EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

By

Enock Chilambula

A dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the degree of Master of Science in Food Safety and Risk Analysis

The University of Zambia
Lusaka

2025

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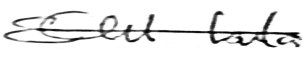
DECLARATION

I, **ENOCK FRANCIS CHILAMBULA (220004314),** do hereby declare that this dissertation represents my own work and that it has never been submitted before for the award of a degree or any other qualification at this university or any other university around the world.

Signature: 

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CERTIFICATE OF APPROVAL

The University of Zambia approves the dissertation submitted by ENOCK FRANCIS CHILAMBULA, as fulfilling the partial requirements for the award of the Master of Science Degree in Food Safety and Risk Analysis by the University of Zambia.

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Examiner 1	Signature	Date
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Chairperson (Board of Examiners)	Signature	Date

ABSTRACT

Dairy products provide nutrition to households, but they could also serve as source of milk-borne diseases when produced under poor hygienic conditions.

This cross-sectional study was conducted from August to September 2023 to evaluate smallholder dairy farmers' knowledge, attitudes, practices (KAP), and factors affecting the hygienic milk production in Malawi's Blantyre Agriculture Development Division (BLADD). A questionnaire was administered to 410 participants in selected districts of Blantyre, Chiradzulu, Mulanje and Thyolo in Malawi to assess knowledge, attitudes and practices. This study collected 90 raw milk which was analysed at Malawi University of Business and Applied Sciences to investigate for compliance to Malawi or European Union Standards. Subsequently, a total of 90 small scale farms were visited to observe hygienic milk production. The version 26 Statistical Package for the Social Sciences was used to analyse data Chi square analysis for associated factors of hygienic milk production. A binary logistic regression to determine hygienic milk production predictors and p value of less than 0.05 was considered significant.

Majority of 60% participants were females. Most of 86.6% and 66% the respondents had formal education and pre-training respectively. The overall KAP knowledge was only 54%, most smallholder dairy farmers reported positive attitudes at 88% and excellent practices at 63%. Most smallholder dairy farmer in Blantyre Agriculture Development Division (BLADD) had passed aggregate 80% while moderate were successful on composite score of 67%. Few farmers (27%; n=410) had low aggregate score of knowledge, attitude and practice were six (OR=5.910, 95% CI: 1.997-17.489) times less likely to produce hygienic milk. Inadequate pre-training and a low aggregate score were identified as key factors behind the failure of smallholder farmers in BLADD to meet Malawian and European Union (EU) standards, raising concerns about potential milk-borne diseases. Out of 90 raw milk samples analysed for presence of *E. coli*, 12% and 56% were within acceptable limits of Malawi and European Union standards, respectively. This could be attributed to unsanitary animal quarters, as half of smallholder dairy farmers in Malawi's Blantyre Agriculture

Development Division do not remove waste daily and some workers milk cows without supervision.

In conclusion, smallholder dairy farmers had positive attitudes and good milk hygiene practices however, their knowledge was inadequate. Surprisingly, farmers' milk was contaminated, it was difficult to meet legal limits of Malawi and European Union standards for *E. coli*. To address this, the study proposed that initial structured training and ongoing annual refresher sessions for dairy farmers coupled with commitment to daily animal barn cleaning to prevent milk borne diseases.

Keywords: *attitudes, compliance, hygienic milk production, knowledge, Malawi and practices*

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LIST OF ABBREVIATIONS AND ACCRONYMS

ACEIDHA	Africa Centre of Excellence for Infectious Diseases of Humans and Animals
AEZ	Agriculture Ecological Zone
AHC	Animal Health Committee
ANOVA	Analysis of Variance
AVO	Assistant Veterinary Officer
BLADD	Blantyre Agriculture Development Division
CFU	Colony Forming Unit
CI	Confidence Interval
DAHLD	Department of Animal Health Livestock Development
DCCMS	Department of Climate Change and Meteorological Services
EC	European Commission
EUS	European Union Standard
FAO	Food and Agriculture Organisation of the United Nations
FBD	Food Borne Diseases
GAP	Good Agriculture Practices
HACCP	Hazard Analysis Critical Control Point
HUS	Heamolytic-Uremic Syndrome
IBM	International Business Machines Corporation
ISO	International Standard Organisation
JICA	Japanese International Cooperation Agency
KAP	Knowledge, Attitude and Practice
LL	Lower Limit
MBGs	Milk Bulking Groups
MBS	Malawi Bureau of Standards
MUBAS	Malawi University of Business and Applied Sciences
NGOs	Non-Governmental Organisations
NSO	National Statistical Office
OR	Odds Ratio
QGIS	Quantum Geographic Information System
SD	Standard Deviation
SHDFs	Smallholder Dairy Farmers
SHMPA	Shire Highlands Milk Producers Association
SPSS	Statistical Package for Social Sciences
TTP	Thrombrocytopenic Purpura
UL	Upper Limit
USA	United States of America
VRBA	Violet Red Bile Agar
WHO	World Health Organisation

