can only be used in cheese, butter and nonfat dry milk. Grade C milk is the last grade milk which violates any of the requirements for grade B milk but is not subjected to adulteration (U.S. Department of Health and Human Services, 2011).

2.8. Overview of food safety and standards in Ethiopia

The food safety and standards system in Ethiopia faces significant challenges, including outdated laws and a lack of comprehensive regulation (Temesgen, 2015). These issues are further compounded by a lack of organized food safety systems and growing population and urbanization pressures (Teferi, 2020). Key stakeholders in the food safety management system include various government bodies, research institutions, and industry players, but there are gaps in legal and policy frameworks, food-borne disease surveillance, and coordination (Ayalew *et al,,* 2013). The safety and quality of dairy products in the country are particularly concerning, with substandard microbiological and physicochemical parameters and an increasing trend of adulteration (Gemechu, 2017).

Food safety is concerned with the production of food that does not pose a threat to human health (Henson and Traill, 1993). Higher bacterial contents exist in developing countries where production of milk and various dairy products takes place under rather unsanitary conditions and poor production (Mogessie A (1990). In Ethiopia, indigenous dairy products are produced by using traditional materials and methods, thus becoming potential hosts for many microorganisms (Alganesh and Fekadu, 2012; Abebe *et al.*, 2013). Quality assurance is mandatory before the milk is consumed. It is achieved up on planned and systematic activities performed in each steps of the quality system (Ahmedsham *et al.,* 2018*).* Previous studies have emphasized that the hygienic practices during production, processing and handling of milk and milk products in different parts of the country are substandard, which made the quality and safety of milk products questionable (Amistu *et al.,* 2015). Milk and milk products in Ethiopia are channeled to consumers through both formal (2%) and informal (95%) marketing systems (Netherlands Development Organization, 2008). HACCP requires a critical examination of the whole food manufacturing process to determine every step where there is a likelihood of physical, chemical, or microbiological contamination. This would make the food unsafe or unacceptable for human consumption. It identifies and sets critical control points (CCP) (DPC, 2001).

Factors which give rise to potential hazards in foods include improper agricultural practices accompanied with traditional milk production; poor hygienic activities at all stages of the food chain; lack of preventive and controlling measures in food processing and preparation operations; misuse of chemicals; contaminated raw materials, ingredients and water; inadequate or improper storage etc (Battu *et al.*, 2004; Buncic, 2006).

2.9. Economic Benefits of Milk Safety System and Quality Assurance

The economic benefits of a robust milk safety system and quality assurance are evident in the potential to increase exports and ensure public health. Ahmedsham *et al.,* (2018) emphasizes the need for a stringent food safety system, particularly in traditional milk production, to prevent food-borne illnesses. Anand (2005) underscores the importance of implementing quality and food safety management systems in the dairy sector, especially with the emergence of new product ideas and technologies. Girma (2014) highlights the public health hazards of milk, including biological, chemical, and physical agents, and the need for control measures. Tian & Li (2019) provides a risk assessment of raw milk quality, identifying feeding and management as high-risk areas.

These studies collectively underscore the economic benefits of a strong milk safety system and quality assurance, including increased export potential and public health protection.

Food safety plays a significant role in the national economy and health by; safe-guarding the health of the nation through improved nutrition, enhancing national and international trade, preventing avoidable losses at pre/post-harvest, reducing public health costs by decreasing food borne illness and reducing export and trade barriers, resulting in countries becoming competitive in the global trade (WHO, 2005). High quality of milk is necessary for consumption and eligible for export thereby contributing to the national economy through foreign currency (Ahmedsham *et al.*, 2018).

2.10. Women's Contribution to Milk Quality and Safety

Quality requirements in the food industry stimulate the development of analytical techniques capable of precise component quantification at a reasonable price of analysis (Kessler, 2013). Milk quality is an important factor in the dairy industry. One of the major factors of milk quality is composition, which affects the properties of the milk. Milk fat plays a significant role not only in the nutritional, physical, and chemical properties of milk, but also in the Purchas ability of milk (Upadhyay *et al.*, 2018). Most importantly, dairy farmers are in the business of producing food for human consumption so they must be confident in the safety and quality of the milk they produce. Good dairy farming practice underpins the production of milk that satisfies the highest expectations of the food industry and consumers (FAO, 2011). Milk and milk products are highly nutritious and essential to healthy diets, particularly for children (Walstra *et al.*, 2006). However, the nutritional content of milk, together with its high-water activity, provides an excellent matrix for the growth of a multitude of pathogenic microorganisms (Oladipo *et al.*, 2016).

Cooperatives are one way that farms can reduce waste by individual farmers combining their products for sale and increasing the capacity for milk processing. One downside of combining milk from multiple farms in a single bulk tank is that if if milk from a single farm is adulterated or temperature abused, it could potentially contaminate an entire batch of milk. This is an incentive for all farmers in cooperatives to share food safety management practices (Yilma *et al.*, 2011; Ruben *et al.*, 2017).

Generally, women’s artisanal food production is tending spontaneously to acquire the characteristics of a special informal quality labelling, a “female label”, with connotations of “home-made” and so traditional, pure and healthy (Anthopoulou and Koutsou, 2010). Women play an important but often unrecognized role in the safe production of milk and milk products, particularly in Ethiopia (Garsow *et al.,* 2022). Men are typically responsible for providing enough milk, while women ensure nutritious diets, but women’s limited decision-making power can restrict their ability to provide sufficient safe milk (Galiè *et al.,* 2021). However, their work is often characterized by unhygienic practices, such as the use of non-tap water and plastic containers, which can compromise the safety and quality of the products (Amentie, 2016). This highlights the need for gender-sensitive interventions to improve food safety and overall family health in the dairy value chain in Ethiopia (Garsow *et al.,* 2021).

2.10.1 Milk Handling Practices by Women

Milk quality and safety are a challenge due to unhygienic handling and non-adherence to food safety standards (Nyokabi *et al.,* 2021). Milk contamination results from improper handling, and poor hygiene and sanitation conditions in the milking environment (Olivier *et al.,* 2005). Poor milk quality and food safety risks are a major challenge in the dairy sector in LMICs (low middle-income countries) with weak food safety management systems and low compliance with food safety standards (Amenu *et al.*, 2019; Kussaga *et al.*, 2014). Women, in general, are more concerned about quality and hygiene than men (Johnson *et al.*, 2015). Women play a crucial role in milk quality and safety as they are often responsible for milking, handling, and processing milk and milk products in pastoral communities (Amenu *et al,*. 2019). Garsow *et al.*, 2022 emphasizes that women in Ethiopia play a crucial part in the safe production of milk and milk products, as they are involved in animal husbandry, health, and milking. Traditional roles with women being primarily managing the daily tasks of the farm such as milking and, women may have a greater risk of exposure to food-borne pathogens through the milking and processing of dairy products (Colverson, 2019; FAO, 2017; Grace *et al.,* 2015; Kebede *et al.,* 2020; Kinati & Mulema, 2018; Njuki *et al.*, 2013; Ruben *et al.,* 2017). The findings highlight the intricate relationship between milk quality, cooperative practices, and the often-underappreciated role of women in ensuring the safety and nutritional value of milk and milk products in Ethiopia's dairy value chain.

Conceptual Framework: Gender Roles in Dairy Value Chain & Milk Quality

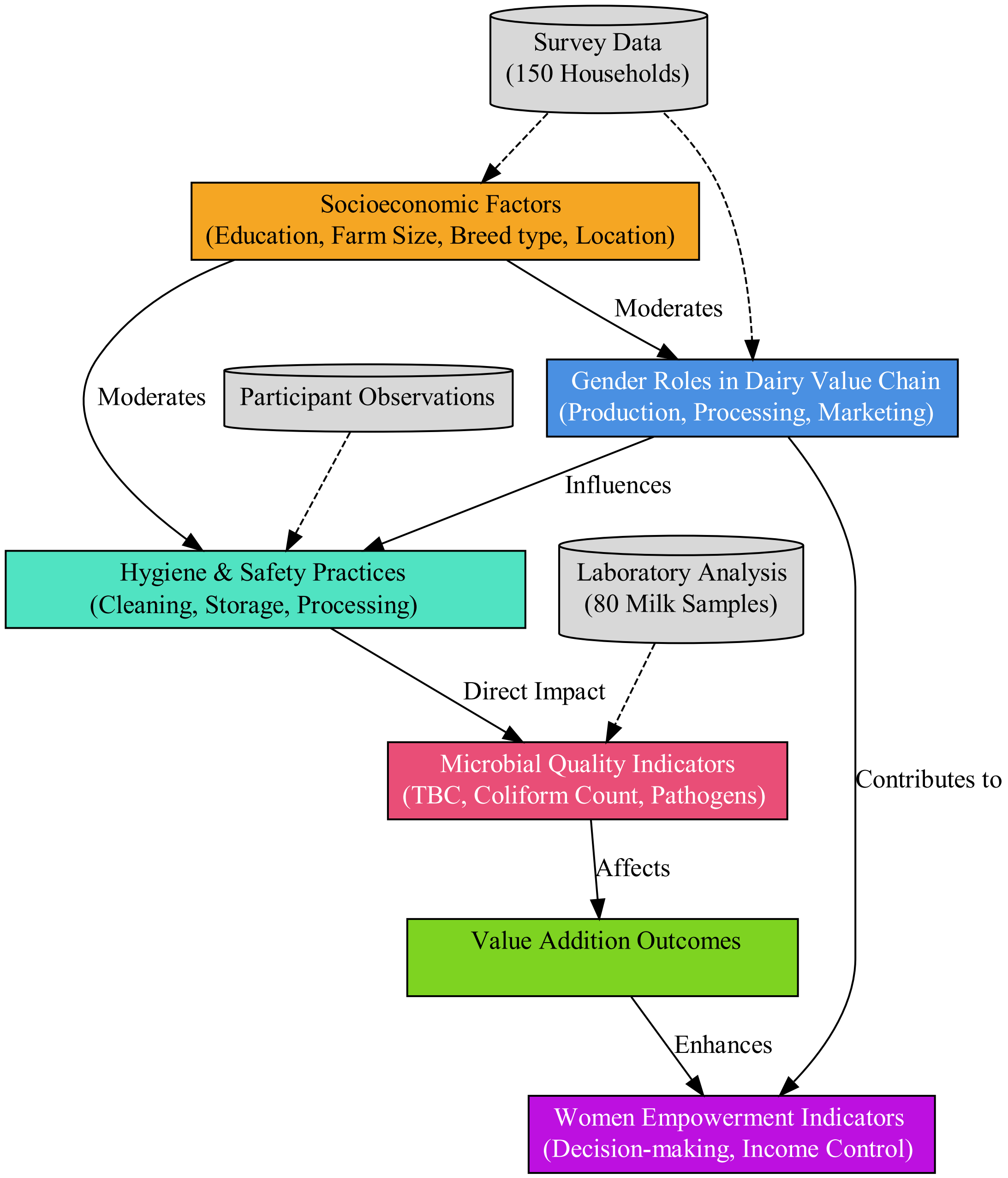

Figure 1. Conceptual Framework

3. GENERAL METHODOLOGY

3.1. Description of the Study Area

This study was conducted in the Shashemene, Hawassa, and Yirgalem districts, area of Ethiopia. The milk area covers a large geographical area, and this research focused on the Shashemene, Hawassa, and Yirgalem district. Hawassa, the capital city of the Sidama region, is located 275 km south of Addis Ababa along the Addis Ababa–Nairobi highway. The city has an altitude of 1,750 meters above sea level and is situated at 6° 83’ to 7° 17’ N latitude and 38° 24’ to 38° 72’ E longitude (AWARDO, 2006).

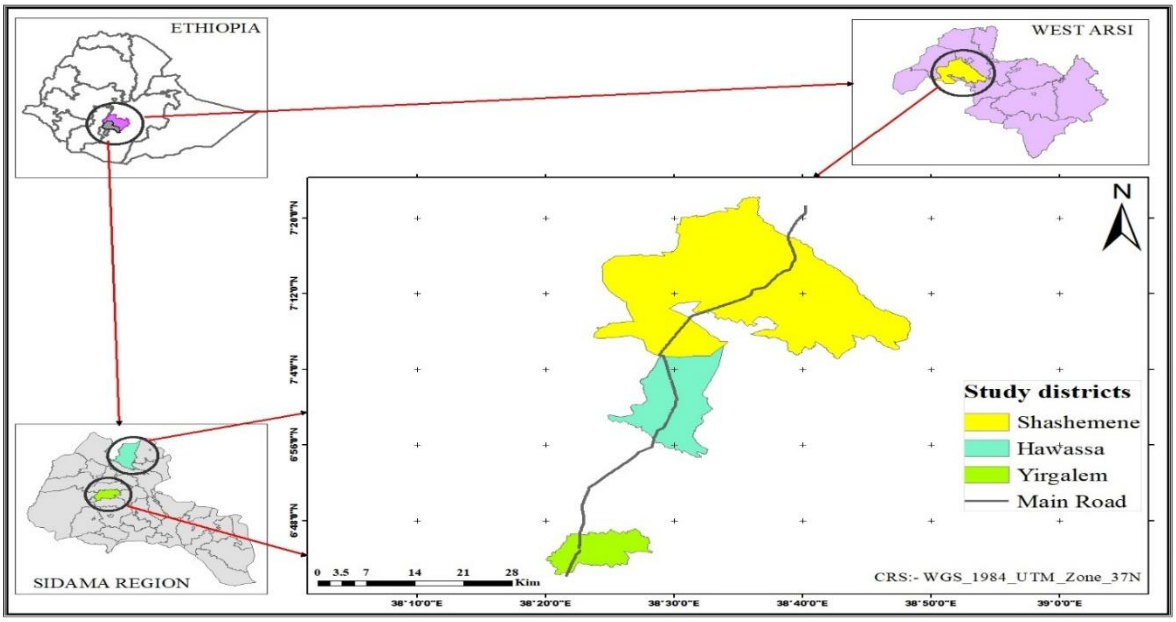

Figure 2: Study Area Map

Hawassa presents significant opportunities for dairy development due to the presence of well-established private and public institutions engaged in dairy research and development. Organizations such as the Netherlands Development Organization (SNV) and the School of Animal and Range Science under Hawassa University’s College of Agriculture, as well as the Research Centre (RC) under the Ethiopian Institute of Agricultural Research (EIAR), contribute to the dairy sector. Also, milk processing centers, including Yirgalem Agro Processing, supply processed milk nationwide.

3.2. Research Design

This research adopted a cross-sectional survey and laboratory analysis approach. Both qualitative and quantitative data were collected using structured and open-ended questionnaires and observations. The microbiological quality of raw whole milk was assessed in the dairy laboratory under the School of Animal and Range Sciences at Hawassa University.

3.3. Data Collection

3.3.1. Survey and systematic observations

Primary data were collected through surveys and observations. The data collection process was designed to actively involve smallholder dairy farmer. The survey instrument was administered to sampled households, incorporating both open-ended and closed-ended questions. Open-ended questions allowed respondents to elaborate on their thoughts, experiences, and opinions, while closed-ended questions facilitated the collection of quantitative data, focusing on the milk value chain system. The study addressed potential oversights by surveying male and female household heads separately. The questions included multiple-choice and Likert scale formats.

The data collection process covered various topics, including hygienic practices during milking, storage, transportation, and marketing, as well as the breed types of cows and feeding systems. The observational checklist was used to quantify dairy management practices across both female- and male-led farm management households. Additionally, secondary data were gathered from government organizations, such as the Hawassa City Livestock Development Office and the Cooperatives Promotion Office.

Observations complemented survey and interview data by offering real-time insights into the daily activities of women in the milk value chain. The observation covered various farm practices like farm infrastructure, herd management, feed management, milking hygiene, milk storage, , transportation practices, hygiene and sanitation, milk processing, value addition activities such as involvement of milk processing, market access, technology adoption, community participation, and community development involvement. A standardized observation protocol was developed to ensure consistency across different sites. On-site observations were documented to assess the practices of milk handlers, and a pre-tested structured questionnaire for the survey in English was translated into the local language.

3.3.2. Microbial assessment in the laboratory

Microbial analysis was conducted to assess the microbiological quality of milk, with samples collected at different stages of production, processing, and distribution. Laboratory analyses were performed to evaluate the microbiological safety and quality of milk. Additional factors such as geographical location, farm size, age, socioeconomic status, education, and rural/urban background were also considered. Microbiological analyses included total bacterial count, coliform count, and Escherichia *coli*. All laboratory work was conducted at the dairy laboratory of Hawassa University's College of Agriculture.

3.3.3. Sampling Strategy and Experimental Procedure

Stratified sampling techniques were employed for the comparative study. The number of elements selected from each stratum was determined using the formula:

By using this formula $= \frac{sample\ \ size\ \ (n)}{no.of\ \ strata\ (k)}$

Select the required number of elements from each stratum with the SRS technique (Ranjit K, 2011).

The population was divided into strata based on gender, and random samples were drawn while considering socioeconomic status, education, age, farm size, and rural/urban backgrounds.

A total of 150 households participated, comprising 75 female led farm management farm management and 75 male led farm management. For microbiological quality analysis, 80 milk samples (40 from male led farm management and 40 from female led farm management) were collected from different stages of the milk value chain, including farms, processing centers, and marketing outlets. Sampling was conducted while considering socioeconomic status, education, age, farm size, and rural/urban background to maintain the integrity of the samples and ensure accurate microbial quality assessment.

3.3.3.1. Bacteriological count

Raw milk quality and microbiological safety are critical for the dairy industry, as contamination can occur from microorganisms, chemical residues, and other sources (Vissers and Driehuis, 2008). According to Burke (2018), microbial quality assessment should begin at the farm level. Deddefo *et al.*, (2023) emphasized the importance of determining microbiological quality and safety at the farm level to ensure the quality of subsequent dairy products. For total plate count (TPC) and coliforms threshold, used Microbial counts were evaluated according to the Ethiopian Standards for raw milk intended for processing (Ethiopian Standards Agency [ESA], 2021). And for E. *coli*, the presence and levels of Escherichia coli in raw milk samples were assessed against international microbiological criteria. Specifically, the thresholds outlined in Regulation (EC) No 2073/2005 of the European Commission on microbiological criteria for foodstuffs were used as the reference standard (European Commission, 2005).

3.3.3.2. Total Bacterial Count (TBC)

Total bacterial count (TBC), also referred to as standard plate count (SPC), aerobic plate count (APC), or viable count, was used to determine the total number of viable bacteria in 1 mL of raw milk, expressed in colony-forming units per milliliter (CFU/mL) (FAO, 2009). The bacterial counts were determined by plating and incubating appropriate dilutions sample volume divided by sample volume +diluted volume, subsequent dilutions were prepared by transferring 1 mL from the previous dilution into 9 mL of fresh diluent, yielding serial dilutions of 10^{-2}, 10^{-3} of milk samples on Standard Plate Count Agar (SPCA) medium at 37°C for 48 hours. Colonies were counted using a manual colony counter, and a count of 10^{7} CFU/mL indicated the end of raw milk's shelf life.

3.3.3.3. Coliform Count

Coliform counts were used to assess potential contamination from udder, milk utensils, or water sources. sample volume divided by sample volume +diluted volume, subsequent dilutions were prepared by transferring 1 mL from the previous dilution into 9 mL of fresh diluent, yielding serial dilutions of 10^{-2}, 10^{-3} etc, of milk samples. The coliform bacteria count was conducted following APHA (1992) guidelines, with samples incubated in Violet Red Bile Agar (VRBA) at 37°C for 24 hours. Coliforms were identified based on their ability to ferment lactose, producing gas and acid within 48 hours at 35°C (Feng *et al.,* 2002). The acceptable coliform limit for raw milk was set at 10 CFU/mL (FDA, 2011).

3.3.3.4. E. coli Identification

The identification of *Escherichia coli* (E. coli) in milk samples was conducted using the Most Probable Number (MPN) method, which involves a series of enrichment, selective, and differential media to confirm the presence of *E. coli*. First, an enrichment step using Tryptic Soy Broth (TSB) was performed to provide a nutrient-rich environment for the growth of *E. coli*. Sterile containers were used to transfer the sample into TSB, and the cultures were incubated at 35°C for 18-24 hours to promote bacterial growth (Bording-Jorgensen *et al.,* 2021). Following enrichment, selective isolation was achieved using MacConkey Agar, which selectively grows Gram-negative bacteria such as *E. coli* while inhibiting the growth of Gram-positive bacteria. A loopful of the enriched culture from TSB was streaked onto MacConkey Agar plates, which were then incubated at 35°C for 18-24 hours. The appearance of pink or red colonies indicated lactose fermentation, characteristic of *E. coli* (Al-blooshi *et al.*, 2021). Finally, to differentiate *E. coli* from other bacteria, a differential media, Eosin Methylene Blue (EMB) Agar, was used. A sample from the pink or red colonies on the MacConkey Agar plate was transferred onto EMB Agar plates and incubated at 35°C for 18-24 hours to confirm the presence of *E. coli* based on its distinct metabolic properties (Lupindu, 2016).

3.4. Data Management and Analysis

In this study, we integrated data from three main sources: household surveys (n = 150), laboratory-based microbial milk tests (n = 80), and structured farm observations. The survey and observational checklist data were collected digitally using Kobo Toolbox.

The household survey provided detailed insights into demographic characteristics, socio-economic conditions, and farm management practices. To ensure balanced gender representation, we included 75 respondents from male led farm managementled farm management households and 75 from female led farm managementled farm management households. For the microbial testing, raw milk samples were collected from 80 households, equally divided between male led farm management and female led farm management, and analyzed in the laboratory for three key indicators of milk safety and quality: Total Plate Count (TPC), Total Coliform Count, and Escherichia coli (E. coli). Simultaneously, we conducted on-site assessments of farm hygiene, infrastructure, and milk handling practices using a structured observational checklist rated on a 5-point Likert scale.

All data were first entered and verified in Microsoft Excel. We performed thorough checks for missing values, outliers, and inconsistencies before importing the cleaned datasets into SPSS (version 27) and R (R version 4.4.2 (released on *October 31, 2024*, codename: *"Pile of Leaves*) for further analysis. To stabilize variance and meet the assumptions of statistical tests, microbial count data were log-transformed using the formula $\log_{10}$ (CFU/mL + 1), following the recommendations of the American Public Health Association (1992), as cited by Dehinenet *et al.*, (2013).

For Total Plate Count, we used a three-tier classification system commonly referenced in food safety literature: low (<10,000 CFU/mL), medium (10,000–99,999 CFU/mL), and high (≥100,000 CFU/mL), based on standards from Jay *et al.*, (2005) and the FAO & WHO (2006). Total Coliform Count data were analyzed both with a Wilcoxon rank-sum test (on log-transformed values) and a chi-square test using a median-based categorical split. E. coli contamination was categorized into 'Low' (≤100 CFU/mL) and 'High' (>100 CFU/mL), following European Commission Regulation (EC) No 2073/2005.

Descriptive statistics such as means, standard deviations, frequencies, and percentages were used to summarize household characteristics, hygiene scores, and microbial loads. Including chi-square tests and Fisher's Exact Tests, were then used to examine associations between gender and various factors related to dairy practices and milk safety (microbial quality). This multi-source, multi-method approach allowed us to capture a nuanced picture of gendered differences in Ethiopia's smallholder dairy sector.

Model $\log(P / (1 - P)) = \beta_0 + \beta_1(\text{Gender}) + \beta_2(\text{Age}) + \beta_3(\text{Urban}) + \beta_4(\text{Education}) + \beta_5(\text{Hygiene}) + \beta_6(\text{Infrastructure}) + \beta_7(\text{TPC}) + \varepsilon$

Where:

P: Probability that a household engages in milk processing

β_0: Intercept

β_i: Coefficients of the respective predictors

ε: Error term

4. RESULTS AND DISCUSSION

4.1. Socio-economic characteristics study households

Figure 3 illustrates the key demographic profiles of our 150 household heads 75 women and 75 men led farm management living in Hawassa, Shashemene, and Yirgalem. When we look at age, most household heads in both groups fall between 31 and 50 years old. About one-third of women (32 %) and men (34 %) are aged 31–40, and roughly a quarter fall into the 41–50 bracket (28 % of women, 26 % of men). Men are a bit more likely to be younger than 30 (28 % vs. 22 %), while women are slightly more represented among those aged 51 and above (18 % vs. 12 %). Education levels also track closely between genders: around 60 % of both women and men have completed primary or secondary school. Beyond that, however, more men hold university degrees (24 % versus 16 %), and more women report having had no formal schooling at all (20 % compared to 12 % of men). Religious affiliations mirror one another almost exactly. Orthodox Christianity is most common (48 % of men, 45 % of women), followed by Protestantism (30 % and 32 %, respectively) and Islam (15 % of men, 18 % of women), with the rest practicing traditional or other faiths.

The slightly younger profile of male heads might hint at earlier household formation or labor migration, whereas the greater share of older female heads could reflect scenarios like widowhood and women stepping into leadership roles. The gap in tertiary education between men and women points to ongoing barriers for women accessing higher learning barriers that could affect everything from adopting new farm technologies to engaging with extension services.

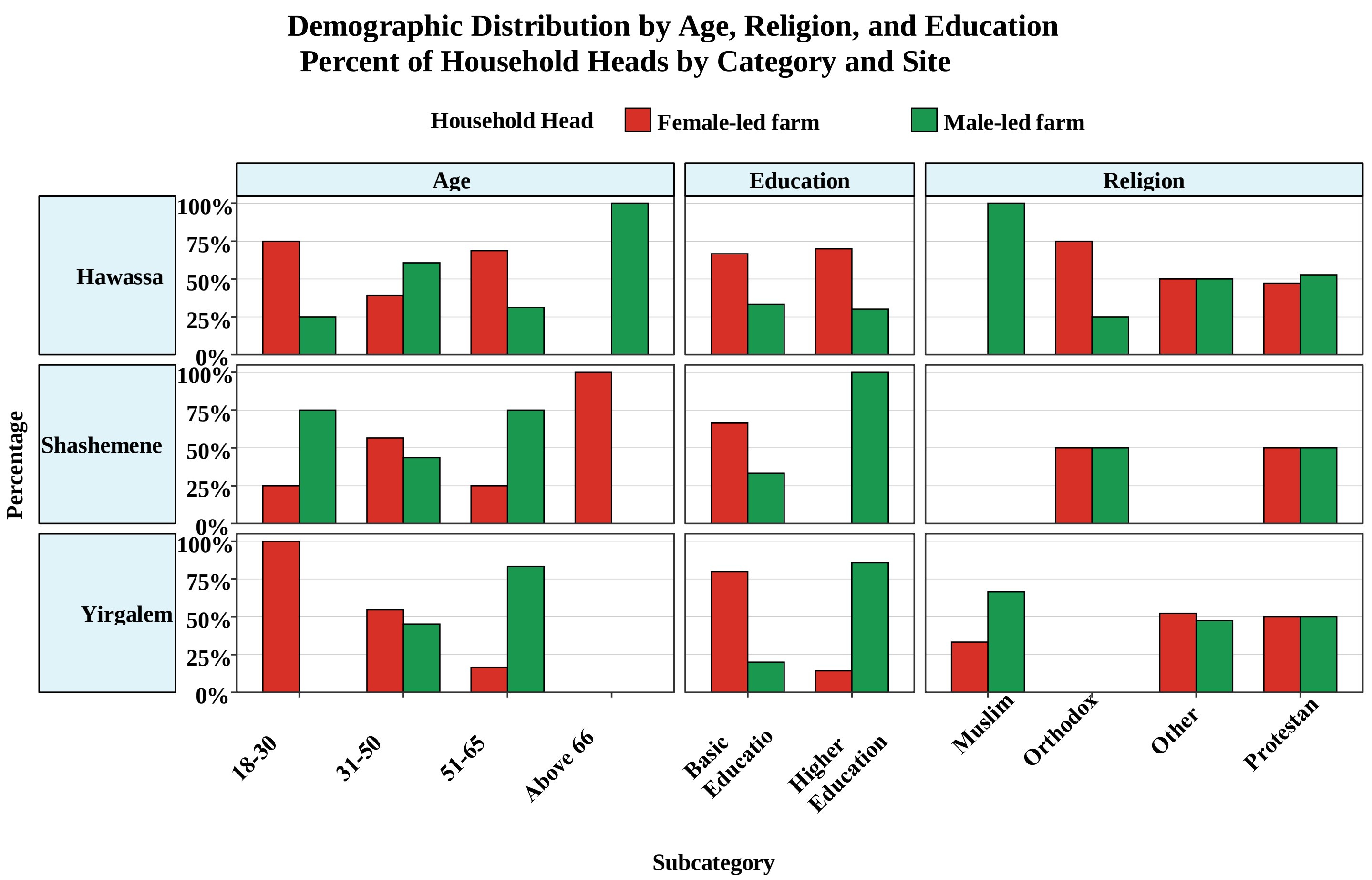

Figure 3 Percentage distribution of household head age, education and religion among male-led farm management and female-led farm management dairy farm households in the study area.

Figure 4 below shows the marital status of household heads. When we look at household heads, we find that a significant portion of households (83.3%) are currently married, which includes 92.0% of men and 74.7% of women-led farm management farms. Interestingly, only 4.0% have never tied the knot, with 5.3% being men and 2.7% women. Additionally, 3.3% are separated, which breaks down to 2.7% of men and 4.0% of women. It's worth noting that all the widowed household heads in this sample are women, representing 18.7% of female heads, while there are no widowed male heads. The dominance of marriage, especially among men (92 %), reflects common household formation patterns, while the fact that all widowed heads are women (18.7 %) highlights their longer life expectancy or men's greater out-migration and risk exposure. Widowed women may face extra financial burdens, strain, limited labor capacity, or social stigma, so programs in farm management, dairy hygiene, and credit should offer targeted support to help them sustain their households effectively.

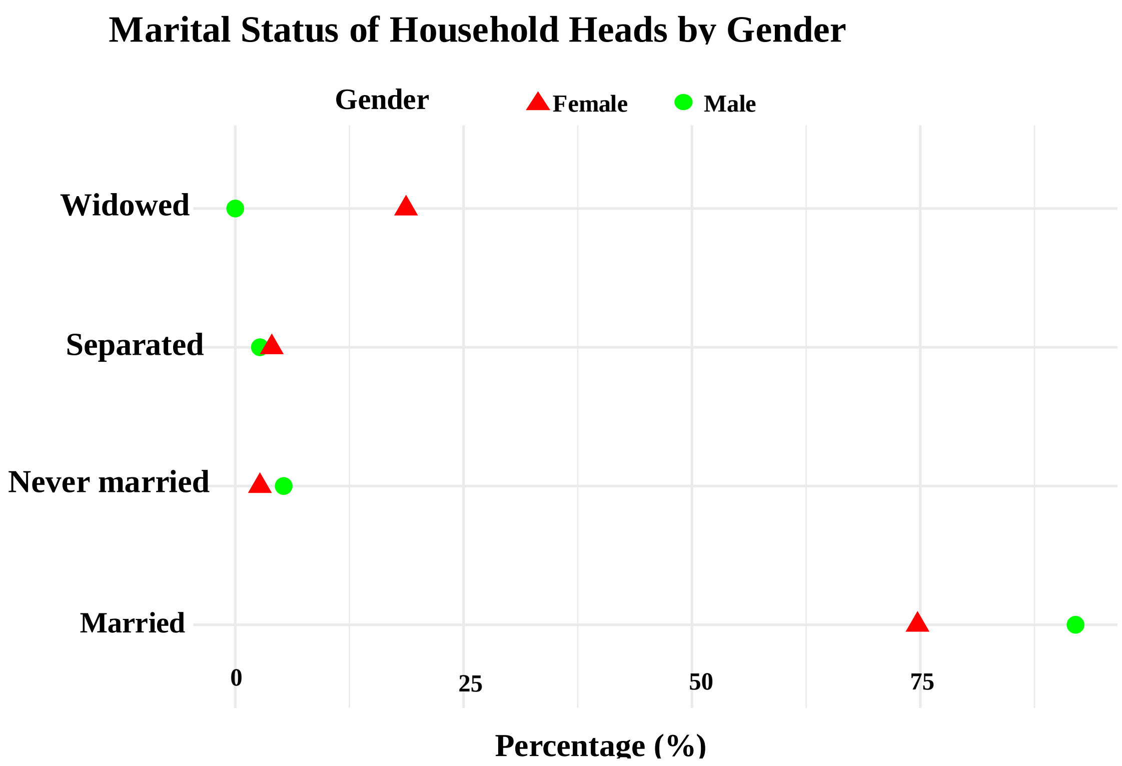

Figure 4. Marital status of led farm management by gender

4.2. Dairy Farm Size

In this study, dairy farms were categorized into three groups based on herd size small-scale farms (1–5 dairy cows), medium-scale farms (6–20 dairy cows), and large-scale farms (more than 20 dairy cows). These thresholds were adapted to better reflect the actual herd size distribution observed in the in Shashemene, Hawassa, and Yirgalem districts, and other peri-urban areas. While Mureda and Mekuriaw (2008) defined farm sizes in Eastern Ethiopia as small (≤5 cows), medium (6–30 cows), and large (≥72 cows), the present study refined these categories by narrowing the medium-scale range and lowering the threshold for large-scale farms. This adjustment aligns with classifications applied in other urban and peri-urban dairy contexts in Ethiopia (ILRI, 2020; Belete, 2009), providing a more context-appropriate basis for analysis. As shown in Figure 5, dairy farm size was further disaggregated by gender of household head, study location, and cattle breed. The majority of farms were small-scale (<5 cows), accounting for 69.4% of the sample, with male-headed households managing 72.2% of these farms. Medium-scale farms (6–20 cows) comprised 28.5% of the sample, where female-headed households (30.6%) slightly outnumbered their male-headed counterparts (26.4%) suggesting women's increasing participation in mid-sized dairy operations. Large-scale farms (>20 cows) represented only 2.1% of the total, with a notably higher share of female-headed households (2.8%) compared to male-headed households (1.4%) in managing large herds. These patterns support the relevance of the adjusted classification system and highlight evolving gender dynamics across different farm scales in the region.