CHAPTER ONE: INTRODUCTION

1.1 Background

Humans have been rearing cattle for at least 10,000 years (Decker *et al*., 2014). In most parts of Malawi, the Zebu breed (*Bos Indicus*) has been kept for subsistence farming since the pre-colonial era (Tebug, 2012). Sindani (2012) narrated that European farmers brought in exotic breeds of cattle in the 1960s, for milk production. Milk is a good source of calcium, proteins, and vitamins that are essential for good health in humans and animals (Zhang *et al*., 2021). In the Blantyre Agriculture Development Division, milk offers not only nutritional security but also income to cover expenses like taxes, healthcare and education (Banda *et al*., 2021). Despite the benefits, raw milk produced under poor hygiene conditions poses a significant threat to human health through milk-borne diseases (Gebremedhin *et al*., 2020).

Smallholder dairy farmers who participate in good hygiene practices and good animal husbandry training are equipped with right knowledge, have positive attitudes to adopt excellent practices to mitigate risk of milk-borne diseases (Berhanu *et al.,* 2021). Farmers' education supports informed decisions (Kainga *et al*., 2022), while continuous learning enhances familiarity with hygiene practices, ultimately reducing the public health burden. The study aimed to generate information on knowledge, attitudes and practices, to assess compliance with established standards and identify factors contributing to hygiene production of raw milk in Blantyre Agriculture Development Division in Malawi.

Studies have shown a strong link between the consumption of contaminated dairy products and increased risk of milk-borne diseases, which represent a concerning 4% of all foodborne zoonotic diseases globally (Pires *et al.*, 2021). Every year in Malawi, an estimated 600 lives are tragically lost to diarrheal diseases linked to unsafe milk consumption (Sapp *et al.,* 2023), highlighting the urgent need for improved hygiene practices among dairy farmers. Blantyre Agriculture Development Division is characterised by abundant raw milk production, making it simpler for vulnerable groups

particularly susceptible to microbiological hazards such as *Escherichia coli (E. coli)* (Akaichi *et al.,* 2016). *Escherichia coli* is commonly employed as an indicator of the hygiene of the raw milk due to its association with faecal matter (Orwa *et al*., 2017 and Ghali-mohammed *et al*., 2023). Farm-level sanitation practices directly impact bacterial safety of milk and subsequent processing activities.

In Blantyre Agriculture Development Division (BLADD), there was lack of information on dairy farmers' knowledge, attitudes and practices (KAP) regarding hygienic milk production, and their compliance with Malawi and European Union (EU) Standards for *E. coli*. This knowledge gap hinders the development of effective mitigation strategies. Therefore, this cross-section study recruited 410 dairy farmers within Blantyre Agriculture Development Division and utilised questionnaire survey, checklist farm observations as well as analysing raw milk samples. The questionnaire survey collected smallholder dairy farmers' demographic information, knowledge, attitudes and self-reported practices on hygienic milk production. The checklist farm observations were carried out to identify factors that contribute to hygienic milk production such as: milking parlour environment, milker's hygiene, farm hygiene training and hygiene of milk equipment. In addition, raw milk samples were analysed from ninety participating smallholder dairy farms to assess compliance with established Malawi and European Union Standards.

1.2 Statement of the problem

Despite being rich in nutrients, raw milk consumption poses a significant public health risk due to the presence of pathogenic microorganisms (Gume *et al*., 2023). Pasteurised milk is limitedly available and 40% of households in Blantyre Agriculture Development Division (BLADD) consume raw milk (Akaichi *et al*., 2016). Furthermore, Legwegoh *et al*., (2014) reported that milk is regarded as food for young children in Blantyre. Havelaar *et al*., 2015 estimated that 600 children die per year in Malawi due to diarrhoeal diseases. Diarrhoea is among the signs and symptoms of *E. coli* infection. Moreover, data from Blantyre Agriculture Development Division highlights this risk further, with Njombwa, (2019) finding 73.3% (n = 15) of raw milk samples

contaminated with *E. coli* at levels of 2.7-8.09 log10 CFU/ml. Previous studies on knowledge, attitude and practice (KAP) in BLADD focused on other zoonotic diseases or animal husbandry (Kothowa, 2021 and Kainga *et al.*, 2022) leaving a knowledge gap on the hygienic milk production. This study was designed therefore, to address the hygienic production of raw milk among small dairy farmers in Blantyre Agriculture Development Division and assess the factors that influence adherence to *E. coli* established regulations for the Malawi Bureau of Standards and European Union.

1.3 Significance of the study

Smallholder dairy farmers are the major supplier of raw milk to processors and direct consumers. Akaichi *et al*., (2016) reported that 40% consume raw milk within Blantyre Agriculture Development Division. Consequently, it was imperative to assess farmers' understanding of proper milking techniques, their attitudes towards milk safety and current self-reported practices on milk hygiene (Fagnani *et al.*, 2021). Farmers are the first line defence in protecting raw milk from hazards through the application of the right knowledge and practices (Bailey *et al*., 2014 and Andrew *et al*., 2021).

Studies conducted around the world have demonstrated how good knowledge and practices assist in hygienic milk production among smallholder dairy farmers (SHDFs) (Young *et al*., 2010, Prakashbabu *et al*., 2020 and Nyokabi *et al*., 2021). In a recent study, Kothowa, (2021) reported that 51.6% of SHDFs knew zoonotic diseases therefore it was crucial to have a study particularly on hygienic production of milk. Despite the crucial role of smallholder dairy farmers, studies exclusively assessing their knowledge, attitudes and practices on hygienic production of raw milk have not been done in Blantyre Agriculture Development Division (BLADD). Thus, there was limited and outdated information on hygiene status of raw milk produced in the study area. This study therefore, addressed the gap in knowledge, attitudes and practices about hygienic milk production among smallholder dairy farmers. The generated data is anticipated to inform the development of targeted training programs tailored to smallholder dairy farmers. These programs will focus on improving sanitation practices, infrastructure like potable water ultimately reducing farm-level contamination and enhancing compliance with Malawi and European Union Standards. By potentially reducing *E. coli* levels and

diarrheal disease burden, these interventions can contribute to improved public health outcomes.

1.4 Research questions

1) What is the level of knowledge, attitudes and practices among smallholder dairy farmers towards hygienic production of milk in Malawi's Blantyre Agriculture Development Division?
2) What factors influence the adoption of hygienic production of milk at various levels (personal, community and institutional) among smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division?

1.5 Study objectives

1.5.1 General objective

To generate information on knowledge, attitude and practice and factors influencing hygienic production of milk among dairy farmers in Malawi's Blantyre Agriculture Development Division.

1.5.2 Specific objectives

1 To identify knowledge, attitudes and practices gaps that can be addressed to ensure hygienic production of milk in Malawi's Blantyre Agriculture Development Division.

2 To assess compliance with the established Malawi Bureau of Standards and European Union (EU) standard set for raw milk using *E. coli*.

3 To determine the factors that influence dairy farmers' attitudes and practices towards hygienic production of raw milk.

1.6 Conceptual framework

The modified and adopted model (Figure 1.1) demonstrates how sociodemographic factors, knowledge, attitudes and practices affect hygienic production of raw milk (Tariq, 2022). Tariq, (2022) model examined on the milk value chain from farm to the customer while the current study focused on the smallholder dairy farmers and farmers hence the modification.