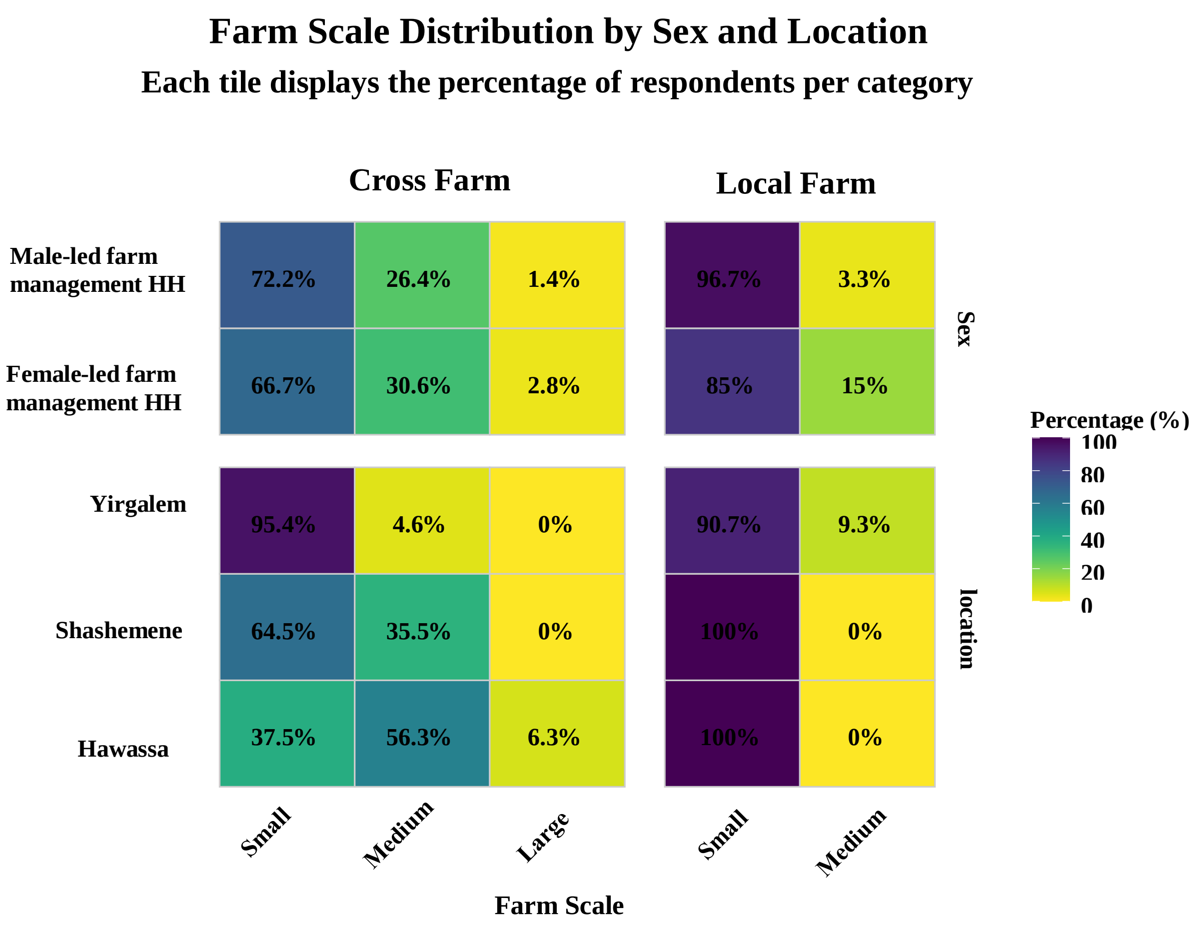

Figure 5. Heatmap of farm scale percentages by household head type (top: female-led farm management vs. male-led farm management HH) (bottom: Hawassa, Shashemene, Yirgalem) across Cross and Local Farms. Darker tiles indicate higher percentages.

This aligns with previous findings that dairy production in developing regions, particularly in Sub-Saharan Africa, is predominantly characterized by smallholder systems with very few large-scale operations (FAO of the United Nations, 2013). The study further compared male-led farm management and female-led farm management households in terms of dairy cattle breed ownership. Female-led farm management households are more likely to focus on local dairy cattle farming, particularly in rural settings. These gender-based patterns are consistent with other findings where access to resources such as land, credit, and extension services has been identified as a significant. This study highlights that female-led farm management households demonstrate notable involvement in medium- and large-scale farming, presenting an opportunity for targeted support to boost productivity. While small-scale farming remains the most common, interventions aimed at improving efficiency and sustainability are critical for both genders. Furthermore, tailored strategies that address the unique challenges faced in rural versus urban areas, along with gender-sensitive interventions, are crucial for promoting sustainable dairy development (FAO, 2019).

4.3. The role of gender in dairy farm management

As illustrated in Figure 6, in female led farm management households, the purpose of keeping dairy cows falls to three main categories namely milk for home and sale, for sale of raw milk only, and to process and consume it at home. While in male led farm management households, milk is mainly produced for two main reasons, as for home consumption and sale as well as for sale only. Both female-led farm management and male-led farm management households primarily keep dairy animals to produce milk for household consumption, with 10% of all households reporting this as their sole motivation. Large proportion of male-led farm management households 48% were more involved in milk sales that their counter female-led farm management households with only 29.3%.

A smaller but noteworthy group (14%) of exclusively female-led farm management households reported raising dairy animals for a combination of household use, raw milk sales, and butter production, indicating a broader approach to value addition. Conversely, raw milk sales alone accounted for 36% of household motivations, with male-led farm management households (41.3%) more likely to rely solely on this income stream than female-led farm management households (30.7%).

These gender patterns in dairy cattle management reflect the broader socio-economic differences which also somehow indicates income diversification and market engagement. As supported by studies like Njuki *et al.*, (2011) and Mutua *et al.*, (2014), female dairy farmers often pursue multi-product strategies (milk, butter, ghee) to meet household needs and mitigate market barriers, while men more frequently specialize in raw milk sales due to stronger market linkages and resource access. These findings also reaffirm Kristjanson *et al.*, (2010), who explained that women's roles in livestock systems are more tightly linked to food security, whereas men are more market-oriented.

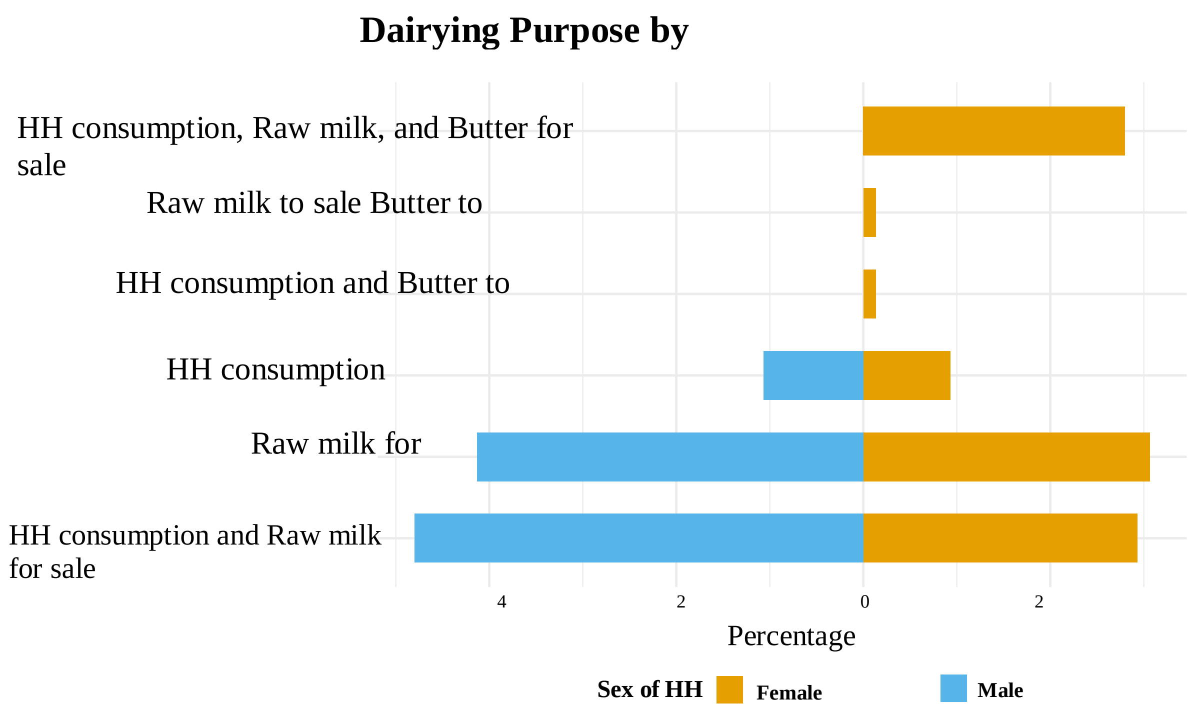

Figure 6 Purpose of keeping dairy animals

Figure 7 shows dairy animal feed resources and role of gender in feed management. The figure shows that roughages and roughage combinations are the predominant feed choices for both female- and male-led farm management households. Among all respondents, 29.3% used roughages alone, with female-led farm management households slightly ahead (32%) compared to male-led farm management households

(26.7%). Similarly, a mix of roughages and by-products was reported by 30% of households, with female-led farm management households (32%) again slightly more inclined than male-led farm management ones (28%).

Interestingly, when it comes to roughages paired with concentrates, male-led farm management households showed a marked preference: 40% compared to only 25.3% among female-led farm management households. Meanwhile, mixed feed was the least used overall, reported by just 8% of households, predominantly female-led farm management (10.7%) compared to male-led farm management (5.3%).

These findings suggest that while roughages and by-products are core to feeding strategies for both genders, male-led farm management households are more inclined towards concentrate use, likely due to greater access to financial resources or commercial feed markets (Tegegne *et al.*, 2013; Tangka *et al.*, 2002). Female-led farm management households, on the other hand, maintain diversified but often lower-cost feeding systems, consistent with their adaptive strategies noted in similar smallholder systems (FAO, 2011; Njuki *et al.*, 2011).

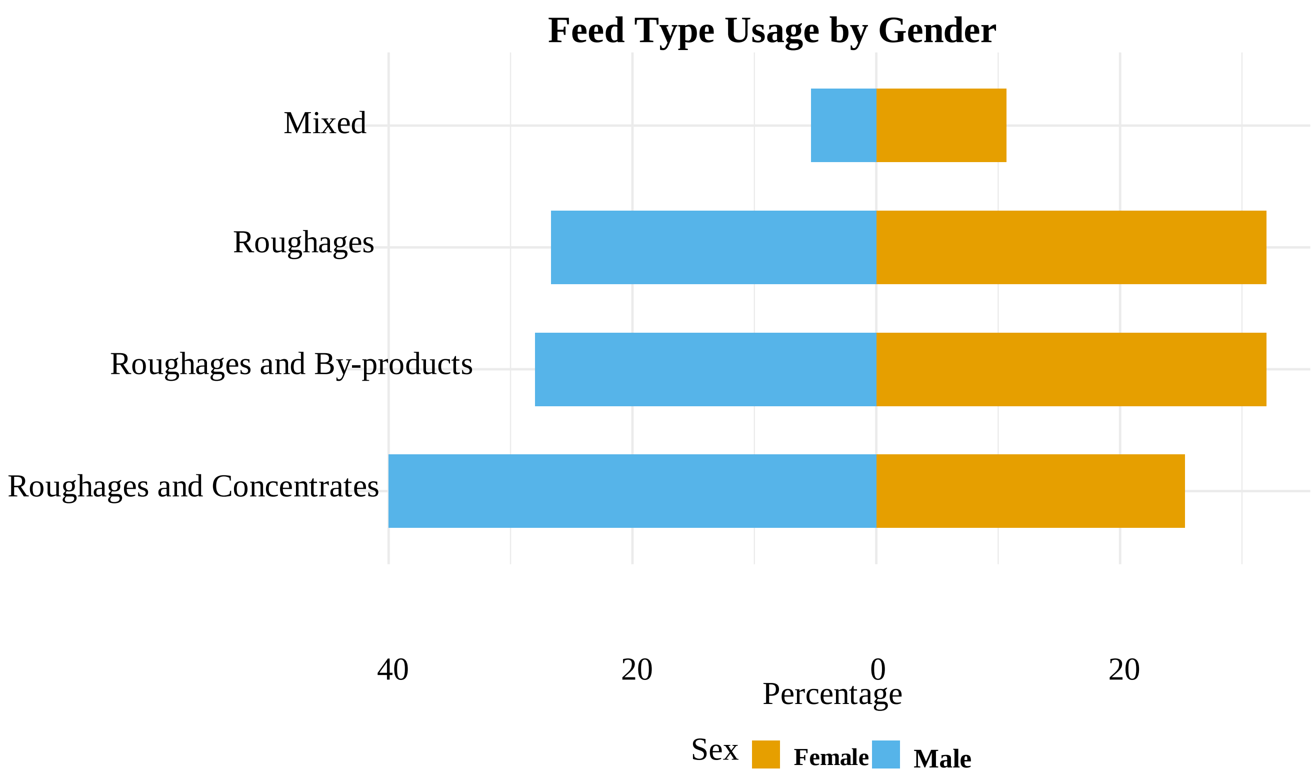

Figure 7. Major feed resources by Gender HH

4.4. The role of gender in dairy barn management and animal care practices

Figure 8 shows dairy barn management and the role of gender. The way cleaning time is distributed in dairy barns and sheds shows some interesting differences between households led by men and those led by women. For male-led farm management households, 16.7% spent four hours cleaning, while 30.7% (23 households) dedicated two hours, and 21.3% (16 households) only spent one hour. On the flip side, female-led farm management households mostly spent three hours on cleaning, with a striking 85.3% (64 households) reporting this duration. Only 14.7% of female-led farm management households took four hours to clean, and none reported spending just one or two hours.