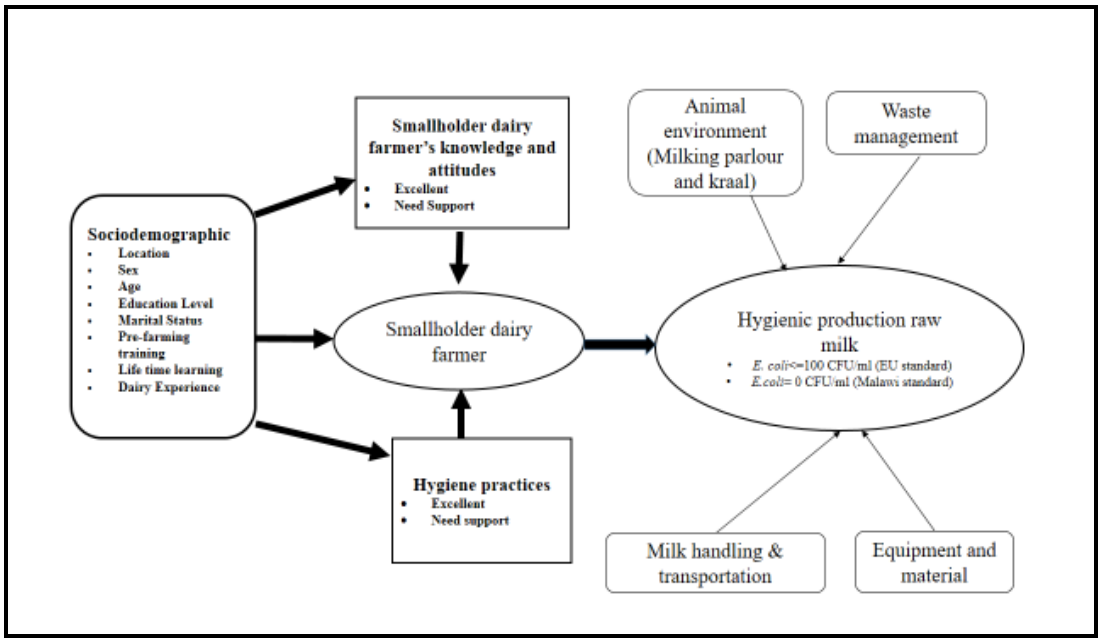

Figure 1.1: Conceptual framework modified and adopted from (Tariq, 2022).

1.7 Operational definitions

Milk Value Chain: The series of steps involved in producing and delivering raw milk from the farm to consumers, encompassing all stages like milking, storage, transportation processing and distribution.

Hygienic production of raw milk: the measures that farmers must take as part of the milk value chain from farm to consumers to guarantee that the milk produced is safe and fit for consumption.

Knowledge: this refers to smallholder dairy farmers' theoretical and practical understanding of good hygiene milking practices.

Attitude: respondents' opinions and sentiments regarding the importance of following milk hygiene practices to prevent contamination and guarantee safe milk. This includes factors like perceived benefits, potential risks and social norms around hygiene.

Practice: application of the existing knowledge and attitudes to milk hygiene production and handling. This includes actions like cleaning equipment, storing milk properly and using appropriate sanitation techniques.

Aggregate score: A farmer's average score on assessment of their knowledge, attitudes and self-reported practices. This provides a general overview of their understanding and adherence to hygiene principles.

Composite score: a method where the participant must meet or exceed the cut-off point of 75% in each of three parameters of knowledge, attitudes and practices to be deemed satisfactory. In contrast, a participant who fails in any of the three parameters is unsatisfactory or incompetent in specific area.

CHAPTER TWO: LITERATURE REVIEW

2.1 Hygienic production of raw milk

Hygienic milk production is essential throughout the milk value chain, yet the level of knowledge and infrastructure support to smallholder dairy farmers varies drastically between developed and developing countries. In developed regions like the United Kingdom (UK), Germany and the United States of America (USA), dairy farms are offered comprehensive support, namely good agriculture practices (GAP) training, risk-based supervision by coordinated food control authorities and subsidies to comply with stringent hygiene standards (Berge *et al*., 2020). This commitment ensures milk safety. Conversely, across Africa many factors contribute to inadequate hygienic practices and a significant public health burden (Mpatswenumugabo *et al*., 2023). Inadequate knowledge about hygienic practices and the potential risks associated with contaminated milk in developing countries like Malawi hinders the adoption of good hygiene practices. (Baur *et al*., 2017 and Kothowa, 2021). In addition, poor access to clean water, exacerbated by water adulteration, contribute to *E. coli* contamination in Blantyre Agriculture Development Division (Njombwa, 2019). Furthermore, weak market incentives for hygienic milk produced discourages farmers from investing to improve practices (Baur *et al*., 2017).