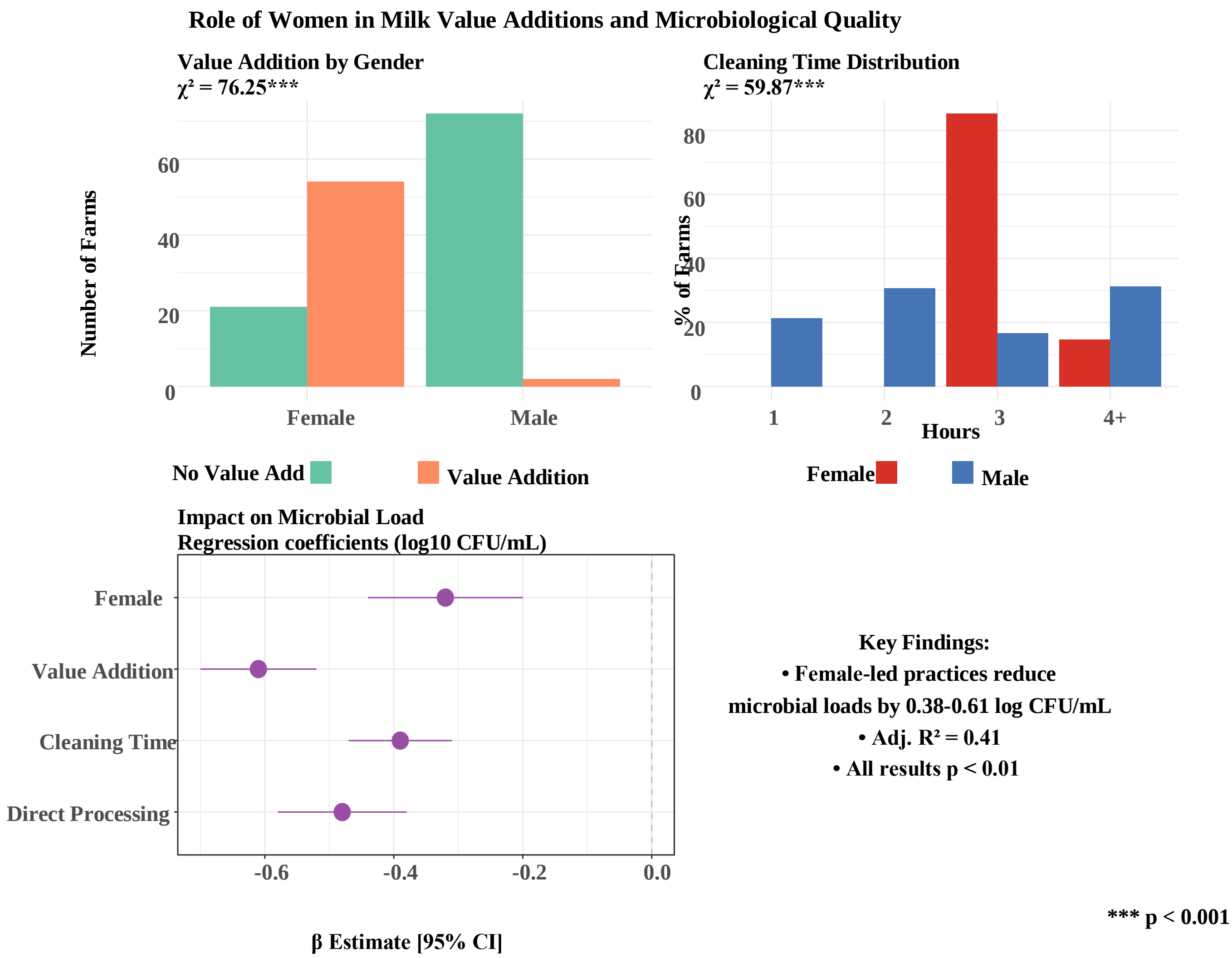

Figure 8 Role of Women in Milk Value Additions and Microbiological Quality

When we look at the Chi-Square test for independence, it shows a significant difference in cleaning times based on the sex of the household head. The Pearson Chi-Square value came in at 59.872 ($p < 0.001$), and the effect size, measured by Cramer's V, was 0.632, indicating a strong effect. This suggests that the time spent cleaning the dairy barn or shed is closely linked to whether the household is led farm management by a man or a woman. Overall, it seems that male-led farm management households have a more varied approach to cleaning times, while female-led farm management households tend to stick to a more consistent three-hour routine. These findings align with studies by Keba *et al.* (2025) and Amenu *et al.* (2020), which underscore the pivotal role women play in enforcing consistent and hygienic milk handling practices. Both studies employed observational checklists and noted that women's involvement in daily barn sanitation was significantly more structured and time-intensive. Similar gendered patterns in agricultural labor division and attention to hygiene have been reported in other contexts as well (Njuki *et al.,* 2011; Kristjanson *et al.,* 2014).

4.5. The role of gender in dairy cows' health management

The way animal service providers are distributed among farmers shows some interesting gender-based trends in how these services are used. Most households, whether led by women or men, reported reaching out to animal health professionals for help. Specifically, 69.3% of female-led farm management households and 57.3% of male-led farm management households turned to these experts, making them the top choice overall, with 63.3% of all respondents seeking their assistance. This indicates that female-led farm management households are more proactive in engaging with animal health professionals, representing 34.7% of all participants, while male-led farm management households accounted for 28.7%. Veterinarians came in as the second most sought-after option, with 30.7% of female-led farm management households and 40% of male-led farm management households relying on them, which together makes up 35.3% of the total sample. On the other hand, traditional animal service providers were hardly used, with only two male-led farm management households (2.7%) reporting their use, and none from female-led farm management households.

Both female- and male-led farm management households depend significantly on modern animal health services, but it seems that female-led farm management farms are more proactive in seeking help from professionals. Interestingly, traditional service providers are seldom utilized, indicating a shift towards formal veterinary care. This trend mirrors findings from Ethiopia, where there's an increasing demand for animal health services and noticeable gender differences in access and usage (Gizaw *et al.*, 2021). It underscores the importance of developing more inclusive and gender-sensitive veterinary outreach, particularly in rural communities.

Table 1, Distribution of Animal Service Providers by Gender of Household Head

Animal Service Providers	**Female (%)**	**Male (%)**	**Total (%)**
Animal health professionals	69.3	57.3	63.3
Traditional	0	2.7	1.3
Veterinarians	30.7	40	35.3

As illustrated in Figure 9, the way animal health management is handled varies between households led by women and those led by men. Interestingly, a significant proportion (77.3%) of female-led farm management households take charge of their animals' health themselves, while only 53.3% of male-led farm management households do the same. This translates to 58 female-led farm management households, making up 38.7% of the total, practicing self-management, compared to 40 male-led farm management households, which account for 26.7%. On the flip side, a larger share of male-led farm management households 46.7% turn to someone else for help with animal health, whereas just 22.7% of female-led farm management households do. Overall, 52 households, or 34.7%, seek assistance from others, with 35 of those being male-led farm management households, representing 23.3% of the total.

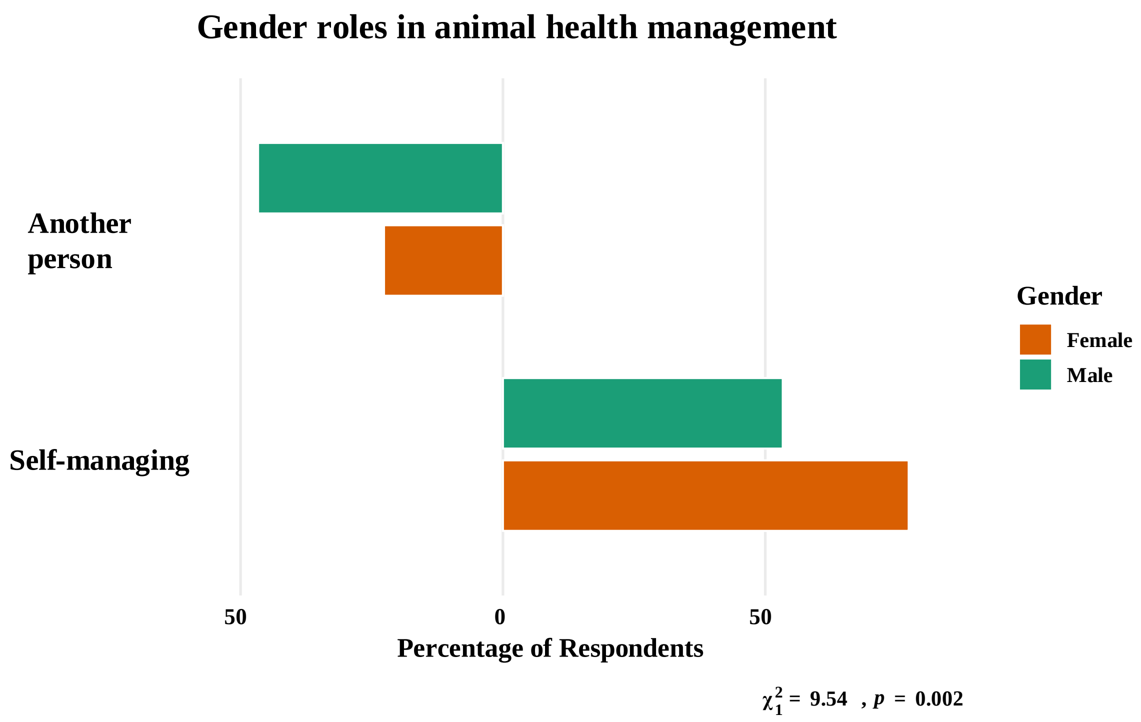

Figure 9: Gender differences in managing animal health among dairy households.

When we look at the Chi-Square test for independence, it reveals a significant link between the sex of the household head and how animal health is managed. The Pearson Chi-Square value stands at 9.537 (p = 0.002), indicating a strong association. These findings suggest that female-led farm management households are more inclined to manage animal health on their own, while male-led farm management households tend to seek help from others.

The results indicate that female-led farm management households are more likely to manage animal health on their own, potentially due to limited access to external support or a stronger sense of responsibility. In contrast, male-led farm management households more often seek assistance, possibly reflecting different management styles or better access to resources. These findings are consistent with recent research showing that women farmers frequently face barriers such as time constraints, mobility limitations, and social norms that reduce their access to veterinary and extension services (Gemechu, 2023). The significant Chi-Square result reinforces the importance of integrating gender considerations into the design of animal health and extension programs to ensure they are accessible and effective for all households.

4.6 Milk production and processing

4.6.1. Gender role in milk production

The analysis of milk production roles by gender highlights some important differences between households led by women and those led by men. Large proportion (93.3%) of female-led farm management households report that they handle both animal care and milk production, while only 42.7% of male-led farm management households share these duties. The most common role for men in these households is just animal care, with 13.3% focusing solely on that task 10 male-led farm management households, or 6.7% of the total, identified it as their main responsibility. Additionally, 22.7% of male-led farm management households mentioned they have other tasks related to milk production, totaling 17 households (11.3%). On the flip side, female-led farm management households are much less likely to take on just animal care or other roles. A mere 1.3% of them are solely responsible for animal care, and 5.3% report having other responsibilities. Interestingly, 70 female-led farm management households (46.7% of the total) manage both animal care and milking.

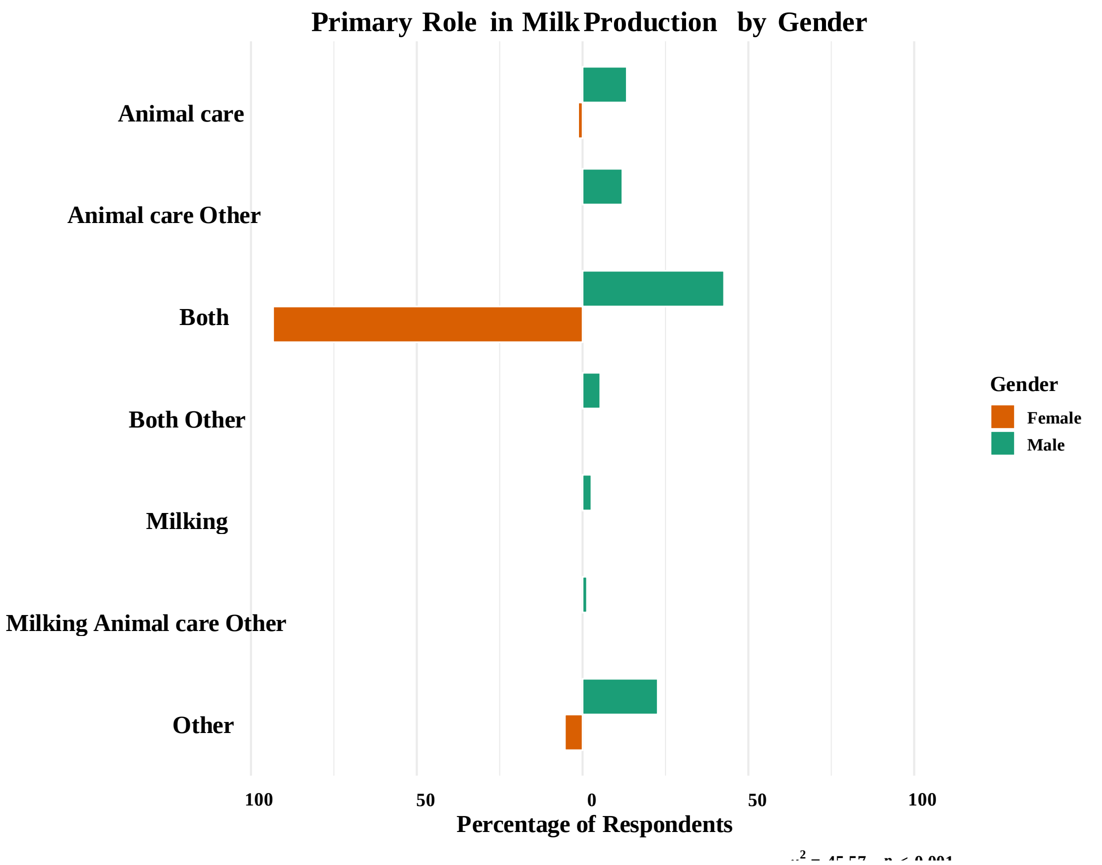

Figure 10. Primary Role in milk Production by Gender HH

The results from the Chi-Square test reveal a strong connection between gender and primary roles in milk production, with a Pearson Chi-Square value of 45.568 ($p < 0.000$). The effect size, measured by Cramer's V, stands at 0.551, indicating a significant impact. This suggests that roles in milk production and animal care vary notably depending on whether the household head is male or female. Female-led farm management households are more likely to juggle both responsibilities themselves, often out of necessity due to limited help at home and a strong commitment to essential farm tasks. In contrast, male-led farm management households tend to split these responsibilities, with men focusing more on specific tasks like animal care, which may reflect different gender expectations or better access to resources.

A study in the Afar region of Ethiopia supports this, showing that women in female-led farm management households take on a broader range of livestock duties because of limited external support, while men in male-led farm management households often concentrate on particular roles, with other family members assisting elsewhere (Nigussie, Hoag, & Alemu, 2014). Similarly, research from the Somali region highlights the critical but often under-recognized role of women in livestock management, despite their challenges in accessing resources and decision-making power (Foelster, Buluma, & Kamel, 2024). These findings align with broader research indicating that women frequently manage multiple livestock-related tasks but lack adequate recognition and support (Kristjanson *et al.,* 2010).

Together, these patterns underscore the urgent need for gender-sensitive extension services that truly reflect and support the realities of who is doing the work in livestock and milk production.

4.6.2. Gender role in milk processing

Large proportion (77.3%) of female-led farm management households are actively engaged in milk processing at home, while only 4.1% of male-led farm management households can say the same. A significant 95.9% of male-led farm management households are involved indirectly in milk processing, compared to only 22.7% of female-led farm management households. When we look at the bigger picture, 59.1% of all households are indirectly involved in milk processing, with 47.7% of those being male-led farm management. In contrast, 40.9% of households are directly involved, and the majority of those (38.9%) are female-led farm management. The results from the Chi-Square test show a statistically significant link between gender and involvement in milk processing, with a Pearson Chi-Square value of 82.724 ($p < 0.000$). Additionally, the effect size measured by Cramer's V was 0.745, which indicates a very strong effect. This suggests that female-led farm management households are much more likely to be directly involved in milk processing, while male-led farm management households tend to be more indirectly involved.

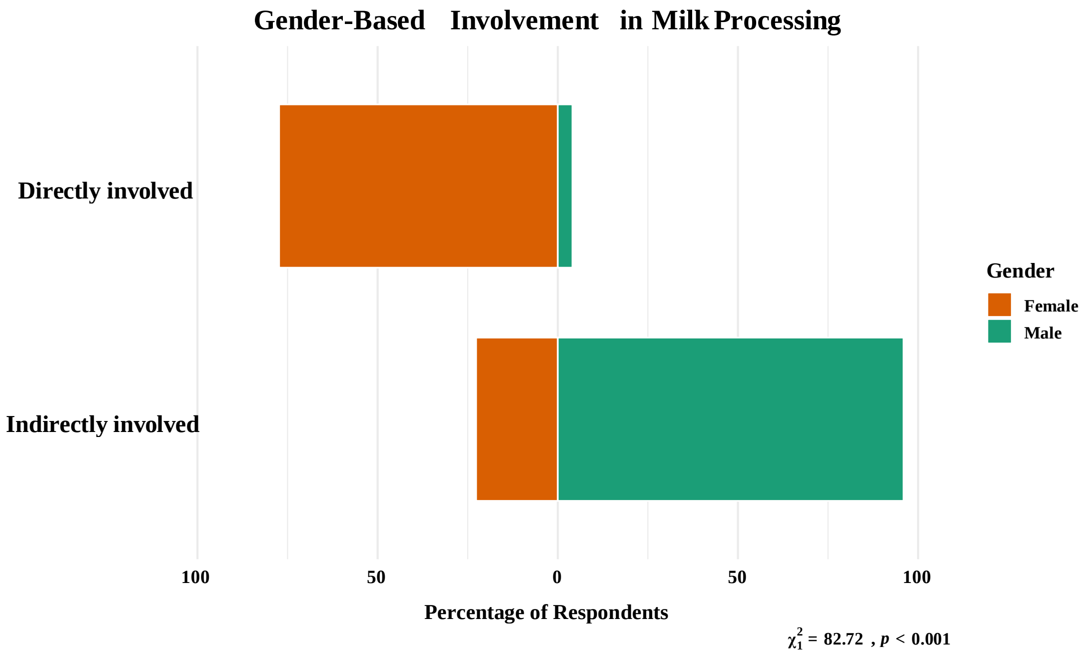

Figure 11. Involvement in Milk Processing

4.7. Income from dairy products

Figure 13 shows the income of farmers from dairy sales, as disaggregated by study locations total income. In Hawassa, 44.1% of households fall into the low milk income category, accounting for households 27.6% of the total sample. On the other side, a larger portion of households 55.9% have high milk income, households representing 14.2% of the total. There are no households in Hawassa that fall into the middle-income category for milk. Moving over to Shashemene, the numbers tilt heavily towards high milk income, with an impressive 93.8% of households reporting high income. Just 6.3% are in the low-income bracket, and again, there are no middle-income households here. Yirgalem presents a more even picture, with 29.4% of households reporting low milk income. A small slice, about 7.4%, fall into the middle-income category, while a solid

63.2% of households in Yirgalem report high milk income. To sum it all up, both Hawassa and Yirgalem have a good number of households with high milk income, but Shashemene stands out with an overwhelming majority reporting high income. Low-income households are more common in Hawassa and Yirgalem, but they're quite rare in Shashemene.