2.2 Factors influencing hygienic milk production

2.2.1 Impact of personal hygiene on hygienic milk production

At the point of milking, farmers need to be in good health and observe stringent personnel hygiene protocols (Mweeba, 2019). This is important to prevent contaminating raw milk with pathogenic microorganisms like *E. coli* (Vissers *et al*., 2009). Improper hygiene practices, such as coughing or sneezing near the udder, wearing dirty clothes and neglecting handwashing, can readily introduce *E. coli* into raw milk (Ghali-mohammed *et al*., 2023). Therefore, promoting awareness and encouraging positive attitudes towards personal hygiene can significantly impact dairy farmers' behaviour (Phiri *et al.*, 2021). Milkers must cover their mouths and nose when coughing or sneezing, excuse themselves from work when having febrile illness with diarrhoea,

wear clean clothes during milking and thoroughly wash their hands with lukewarm water and soap before and after milking to remove potential *E. coli* contaminants (Berhe *et al.*, 2020). In addition, trimming fingernails further reduces the risk of transferring *E. coli* during milking (Ghali-mohammed *et al*., 2023). Farmworkers who consistently implement simple personal hygiene practices yet crucial can significantly contribute to the safety of raw milk and protect consumer health (Phiri *et al*., 2021).

2.2.2 Contribution of animal housing environment to contamination of raw milk

Apart from milk being contaminated during milking, the environment where cattle are raised, significantly contribute to the contamination of raw milk (Mweeba, 2019). In developed countries like Netherlands cattle housing is supported with automation and technology to regulate humidity, air and lighting (Vissers *et al*., 2009). Cattle housing and milking parlours should be designed, maintained and used in a manner that minimises the introduction of *E. coli* into raw milk (Njombwa *et al*., 2021). However, cattle housing which are poorly designed with inadequate maintenance can be source of contamination to the dairy cow and milk it produces (Olofsson, 2013).

2.2.3 Waste management and milk contamination

Smallholder dairy farmers require right waste management practices so that manure and waste milk should be disposed of properly (Bekuma *et al*., 2018). Furthermore, accumulation of waste in animal housing and animal parlour are also an occupational hazard to the farmworkers (Lencho *et al*., 2018). Animals, therefore, need to be raised in a hygienic environment for them to produce safe milk (Lemma *et al.*, 2018). Hygienic production of milk requires maintaining a clean animal housing environment and potable water for feeding and cleaning.

2.2.4 Milk handling and transportation

Inadequate hygiene practices and improper storage conditions during milking and handling significantly contribute to the proliferation of *E. coli* in raw milk produced by

smallholder dairy farmers in developing countries, posing a major public health risk (Berhe *et al*., 2020). Manual milking without proper handwashing, often performed in dusty or open environments, readily introduces *E. coli* from the milker's hands and the environment into the milk (Bekuma *et al*., 2018). Furthermore, once milk is harvested, temperature and time are critical to preventing the proliferation of spoilage and pathogenic microorganisms (Giacometti *et al*., 2012). Likewise, in Zimbabwe, Paraffin *et al*., (2018) reported that smallholder dairy farmers travel long distances and deliver milk at uncontrolled temperatures, which affects the safety of milk. Similarly, Njombwa (2019) indicated that farmers in three agricultural ecological zones (AEZ) in Malawi kept milk for more than six hours at temperatures more than 4 °C before delivering it to cooling centres. Even when the initial *E. coli* load may be low at the farm, travelling with milk for more than two hours at ambient temperatures exceeding 20 °C is ideal for *E. coli* growth (Giacometti *et al*., 2017). Additionally, the composition of milk, rich in lactose and amino acids, provides an ideal growth medium for *E. coli* (Grace *et al*., 2020). Therefore, milk needs rapid cooling to 4 °C within two hours after milking at facilities with reliable electricity to maintain the cold chain, which is key to preventing *E. coli* proliferation (Vissers *et al*., 2009).

2.2.5 Equipment and material contribution to hygienic milk production

Plastic equipment is commonly used in the dairy sector; however, it is scratched easily (Andrew *et al*., 2021). Moreover, plastic containers micropores are difficult to clean (Duguma, 2022). Methods of cleaning containers vary from the use of hot water to scouring the material and using different types of detergent (Lencho *et al*., 2018). Milk residues in the milking equipment lead to the growth of microorganisms (Knight-Jones *et al.*, 2016). As a result, stainless steel equipment is recommended and preferred over plastic materials, which should be sanitized properly (Olofsson, 2013).

2.3 Overview of dairy industry in Malawi

2.3.1 Dairy production system

The Malawi dairy sector is dominated by smallholder dairy farmers with zero grazing production preferred in Blantyre Agriculture Development Division (Njombwa, 2019 and Kothowa, 2021). This production system is necessitated by limited land availability where cows are confined, fed on cut forage and supplemented with concentrates (Baur *et al.*, 2017). However, improper management of left-over feed when mixed with contaminated urine and manure can create a source of continuous infection like *E. coli* to the cow and raw milk (Sindani, 2012). Farmers need excellent knowledge and a positive attitude to maintain animal housing to provide the conducive bedding for the comfort of animals (Mogotu *et al*., 2022).

Dairy farmers primarily keep Friesians, Malawian Zebu and cross-breed (Friesian-Zebu) for milk in Malawi's Blantyre Agriculture Development Division. However, farmers face several challenges, including long travel distances for forage acquisition, limited access to protein supplements and occasional milk spoilage due to inadequate hygiene practices (Njombwa *et al*., 2021). In Blantyre Agriculture Development Division to improve safety of milk produced, it is crucial to generate smallholder dairy farmers' knowledge, their attitudes and practices related to hygienic milk production

2.3.2 Organisation of the dairy value chain

The organisation of the dairy value chain in Malawi provides for both formal and informal channels for raw milk marketing, as shown in Figure 2.1. Small dairy farmers are organised into milk bulking groups, owned by private companies and cooperative associations, where they pool and cool their raw milk before selling to processors in a formal market (Kainga *et al*., 2022). Apart from bulking and cooling milk at milk bulking groups, smallholder dairy farmers exchange knowledge through farmer to farmer interaction. In contrast, informal markets are characterized by some small dairy farmers selling raw milk to vendors, small scale producers, direct consumers and local restaurants.