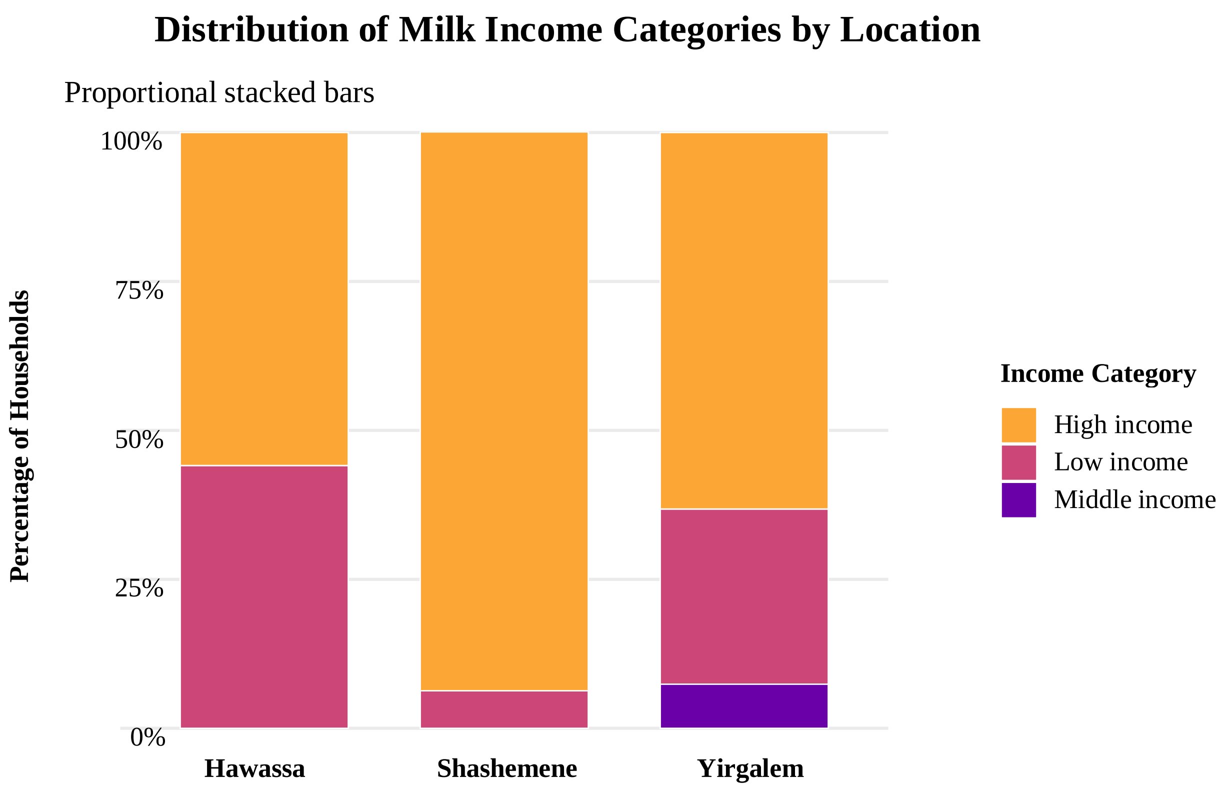

Figure 12: Total income by location

Figure 13 shows dairy incomes as disaggregated by gender. The breakdown of total milk income by gender shows that female- and male-led farm management households have a pretty balanced income distribution. Both types of households report similar percentages across different income brackets. When we look at low-income households, 28.4% of female-led farm management households report low milk income, while 26.9% of male-led farm management households are in the same boat. This indicates a slight edge for female-led farm management households in this category. For middle-income households, the numbers are 3.0% for female-led farm management households and 4.5% for male-led farm management households. The difference is minimal, but it does show a slightly higher percentage of male-led farm management households in this income range. Most households, regardless of gender, report high milk income, with 68.7% of both groups landing in this category.

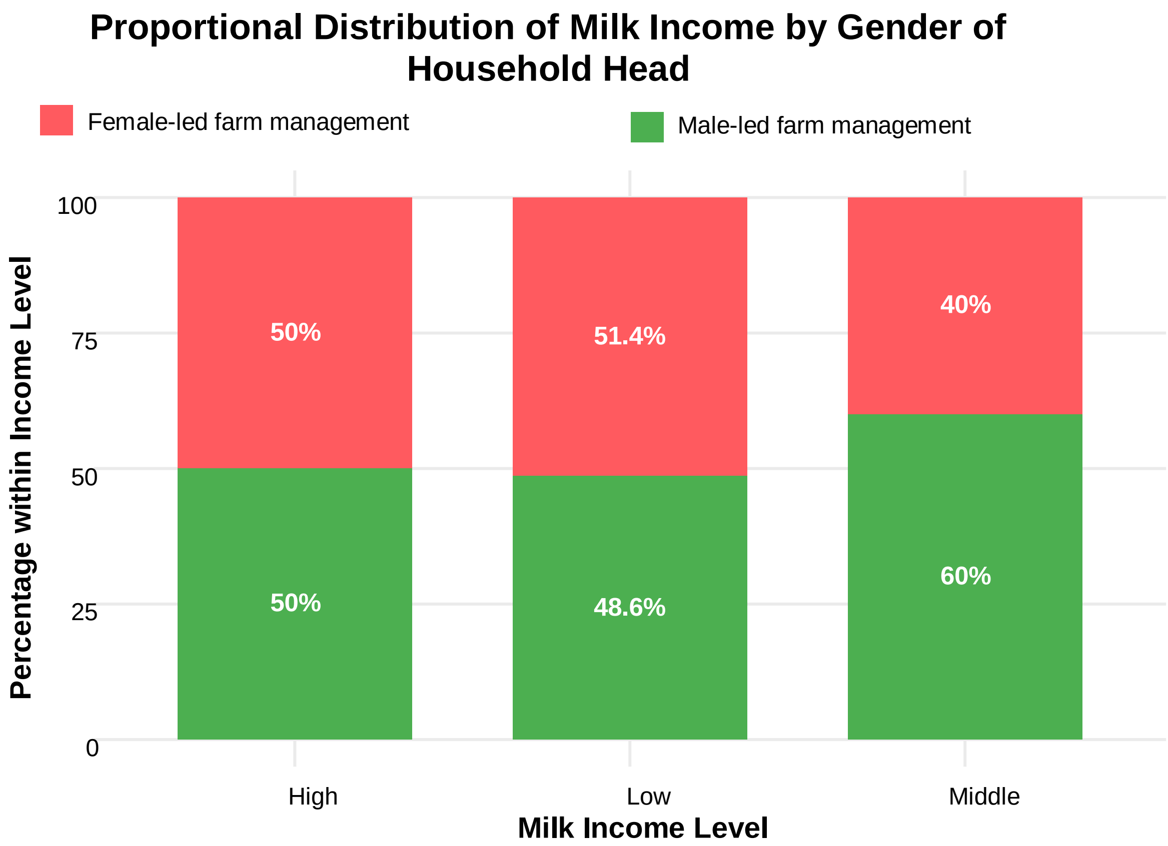

Figure 13: Distribution of income by sex of HH

It's crucial to recognize that these findings might obscure deeper gender-related disparities in areas like labor, asset ownership, and decision-making authority that income categories alone don't reveal. As Kristjanson *et al.*, (2010) pointed out, traditional gender roles within households often lead to unequal control over income, assets, and productive resources, which can have a significant impact on economic outcomes. Moreover, research from Doss (2013) and Quisumbing & Maluccio (2003) highlights that women's involvement in decision-making especially concerning agricultural resources might not be adequately represented in income distributions. Additionally, qualitative research could shed light on how income is generated, utilized, and managed within households, particularly when gender dynamics play a role in resource allocation (Njuki & Sanginga, 2013).

4.8 Observations on dairy farms: role of gender in Dairy Farm Management Practices

The results revealed that out of the 14 variables, 8 demonstrated statistically significant differences ($p < 0.05$) between the two household head categories. Chi-Square tests were primarily used for the analysis, and Fisher's Exact Test was applied for those variables with small expected frequencies where the Chi-Square assumptions were not met.

Female-led farm management households (FHHs) were found to have significantly higher engagement or better practices in several critical areas. Specifically, milking hygiene ($p = 0.0001$), milk storage ($p = 0.0027$), product quality and safety measures ($p < 0.0001$), and hygiene and sanitation practices ($p = 0.0002$) were all more consistently observed among female-led farm management households. These findings suggest that FHHs may be more attentive to hygienic and quality-related practices in milk production, which are essential for ensuring food safety and consumer health.

In addition to hygiene practices, FHHs were also more involved in milk processing activities ($p < 0.0001$) and the utilization of value-added opportunities ($p < 0.0001$), indicating a stronger role in transforming raw milk into processed products, potentially as a strategy to increase household income and product shelf life. Furthermore, FHHs showed significantly better practices in feed management ($p = 0.0282$), which may reflect careful resource allocation or stronger adherence to nutritional requirements for livestock.

Conversely, male-led farm management households (MHHs) showed higher involvement in farm infrastructure development ($p = 0.0482$) and herd management practices ($p = 0.0021$). This suggests that MHHs may have greater access to capital and labor for infrastructure investment, or they may prioritize herd expansion and routine animal care more than FHHs.

For the remaining six variables transportation practices, access to markets, technology adoption, community social aspects, and community development initiatives no statistically significant gender differences were observed ($p > 0.05$). This indicates that both male-led farm management and female-led farm management households face similar conditions or exhibit comparable behaviors in these domains, possibly due to shared challenges or equal exposure to external interventions such as community programs and training.

Findings from the observational checklist in this study highlight meaningful gender-based disparities in several key areas of dairy farming, particularly those related to hygiene, milk processing, and feed management. Female-led farm management households demonstrated greater attention to milk safety and value addition, while male-led farm management households had advantages in physical infrastructure and herd management. These insights suggest the need for gender-responsive agricultural interventions that build on the strengths of each group while addressing their specific constraints to enhance overall productivity, quality, and economic outcomes in dairy value chains.

Gender Comparison of Dairy Practice Ratings

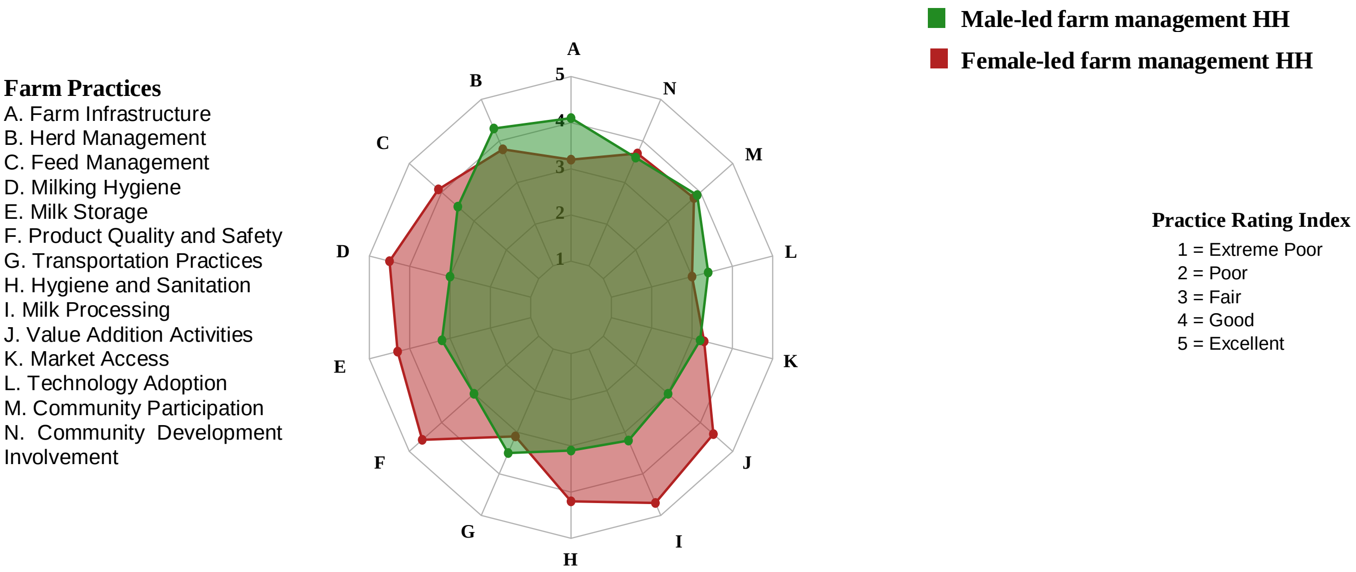

Figure 14: Farm management practice from observational checklist

This study adds to the growing body of research that highlights women's often underrecognized contributions to dairy management. While Keba *et al.*, (2025) used a similar observational approach to track improvements in dairy hygiene after training programs. Amenu *et al.*, (2020) relied on what farmers said they did, rather than what was directly observed and they acknowledged this as a limitation. By combining reported data with on-site observations, this study fills that gap and provides a more complete, trustworthy picture. It also shows how powerful observational tools can be when it comes to understanding and comparing gender roles in farming practices.

4.9 Microbial quality and safety of milk

4.9.1 Total plate count (TPC)

As shown in Figure 14, in this study, while all milk samples from both female- and male-led farm management households met the Ethiopian Standard for microbial load (≤1,000,000 CFU/ml), a closer look at the data revealed a notable gender-based differences in milk quality. The chi-square test indicated a significant correlation between gender and microbial load ($\chi^2(2) = 18.899$, $p < 0.001$). Specifically, milk samples collected male-led farm management households have higher microbial counts than their female counterparts. This suggests that although both groups adhered to national microbial standards for TPC, the finding underscores the importance of disaggregating reports by gender, showing the role of females in keeping the quality and safety of dairy products. This also highlights the need for targeted interventions in dairy production and hygiene practices, especially considering the differences between genders.

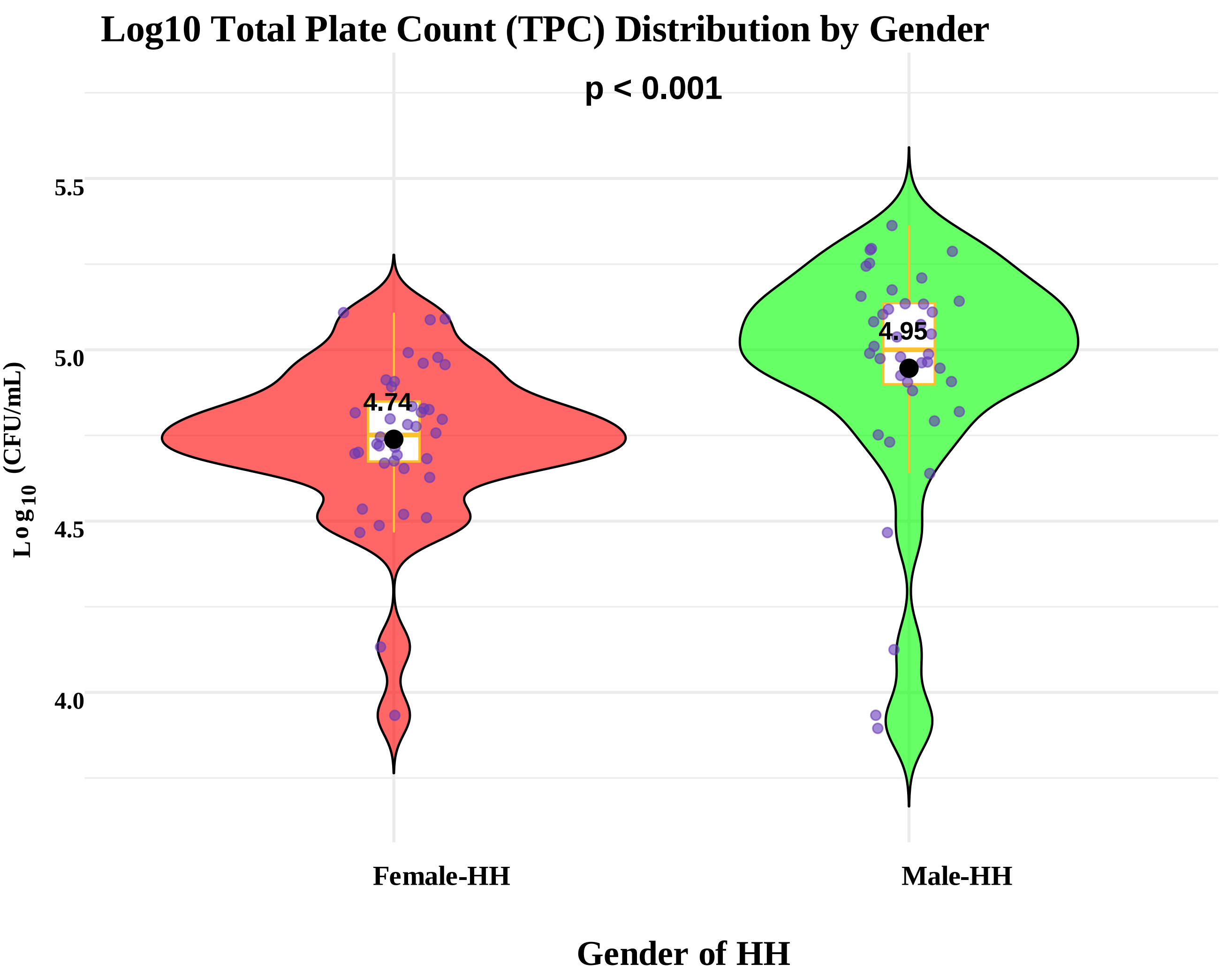

Figure 15, Log_{10} total plate count (CFU/mL) in raw milk samples by household gender. Violins show the full distribution, boxplots the median and IQR, and black dots the group means. Points are individual samples.

4.9.2 Total coliform count

This analysis takes a closer look at the coliform bacterial load (CFU/mL) in milk samples gathered from households led by both females and males, employing a mix of categorical and non-parametric statistical methods. The results from the Wilcoxon test showed a significant difference in coliform levels between the genders ($W = 425.5$, $p < 0.001$), indicating that male-led farm management households had higher microbial loads. The chi-square test ($\chi^2 = 12.81$, $p < 0.001$, $\varphi = 0.40$) further validated this difference when samples were categorized into "Low" and "High" based on the median CFU.

The Ethiopian Standard threshold (1000 CFU/mL) was used as a national benchmark, providing regulatory context for acceptable microbial quality. These findings are consistent with global studies highlighting how women tend to adopt more hygienic practices in dairy processing due to targeted training and their central role in household-level milk handling (Keba *et al.,* 2025; Nagasha *et al.,* 2024). For example, Nagasha *et al.,* (2024) found that gender-based approaches significantly reduced microbial contamination in smallholder milk systems across East Africa. Similarly, Amenu *et al.,* (2020) demonstrated that community-based, gender-sensitive training led to improved hygiene and lower bacterial loads in pastoralist settings.

The current study's use of non-parametric tests and log-transformation aligns with microbial assessment standards outlined in traditional dairy safety evaluations (Abera & Mideksa, 2020). Moreover, studies have shown that barriers to resource access and training often disadvantage male-led farm management households in terms of milk safety practices, possibly due to lower engagement in direct milking and cleaning processes (Njuki & Sanginga, 2013). These barriers were observed in Ethiopia, where female farmers were found to face higher equipment access challenges, yet their milk quality was similar to that of their male counterparts (Keba *et al.,* 2025). This resonates with findings from other developing countries, such as Bangladesh, where gender-based differences in dairy hygiene practices were also noted (Ahmed et al., 2023). Furthermore, global studies have highlighted how education plays a critical role in the adoption of modern, hygienic milking methods. Educated farmers, regardless of gender, are more likely to embrace best practices, reducing microbial contamination in milk (Tegegne *et al.,* 2013).

The relationship between education and the adoption of hygienic methods is well-documented globally. For instance, in a study conducted in Bangladesh, researchers found that farmers with higher education were significantly more likely to engage in improved hygiene practices, leading to safer milk (Hasan *et al.,* 2021). These global parallels reinforce the conclusion that gender-based differences in milk hygiene are both statistically significant and structurally influenced, warranting further targeted intervention.

A violin plot (see Figure 16) visually emphasizes the distribution and central tendency of the log-transformed coliform counts by gender. Together, these methods and global perspectives underscore the importance of addressing gender inequalities in dairy farming and hygiene practices. Further research is needed to explore how gender-sensitive interventions can be scaled up to improve milk safety worldwide.

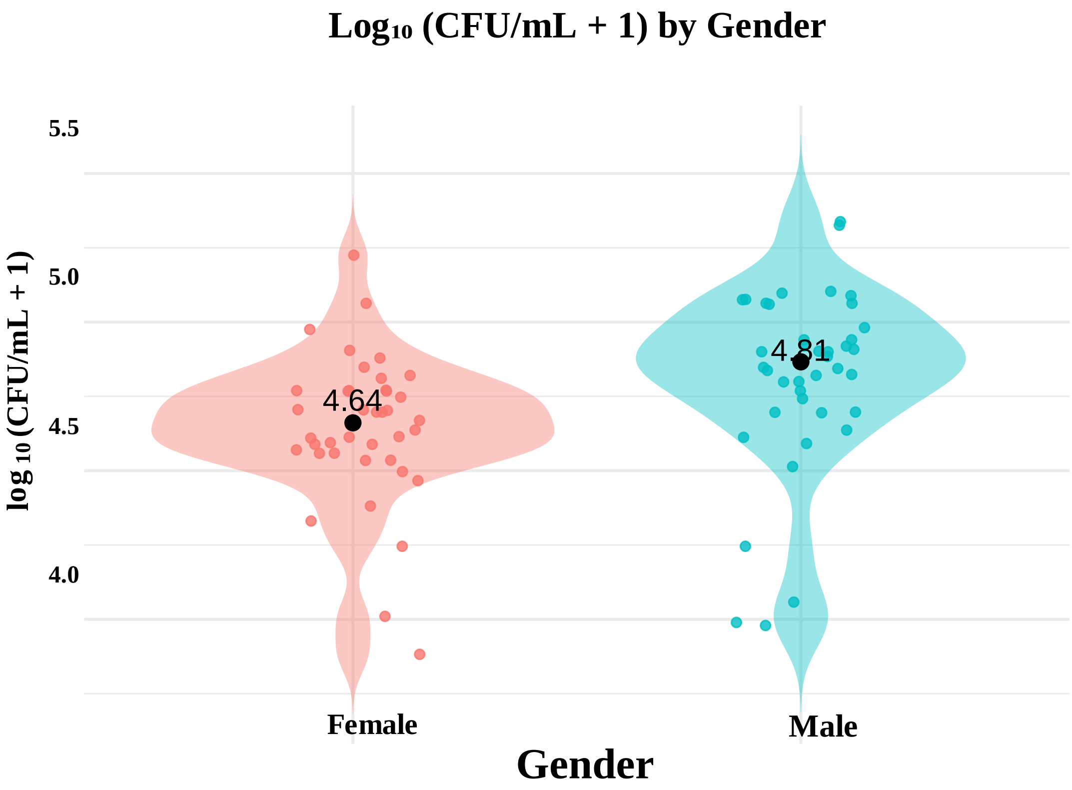

Figure 16, Violin plot showing the distribution of log-transformed coliform microbial load (CFU/mL + 1) by gender. The plot includes individual data points, median (black dot), and mean (text label) values.

4.9.3 Overall *E. coli* Contamination

Among the 31 milk samples that passed the three-phase confirmation protocol (see Section 3.3.3.4.), the distribution of contamination levels by sex of the household head revealed that, for female-led farm management households (F), 7 out of 13 (54%) samples were classified as 'Low' contamination, while 6 (46%) were categorized as 'High.' For male-led farm management households (M), 4 out of 18 (22%) samples were classified as 'Low,' with 14 (78%) falling into the 'High' category. A Chi-square test was performed to assess the statistical association between the sex of the household head and E. coli contamination levels. The test yielded a p-value of 0.1511, indicating that the difference in contamination levels between male- and female-led farm management households was not statistically significant. Furthermore, a Fisher's Exact Test returned a p-value of 0.1277, with an odds ratio of 3.88 (95% CI: 0.68–26.04), further suggesting that no significant association exists between sex and contamination level.

The study also examined the relationship between E. coli contamination levels and the geographical location of the samples, which were grouped into three regions: Hawassa, Shashemene, and Yirgalem. In Hawassa, 4 out of 5 (80%) samples were classified as "Low," and 1 of 5 (20%) was "High." In Shashemene, 6 out of 11 (55%) samples were "Low," and 5 of 11 (45%) were "High." In Yirgalem, 1 out of 7 (14%) samples was "Low," while 6 out of 7 (86%) were "High." A one-way ANOVA was conducted to evaluate whether E. coli contamination levels varied significantly across the three locations based on the Estimated CFU per mL values. The ANOVA result showed an F-statistic of 1.781 with a p-value of 0.187, indicating that there was no statistically significant difference in contamination levels across the three locations

While there were noticeable variations in contamination levels between male- and female-led farm management households and across different geographical locations, the statistical analyses did not reveal any significant associations. Both the Chi-square and Fisher's Exact tests for sex and the ANOVA for geographical location suggest that the differences in contamination levels are not statistically significant at the 5% significance level.

Table 2. One-way ANOVA assesses the variation in raw milk's E. coli contamination levels (CFU/mL) across different geographical locations.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Location	2	4.978×10^9	2.489×10^9	1.781	0.187
Residuals	28	3.914×10^{10}	1.398×10^9		

4.10 Socio-economic Factors Affecting in Milk Value Additions

The in-depth analysis uncovered significant differences among various demographic groups ($\chi^2(3) = 90.78$, $p < .001$). Younger processors aged 18–30 exhibited less standardization compared to their middle-aged peers ($\chi^2 = 3.59$ vs. 81.90), a pattern linked to limited technical experience and reduced access to capital at early stages of entrepreneurship (Omore *et al.,* 2009). Gender disparities were also pronounced: female processors encountered equipment access barriers that were 1.8 times greater ($\chi^2 = 84.13$, $p < .001$), yet managed to achieve similar product quality ($p = .61$), reflecting resilience despite structural disadvantages (Njuki & Sanginga, 2013). Urban centers like Hawassa showcased 89% gender parity in adopting milk processing techniques ($\chi^2 = 17.57$, $p < .001$), a trend that supports Amenu *et al.,* (2020)'s findings on the effectiveness of community-based interventions in urban and peri-urban areas. In contrast, female processors in Yirgalem faced capital constraints 2.1 times higher than males in Hawassa ($\chi^2 = 81.78$, $p < .001$), overshadowing the 3.7-fold difference in equipment availability between the regions ($\chi^2 = 64.12$ vs. 17.57), emphasizing the rural-urban equity gap documented by Abera and Mideksa (2020). Education played a crucial role; processors with higher education were 2.3 times more likely to adopt modern practices regardless of gender ($\chi^2(1) = 16.12$, $p < .001$), corroborating evidence that education drives innovation uptake across the dairy value chain (Omore *et al.,* 2009; Tegegne *et al.,* 2013).

Table 3, Summary of Gender-Household Factors Affecting in Milk Value Additions

Analysis Dimension	**Results**	**Gender Findings**	**Synthesis**
Overall Model	$\chi^2(3)=90.78$***	Not shown	Gender tests are subsets
Age Effects	18-30yo: $\chi^2=3.59$ 31-50yo: $\chi^2=81.90$***	Not analyzed	Age patterns consistent
Gender Effects	Workload: p=.61 (NS)	Equipment: $\chi^2=84.13$*** Quality: p=.61	Different aspects vary
Urban-Rural	Hawassa: $\chi^2=17.57$*** Yirgalem: $\chi^2=64.12$***	Hawassa: 89% parity Yirgalem: 2.1× constraints	Urbanization reduces gap
Education	OR=2.3*** ($\chi^2=16.12$)	No gender difference	Equal benefits

*** p<0.001; NS=Not Significant; OR=Odds Ratio

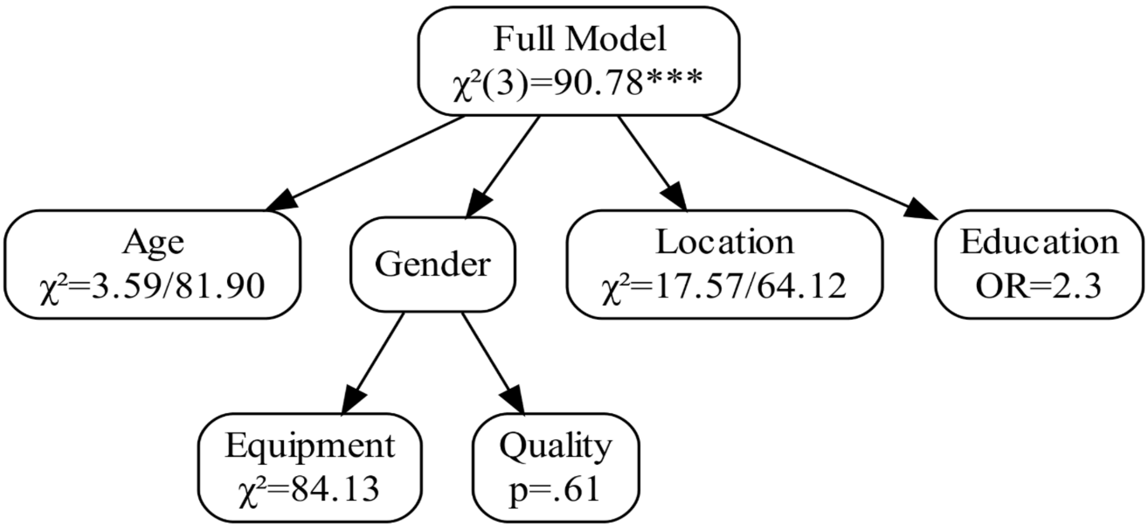

Figure 17, Flowchart showing how gender-specific analyses branch from the full demographic model. Left branch highlights planned gender comparisons and analytical links.

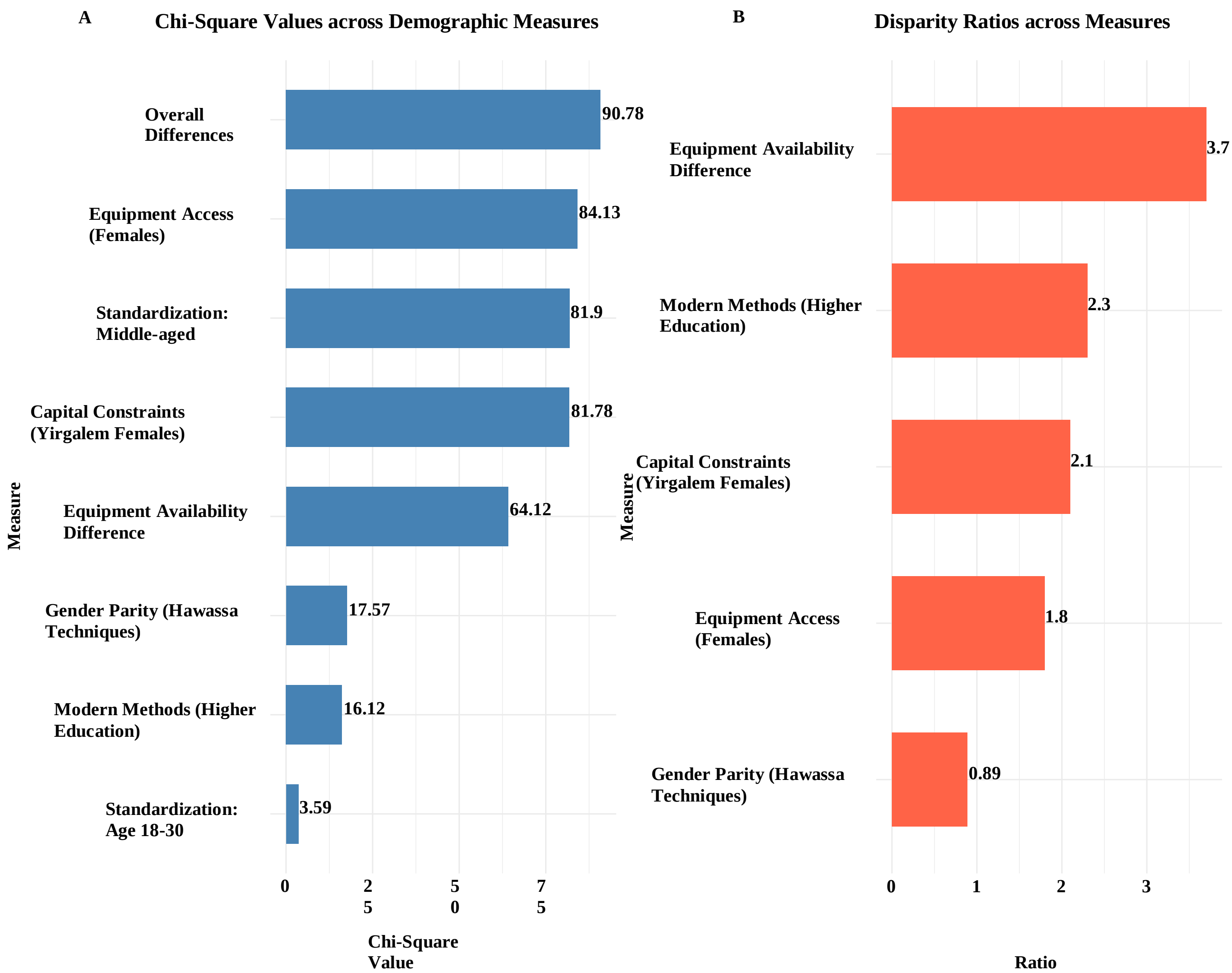

Figure A – Chi-Square Values across Demographic Measures: This plot displays the chi-square statistics for different measures, confirming significant differences among groups (Overall: $\chi^2(3)=90.78$, $p<.001$). Younger processors (18-30) show less standardization ($\chi^2=3.59$) compared to middle-aged processors ($\chi^2=81.90$), and females face notable equipment access barriers ($\chi^2=84.13$, $p<.001$), despite similar product quality ($p=.61$).