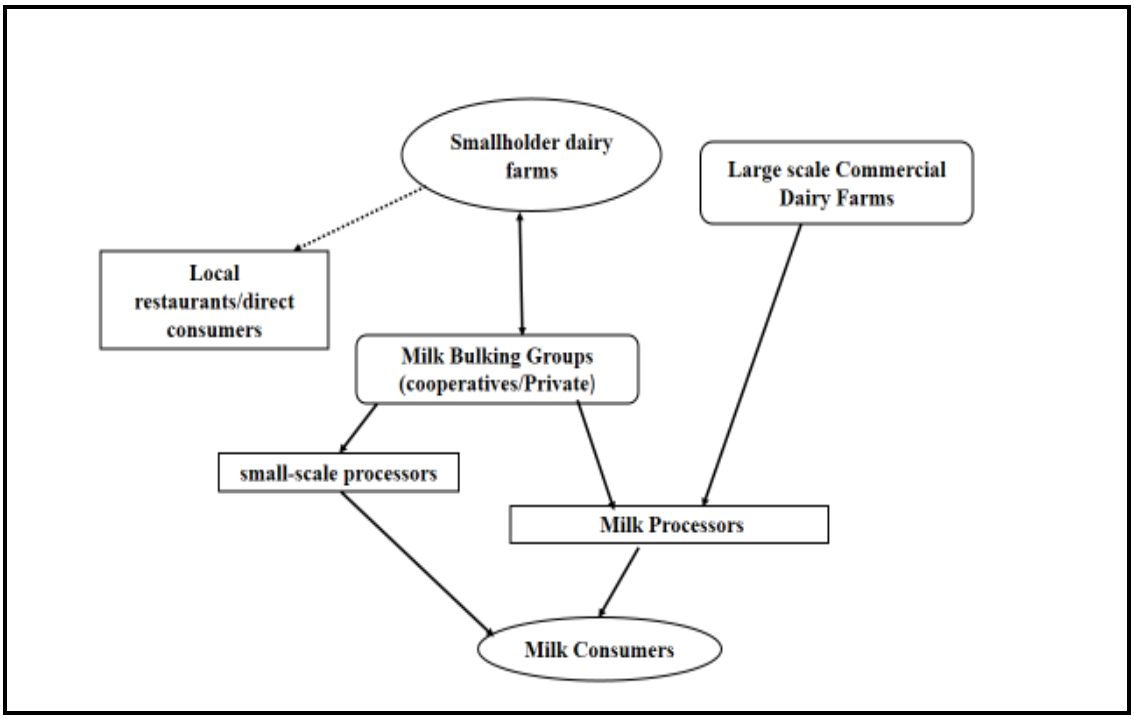

Figure 2.1: Malawi dairy value chain.

2.3.3 Malawi dairy sector regulations

Malawi dairy sector has an elaborate institutional framework guided by the National Livestock Policy (2021-2026) and the Milk and Milk products Act of 1989 (Sindani, 2012). These documents delineate regulations for production, processing, distribution and development of the dairy industry. The current law that guide the dairy industry is Milk and Milk Products Act of 1989. It provides for production, regulation, distribution and development of the dairy sector (Kothowa, 2021). Besides, the Public Health Act of Chapter 34:1948, under the Ministry of Health addresses hygiene standards of premises producing food, including milk (Morse, 2018).

Despite this comprehensive framework, challenges in milk safety still remain. Notably, the Malawian dairy sector lacks a dedicated food safety authority, creating ineffective oversight across all foodborne diseases prevention efforts (Morse, 2018). Furthermore, some regulatory frameworks are outdated and need to be reviewed to address evolving dynamics of the dairy sector (Baur *et al.*, 2017). The outdated regulatory frameworks coupled with insufficient coordination among regulatory bodies lead to confusion and

delays in addressing food safety issues particularly farm level hygiene inspections (Morse, 2018).

2.4 Blantyre Agriculture Development Division dairy farmers' compliance with Malawi Standards and European Union Standards.

Most of raw milk from Blantyre Agriculture Development Division is primarily supplied to Malawian processors (Njombwa *et al*., 2021). The raw milk from Blantyre Agriculture Development Division has the potential to contribute to the national economy, through access to international markets like Common Market for Eastern and Southern Africa (COMESA), the African Continental Free Trade Area (AfCTA) and the European Union (EU) (Grace *et al*., 2020). However, access to such markets require strict adherence to sanitary measures set by regulatory bodies like Malawi Bureau of Standards and European Union Standards. Unfortunately, 76.1 % of the raw milk supplied by small holder dairy farmers in Malawi has high level of *E. coli* (Njombwa, 2019). Most small holder dairy farmers in developing countries lack awareness of good agricultural practices (GAP) and hazard analysis critical control point (HACCP) as compared to their counterparts in developed countries (Grace *et al*., 2020). The lack of infrastructure like decent animal housing and potable water are among the challenges for smallholder farmers to comply with standards (Nyokabi *et al*., 2021). Moreover, the inconsistent implementation and inadequate government financial support limit the effectiveness of regulatory frameworks to raise hygiene standards among smallholder dairy farmers (Grace *et al*., 2020). In addition, absence of a fair and innovative rewarding system for hygienically produced raw milk is a significant barrier to sustained adoption of hygienic practices by small holder farmers (Revoredo-Giha *et al*., 2013).

2.5 Public health importance of raw milk

According to FAO statistics for 2022, India, the United States of America (USA) and China were major producers of milk (Smith *et al*., 2022). It is estimated that almost 150 million farm households are involved in milk-production around the world, with the majority of them located in developing countries (Duguma, 2022). Eastern Africa is

Africa's top milk producing region, accounting for 68% of the milk supply (Grace *et al*., 2020). Ethiopia, Kenya, and Tanzania are among Africa's largest dairy producers (Gülzari *et al*., 2020). In Malawi, BLADD contributes 70% of dairy cows (Kothowa, 2021) and is the major supplier of milk. Milk is a source of calcium, proteins, amino acids and vitamins, which are vital for body growth (Smith *et al*., 2022). Beside its nutritional value, milk is also a source of employment and financial capital (Chisowa, 2022). Dairy production is rapidly increasing in developing countries, making significant contributions to health, nutrition, the environment, and livelihoods, and it has the potential to make even greater contributions (Andrew *et al*., 2021).