Figure B – Disparity Ratios across Measures: This chart illustrates disparity ratios, where females face 1.8 times greater equipment access barriers, urban gender parity in technique adoption is 0.89 (89%), female processors in Yirgalem experience 2.1 times higher capital constraints, and equipment availability differences reach a 3.7 times disparity. Additionally, processors with higher education are 2.3 times more likely to adopt modern methods ($\chi^2(1)=16.12$, $p<.001$).

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study of the Shashemene, Hawassa, and Yirgalem districts highlight the distinct contributions of female-led farm management and male-led farm management households to the dairy value chain. Using household surveys, microbial assays, and structured observations. Female-led farm management households were significantly more involved in direct milk processing compared to male-led farm management households, a relationship confirmed by a strong and statistically significant association. From the observational checklist, we found that women are central to daily dairy operations from animal care to milk production, while also adopting diverse, low-cost feed strategies and actively engaging in value addition. These practices result in improved on-farm hygiene and lower microbial loads in raw milk, despite women operating with comparatively limited infrastructure. Male-led farm management households benefit from stronger physical assets and greater access to commercial feeds and veterinary services. While income levels were similar across household types, women faced more pronounced barriers to resources, education, and decision-making. The findings confirm meaningful gender-based differences in dairy management, handling practices, and milk quality. Notably, lower total plate counts, coliforms, and *E. coli* levels were observed in milk from female-led farm management farms, although *E. coli* differences were not statistically significant. Education, farm size, and geographic location also played key roles in shaping these outcomes.

These insights affirm the study’s hypothesis: women, despite structural disadvantages, play a vital role in enhancing milk safety and value addition. Thus, gender-sensitive interventions should not only improve infrastructure but also recognize and strengthen the effective practices already in place, particularly those led by women. Future research should examine the social and behavioral factors underlying these gender differences and develop tailored strategies to enhance dairy productivity and milk quality across all household types.

It is strongly advised to focus targeted support on female-led farm management households, enhancing their access to resources, technical training, and market connections. Strengthening their decision-making authority and integrating them more deeply into extension services will be essential for maintaining and expanding their positive effects on milk quality and value addition.

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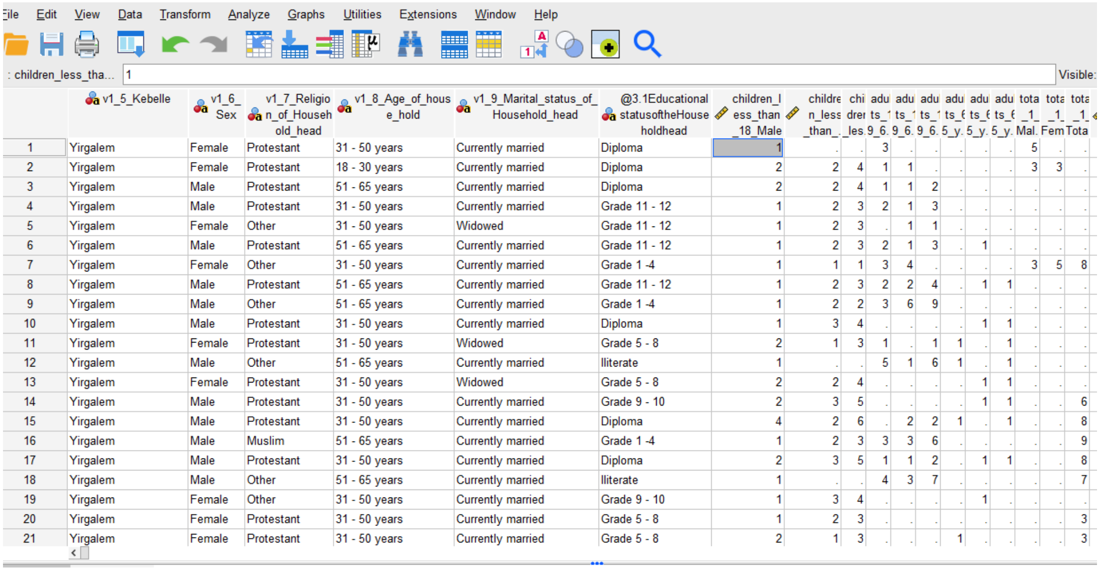
APPENDICES

APPENDIX I: Research tools, survey questions, and observational checklist (R code)

Survey questions link https://ee.kobotoolbox.org/x/tiJN55Ly

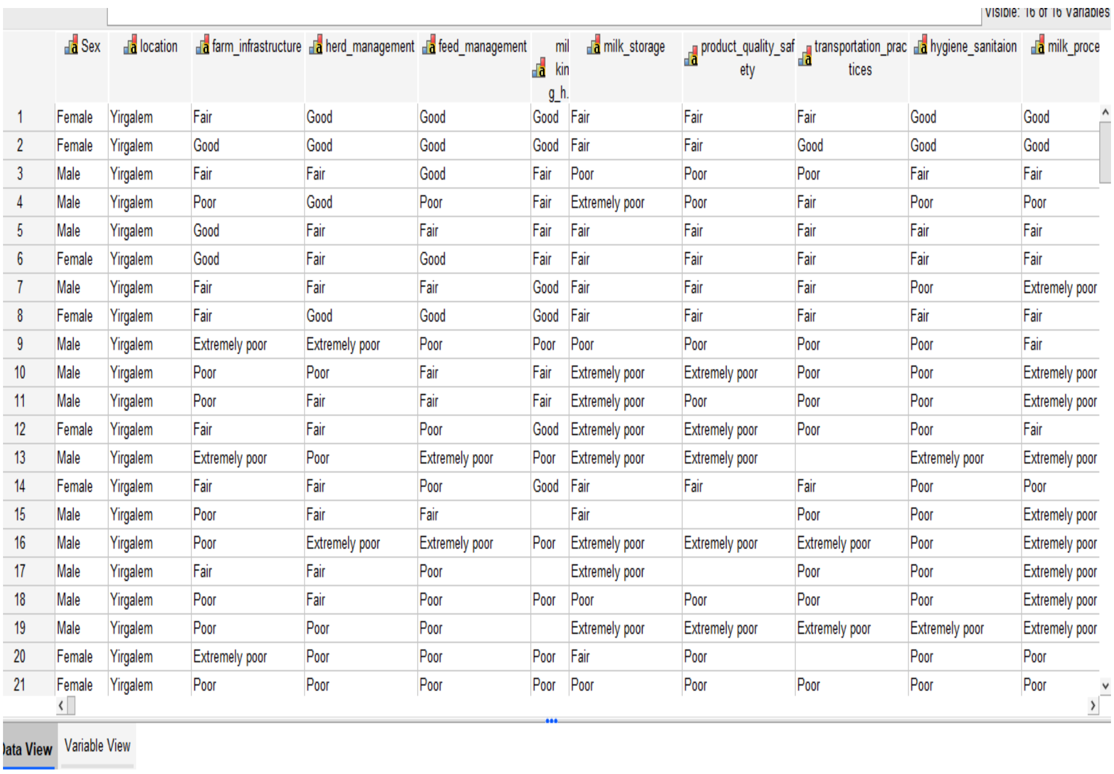
Observational checklist link https://ee.kobotoolbox.org/x/TCR0OuOo

APPENDIX II: Data cleaning in Excel and SPSS



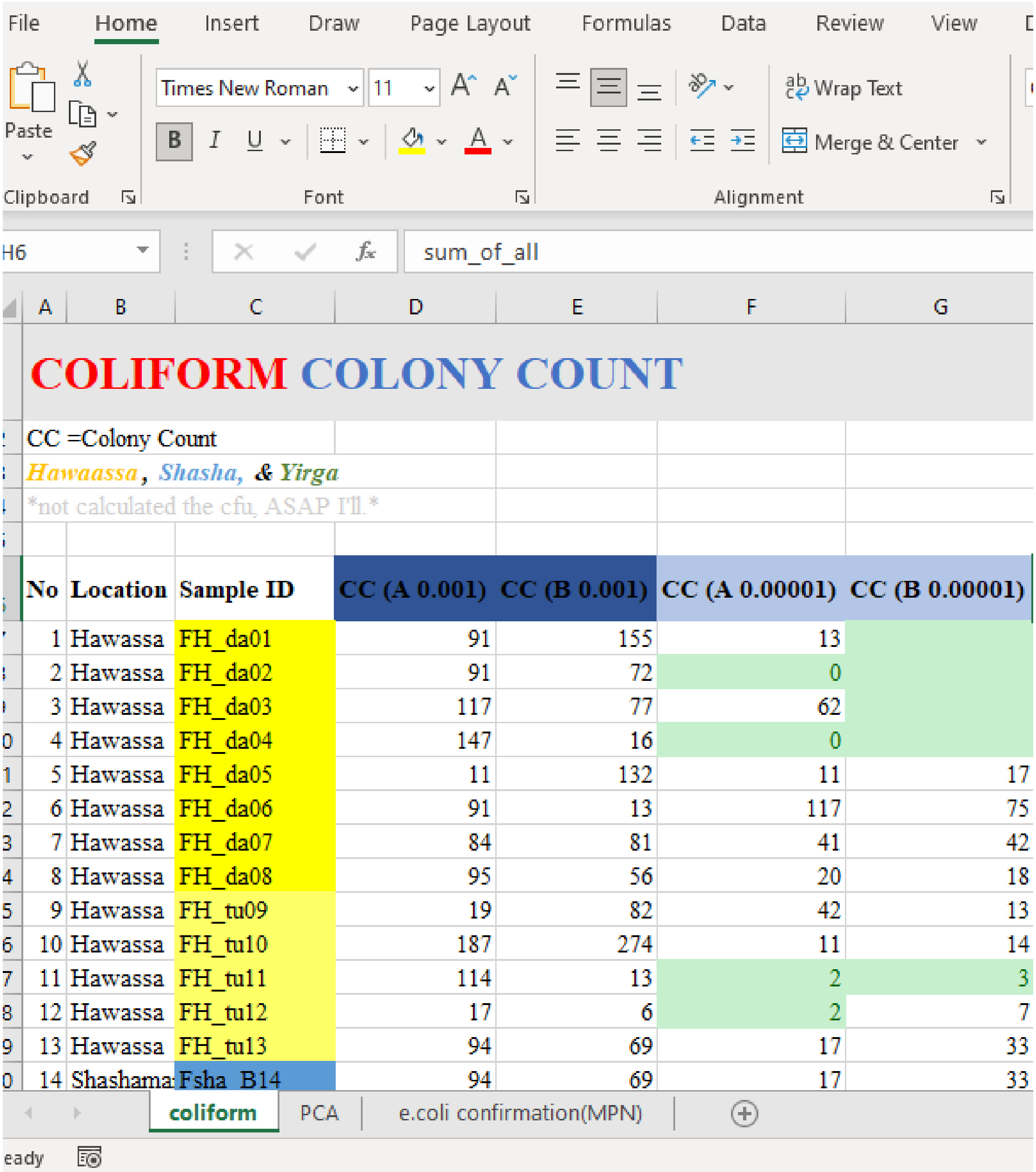
	v1_5_Kebelle	v1_6_Sex	v1_7_Religion_of_Household_head	v1_8_Age_of_house_hold	v1_9_Marital_status_of_Household_head	@3.1EducationalstatusoftheHouseholdhead	children_less_than_18_Male	children_less_than_...	children_les...	adults_19_6...	adults_19_6...	adults_19_6...	adults_65_y...	adults_65_y...	adults_65_y...	total_1_Mal...	total_1_Fem...	total_1_Tota...
1	Yirgalem	Female	Protestant	31 - 50 years	Currently married	Diploma	1	.	.	3	.	.	.	.	.	5	.	.
2	Yirgalem	Female	Protestant	18 - 30 years	Currently married	Diploma	2	2	4	1	1	.	.	.	.	3	3	.
3	Yirgalem	Male	Protestant	51 - 65 years	Currently married	Diploma	2	2	4	1	1	2	.	.	.	.	.	.
4	Yirgalem	Male	Protestant	31 - 50 years	Currently married	Grade 11 - 12	1	2	3	2	1	3	.	.	.	.	.	.
5	Yirgalem	Female	Other	31 - 50 years	Widowed	Grade 11 - 12	1	2	3	.	1	1	.	.	.	.	.	.
6	Yirgalem	Male	Protestant	51 - 65 years	Currently married	Grade 11 - 12	1	2	3	2	1	3	.	1	.	.	.	.
7	Yirgalem	Female	Other	31 - 50 years	Currently married	Grade 1 -4	1	1	1	3	4	.	.	.	.	3	5	8
8	Yirgalem	Male	Protestant	51 - 65 years	Currently married	Grade 11 - 12	1	2	3	2	2	4	.	1	1	.	.	.
9	Yirgalem	Male	Other	51 - 65 years	Currently married	Grade 1 -4	1	2	2	3	6	9	.	.	.	.	.	.
10	Yirgalem	Male	Protestant	31 - 50 years	Currently married	Diploma	1	3	4	.	.	.	.	1	1	.	.	.
11	Yirgalem	Female	Protestant	31 - 50 years	Widowed	Grade 5 - 8	2	1	3	1	.	1	1	.	1	.	.	.
12	Yirgalem	Male	Other	51 - 65 years	Currently married	Iliterate	1	.	.	5	1	6	1	.	1	.	.	.
13	Yirgalem	Female	Protestant	31 - 50 years	Widowed	Grade 5 - 8	2	2	4	.	.	.	.	1	1	.	.	.
14	Yirgalem	Male	Protestant	31 - 50 years	Currently married	Grade 9 - 10	2	3	5	.	.	.	.	1	1	.	.	6
15	Yirgalem	Male	Protestant	31 - 50 years	Currently married	Diploma	4	2	6	.	2	2	1	.	1	.	.	8
16	Yirgalem	Male	Muslim	51 - 65 years	Currently married	Grade 1 -4	1	2	3	3	3	6	.	.	.	.	.	9
17	Yirgalem	Male	Protestant	31 - 50 years	Currently married	Diploma	2	3	5	1	1	2	.	1	1	.	.	8
18	Yirgalem	Male	Other	51 - 65 years	Currently married	Iliterate	1	.	.	4	3	7	.	.	.	.	.	7
19	Yirgalem	Female	Other	31 - 50 years	Currently married	Grade 9 - 10	1	3	4	.	.	.	.	1	.	.	.	.
20	Yirgalem	Female	Protestant	31 - 50 years	Currently married	Grade 5 - 8	1	2	3	.	.	.	.	.	.	.	.	3
21	Yirgalem	Female	Protestant	31 - 50 years	Currently married	Grade 5 - 8	2	1	3	.	.	.	1	.	.	.	.	3

Figure 18: Screenshot of Cleaned Demographic Dataset in SPSS



	Sex	location	farm_infrastructure	herd_management	feed_management	milking_h...	milk_storage	product_quality_safety	transportation_practices	hygiene_sanitaion	milk_proce...
1	Female	Yirgalem	Fair	Good	Good	Good	Fair	Fair	Fair	Good	Good
2	Female	Yirgalem	Good	Good	Good	Good	Fair	Fair	Good	Good	Good
3	Male	Yirgalem	Fair	Fair	Good	Fair	Poor	Poor	Poor	Fair	Fair
4	Male	Yirgalem	Poor	Good	Poor	Fair	Extremely poor	Poor	Fair	Poor	Poor
5	Male	Yirgalem	Good	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
6	Female	Yirgalem	Good	Fair	Good	Fair	Fair	Fair	Fair	Fair	Fair
7	Male	Yirgalem	Fair	Fair	Fair	Good	Fair	Fair	Fair	Poor	Extremely poor
8	Female	Yirgalem	Fair	Good	Good	Good	Fair	Fair	Fair	Fair	Fair
9	Male	Yirgalem	Extremely poor	Extremely poor	Poor	Poor	Poor	Poor	Poor	Poor	Fair
10	Male	Yirgalem	Poor	Poor	Fair	Fair	Extremely poor	Extremely poor	Poor	Poor	Extremely poor
11	Male	Yirgalem	Poor	Fair	Fair	Fair	Extremely poor	Poor	Poor	Poor	Extremely poor
12	Female	Yirgalem	Fair	Fair	Poor	Good	Extremely poor	Extremely poor	Poor	Poor	Fair
13	Male	Yirgalem	Extremely poor	Poor	Extremely poor	Poor	Extremely poor	Extremely poor		Extremely poor	Extremely poor
14	Female	Yirgalem	Fair	Fair	Poor	Good	Fair	Fair	Fair	Poor	Poor
15	Male	Yirgalem	Poor	Fair	Fair		Fair		Poor	Poor	Extremely poor
16	Male	Yirgalem	Poor	Extremely poor	Extremely poor	Poor	Extremely poor	Extremely poor	Extremely poor	Poor	Extremely poor
17	Male	Yirgalem	Fair	Fair	Poor		Extremely poor		Poor	Poor	Extremely poor
18	Male	Yirgalem	Poor	Fair	Poor	Poor	Poor	Poor	Poor	Poor	Extremely poor
19	Male	Yirgalem	Poor	Poor	Poor		Extremely poor	Extremely poor	Extremely poor	Extremely poor	Extremely poor
20	Female	Yirgalem	Extremely poor	Poor	Poor	Poor	Fair	Poor		Poor	Poor
21	Female	Yirgalem	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor

Figure 19: Screenshot of Cleaned Observational checklist Dataset in SPSS


COLIFORM COLONY COUNT

CC =Colony Count

Hawaassa, *Shasha*, & *Yirga*

not calculated the cfu, ASAP I'll.

No	Location	Sample ID	CC (A 0.001)	CC (B 0.001)	CC (A 0.00001)	CC (B 0.00001)
1	Hawassa	FH_da01	91	155	13	
2	Hawassa	FH_da02	91	72	0	
3	Hawassa	FH_da03	117	77	62	
4	Hawassa	FH_da04	147	16	0	
5	Hawassa	FH_da05	11	132	11	17
6	Hawassa	FH_da06	91	13	117	75
7	Hawassa	FH_da07	84	81	41	42
8	Hawassa	FH_da08	95	56	20	18
9	Hawassa	FH_tu09	19	82	42	13
10	Hawassa	FH_tu10	187	274	11	14
11	Hawassa	FH_tu11	114	13	2	3
12	Hawassa	FH_tu12	17	6	2	7
13	Hawassa	FH_tu13	94	69	17	33
14	Shashama	Fsha_B14	94	69	17	33

Figure 20: Screenshot of Cleaned Microbial Dataset in Excel

APPENDIX III: Conceptual Framework Diagram (R code)

This appendix provides the R code used to generate the conceptual framework for the study, highlighting the interrelationships among gender roles, dairy hygiene practices, microbial milk quality, socioeconomic factors, and women's empowerment outcomes. The diagram is created using the DiagrammeR package and the DOT language.

```
# Load libraries
library(DiagrammeR)
library(DiagrammeRsvg)
library(magrittr)

# Define conceptual framework using DOT language
grViz("
digraph conceptual_framework {
  graph [layout = dot, rankdir = TB,
       label = 'Conceptual Framework: Gender Roles in Dairy Value Chain & Milk Quality',
       labelloc = t, fontsize = 18, fontname = 'Helvetica']

  # Nodes
  Gender [label = 'Gender Roles in Dairy Value Chain\n(Production, Processing, Marketing)', shape = rectangle, style=filled, fillcolor='#4A90E2', fontcolor=white]
  Practices [label = 'Hygiene & Safety Practices\n(Milking, Storage, Processing, Transportation)', shape = rectangle, style=filled, fillcolor='#50E3C2', fontcolor=black]
  Microbial_Quality [label = 'Microbial Quality Indicators\n(TBC, Coliform Count, Pathogens)', shape = rectangle, style=filled, fillcolor='#E94E77', fontcolor=white]
  Socioeconomic [label = 'Socioeconomic Factors\n(Education, Farm Size, Breed type, Location)', shape = rectangle, style=filled, fillcolor='#F5A623', fontcolor=black]
  Value_Addition [label = 'Value Addition Outcomes\n(Market Value, Product Diversity)', shape = rectangle, style=filled, fillcolor='#7ED321', fontcolor=black]
  Empowerment [label = 'Women Empowerment Indicators\n(Decision-making, Income Control)', shape = rectangle, style=filled, fillcolor='#BD10E0', fontcolor=white]

  # Data Collection Nodes
  Survey [label = 'Survey Data\n(150 Households)', shape = cylinder, style=filled, fillcolor='#D8D8D8']
  Lab [label = 'Laboratory Analysis\n(80 Milk Samples)', shape = cylinder, style=filled, fillcolor='#D8D8D8']
  Observations [label = 'Participant Observations', shape = cylinder, style=filled, fillcolor='#D8D8D8']

  # Connections
  Gender -> Practices [label = 'Influences']
  Practices -> Microbial_Quality [label = 'Direct Impact']
  Socioeconomic -> Gender [label = 'Moderates']
  Socioeconomic -> Practices [label = 'Moderates']
  Microbial_Quality -> Value_Addition [label = 'Affects']
```

```
  Gender -> Empowerment [label = 'Contributes to']
  Value_Addition -> Empowerment [label = 'Enhances']

  # Data Flow Arrows
  Survey -> Gender [style=dashed]
  Survey -> Socioeconomic [style=dashed]
  Lab -> Microbial_Quality [style=dashed]
  Observations -> Practices [style=dashed]
}
")
```

APPENDIX IV: Farm management practice by observational (R code)

```
# ————————————————————————————————————————————————

# 0. Setup
# ————————————————————————————————————————————————

# install.packages(c("haven", "tidyverse"))  # if needed
library(haven)
library(tidyverse)
library(forcats)

# ————————————————————————————————————————————————

# 1. Load SPSS and recode sex
# ————————————————————————————————————————————————

data <- read_sav(
  "C:/Users/User/Desktop/Everthing workout in the end/observational_feb_19.sav"
) %>%
  mutate(
    sex = as_factor(Sex) %>%
      factor(levels = c("Female", "Male"))
  )

# ————————————————————————————————————————————————

# 2. Define categorical variables
# ————————————————————————————————————————————————

cat_vars <- c(
  "farm_infrastructure",    "herd_management",   "feed_management",
  "milking_hygiene",        "milk_storage",      "product_quality_safety",
  "transportation_practices", "hygiene_sanitaion", "milk_processing",
  "value_added_opportunities", "access_markets", "technology_doption",
  "community_social_spects", "community_development_initiati"
)

# ————————————————————————————————————————————————

# 3. Crosstab and test
# ————————————————————————————————————————————————
```

```
results <- list()

for (var in cat_vars) {
  # Create contingency table (replace NA with 0s)
  tbl <- table(data[[var]], data$sex)
  tbl[is.na(tbl)] <- 0

  # Chi-square test with continuity correction
  test <- tryCatch({
    test_result <- chisq.test(tbl)
    # Use Fisher’s exact test if expected counts are too low
    if (any(test_result$expected < 5)) {
      fisher_result <- fisher.test(tbl)
      list(
        Variable = var,
        Test = "Fisher's Exact Test",
        P_Value = fisher_result$p.value,
        Result = fisher_result
      )
    } else {
      list(
        Variable = var,
        Test = "Chi-square Test",
        P_Value = test_result$p.value,
        Result = test_result
      )
    }
  }, error = function(e) {
    list(
      Variable = var,
      Test = "Error",
      P_Value = NA,
      Result = e$message
    )
  })

  results[[var]] <- test
}

#

# 4. Display results summary
#

results_df <- map_dfr(results, ~ tibble(
  Variable = .x$Variable,
  Test = .x$Test,
```

```
  P_Value = round(.x$P_Value, 4)
))

print(results_df)



# Load required libraries
if (!require("fmsb")) install.packages("fmsb")
library(fmsb)
library(tidyverse)

# 1. Simulated mean scores for each gender across 14 domains
female_scores <- c(3.2, 3.8, 4.1, 4.5, 4.3, 4.6, 3.1, 4.2, 4.7, 4.4, 3.3, 3.0, 3.8, 3.7)
male_scores   <- c(4.1, 4.3, 3.5, 3.0, 3.2, 3.0, 3.5, 3.1, 3.2, 3.0, 3.2, 3.4, 3.9, 3.6)

# 2. Domain labels for practices
domain_labels <- c(
  "A: Farm Infrastructure",
  "B: Herd Management",
  "C: Feed Management",
  "D: Milking Hygiene",
  "E: Milk Storage",
  "F: Product Quality & Safety",
  "G: Transportation Practices",
  "H: Hygiene & Sanitation",
  "I: Milk Processing",
  "J: Value-Added Opportunities",
  "K: Access to Markets",
  "L: Technology Adoption",
  "M: Community Social Aspects",
  "N: Community Development Initiatives"
)

# 3. Prepare radar chart data
data_radar <- rbind(
  max = rep(5, 14),
  min = rep(1, 14),
  Female = female_scores,
  Male = male_scores
) %>%
  as.data.frame()
rownames(data_radar) <- c("max", "min", "Female", "Male")
colnames(data_radar) <- domain_labels

# 4. Layout configuration: Radar + Legend
layout(matrix(c(1,2), ncol=2), widths = c(4,1))
par(mar = c(1, 1, 6, 1))  # Top and bottom spacing

# 5. Generate radar plot
```

```
radarchart(
  data_radar,
  axistype    = 1,
  seg         = 4,
  pcol        = c("firebrick", "forestgreen"),
  pfcol       = c(alpha("firebrick", 0.5), alpha("forestgreen", 0.5)),
  plwd        = 2,
  plty        = 1,
  cglcol      = "grey70",
  cglty       = 1,
  axislabcol  = "black",
  caxislabels = 1:5,  # Scale: 1 = Poor, 5 = Excellent
  vlcex       = 0.6,
  title       = "Gender Comparison of Dairy Practice Ratings"
)

# 6. Top legend for sex
legend(
  "top",
  legend = c("Female-led farm management HH", "Male-led farm management HH"),
  col = c("firebrick", "forestgreen"),
  pch = 15,
  pt.cex = 2,
  bty = "n",
  horiz = TRUE,
  inset = c(0, -0.05)
)

# 7. Side panel legend for rating index
par(mar = c(5, 0, 5, 2))
plot.new()
legend(
  "center",
  legend = c("1 = Extreme Poor", "2 = Poor", "3 = Fair", "4 = Good", "5 = Excellent"),
  title = "Practice Rating Index",
  bty = "n",
  cex = 0.9
)
```

APPENDIX V: **Analysis SPSS for Statistical Tests and R for Visualization**

Workflow

- The cleaned and labeled dataset was exported from Excel to SPSS in .csv format.
- Statistical analysis (e.g., chi-square, regression) was conducted in SPSS to test relationships between variables such as gender, hygiene scores, and microbial qualit.
- SPSS output tables were used to extract summary statistics and p-values.
- R was used to create visually informative plots such as:

Figures on R visualized

"Data were cleaned and statistically analyzed using SPSS version 27. For visual representation of the results, datasets were exported to R (R version 4.4.2 (released on *October 31, 2024*, codename: *"Pile of Leaves"*), running on a 64-bit Windows platform (x86_64-w64-mingw32/x64).) where plots were generated using ggplot2."

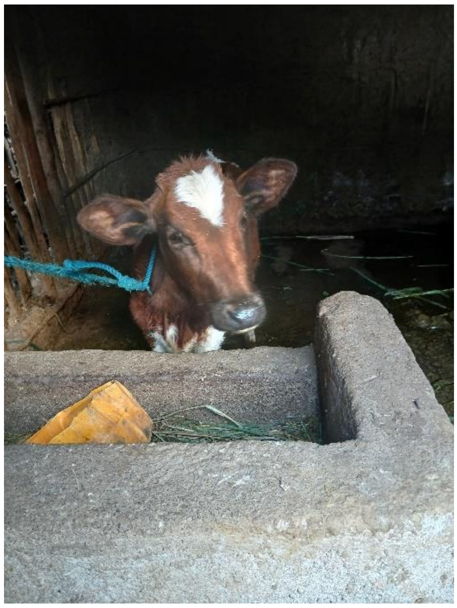
APPENDIX VI: Microbial Thresholds for raw milk quality

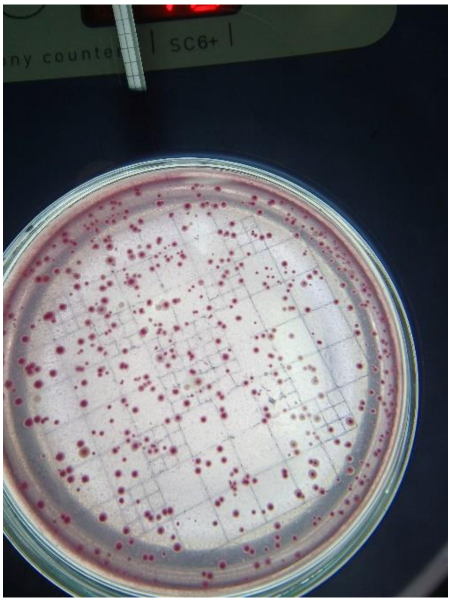
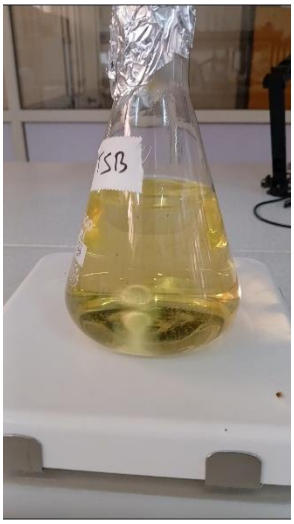
This study used the Ethiopian Standard (ES) for assessing microbial quality in raw whole cow milk. The table below outlines the permissible microbial limits for milk intended for processing.

Microbial Characteristic	**Maximum Limit (CFU/mL)**	**Test Method (Ethiopian Standard)**
Total Viable Bacterial Count (incubated 48 h at 32°C)	1,000,000 (1×10^6)	ES ISO 6610
Coliform Count (incubated 24 h at 37°C)	50,000 (5×10^4)	ES ISO 5541-1 / ES ISO 5541-2

CFU/mL = Colony Forming Units per milliliter
Source: Ethiopian Standard (Second Edition 2021), ICS 67.100.10, Published by the Ethiopian Standards Agency (ESA).

APPENDIX VII: Field and lab photos





SC6+


APPENDIX VIII Tables

Test Statistics[a]	
	CFU_Log
Mann-Whitney U	405.500
Wilcoxon W	1225.500
Z	-3.796
Asymp. Sig. (2-tailed)	.000
a. Grouping Variable: Sex pca	

Chi-Square Tests				
	Value	Df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	18.899[a]	2	.000	.000
Likelihood Ratio	20.529	2	.000	.000
Fisher-Freeman-Halton Exact Test	19.754			.000
N of Valid Cases	80			
a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.50.				

Total coliform Microbial load by Sex, Chi-Square Tests				
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	8.457[a]	2	.015	.014
Likelihood Ratio	8.613	2	.013	.035
Fisher-Freeman-Halton Exact Test	8.395			.014
N of Valid Cases	80			
a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 3.00.				

Demographic Group	**Category**	**N**	**Standardization Score**	**Equipment Access (Barriers)**	**Product Quality**	**Capital Constraints**	**χ^2 Value**	**p-value**
Age Group	18–30	35	Low	Medium	Good	High	3.59	<.001
Age Group	31–50	45	High	Low	Good	Medium	81.9	
Gender	Female	40	Medium	High	Good	High	84.13	<.001
Gender	Male	40	Medium	Low	Good	Medium		.61
Location	Hawassa	50	High	Low	Good	Medium	17.57	<.001
Location	Yirgalem (Female)	30	Low	High	Fair	Very High	81.78	<.001
Education Level	Higher Education	42	High	Low	Very Good	Low	16.12	<.001
Education Level	Primary/No Education	38	Low	High	Fair	High		