2.6 *Escherichia coli* risks through consumption of raw milk

Among milk-borne pathogens, *E. coli* is studied frequently because its strains have evolved to be a primary concern for milk safety and public health (Ghali-mohammed, *et al*., 2023). The presence of *E. coli* in milk is suggestive of faecal contamination from cattle or humans (Mweeba, 2019). Even though *E. coli* strains are commensal in the gastrointestinal tract (GIT), some are pathogenic, causing outbreaks and diseases globally (Gambushe *et al*., 2022). Pathogenic *E. coli* affects both cattle and humans (Kapoor *et al.*, 2023). Contaminated raw milk is a vehicle for the propagation of *E. coli* through when undetected at milk bulking groups posing a significant public health risk (Gambushe *et al*., 2022). In such scenarios, a single contaminated batch can quickly lead to mass distribution of *E. coli* outbreaks affecting numerous consumers (Grace *et al*., 2020). Luckily, pasteurisation, a process that exposes milk to high temperatures for a short time significantly reduces *E. coli* levels lowering the risk of contamination and promoting safe milk (Kapoor *et al*., 2023). Unlike in developed countries, where pasteurisation is widely adopted, in many developing countries like Malawi raw milk consumption remains more prevalent due to limitations in knowledge and resources for implementing safe milk production at farms (Koski *et al.*, 2022). It is therefore critical to estimate the level of *E. coli* in raw milk.

2.7 Knowledge and attitudes during milk production in Malawi

Understanding how smallholder farmers in Blantyre Agriculture Development Division (BLADD) acquire knowledge and adopt excellent milk production practices is important if farmers are to adhere to *E. coli* guidelines set by the European Union (Takahashi *et al*., 2016). This study employed two key theoretical frameworks-diffusion of innovations (DOI) and social network theory (SNT) to analyse the drivers and barriers in adopting hygienic production of raw milk within milk bulking groups (MBGs). Diffusion of Innovations proposes adopt of new ideas, technologies and practices start with a small group who share or/and influence the larger group gradually (Green *et al*., 2009). A prominent example in this context of dairying, when introducing concepts like good animal husbandry and hygienic milk production extension worker should be identifying early adopters within the milk bulking group. These farmers can serve as role model and influencers to others on their demonstration farms. In contrast, emphasizes on how social interactions and network structures influence dairy farmers' attitudes and behaviour potentially leading to the collective adoption of practices within the milk bulking groups (Iqbal *et al.*, 2022). This has been seen in the case of milk bulking groups and dairy farmer associations which are used as part of network to disseminate new information and technologies (Kainga *et al*., 2022).

2.8 Dairy farmers' Knowledge, Attitudes and Practices (KAP) studies related to hygienic milk production

Studies on knowledge, attitude and practices have been shown to be valuable in assessing the vulnerability of smallholder dairy farmers to food safety hazards in resource-limited settings (WHO, 2008). In line with this, studies have been done to address and prevent public health hazards in Southeast Asia, Eastern Africa and Southern Africa (Paraffin *et al*., 2018, Shanta *et al*., 2021 and Mpatswenumugabo *et al*., 2023). Decision makers use KAP studies to develop strategies for public health preventive programmes.

Two studies in Southeast Asia found opposing views on smallholder dairy farmers' knowledge of clean milk production. Shanta *et al.* (2021), used a cross-sectional survey

to analyse milk hygiene awareness and practices among dairy farmers in Baghabarighat milk shed areas of Sirajgonj and Pabna districts in Bangladesh. In this study, 270 dairy farmers were selected randomly from October 2018 to March 2019. It was found that approximately 60% of respondents did not wash their hands before milking. Dairy farmers' hygiene practices in the studied areas were substantially below standard (Shanta *et al*., 2021). However, from 2009 to 2011, Lindahl *et al*. (2018) conducted a comprehensive hygiene study in Assam, a state in India, to assess milk producers' knowledge, attitudes and practices. The first survey was done in 2009 with 405 producers from four areas. The second study was done in 2012, with 161 producers from two areas. In addition to surveys, hygiene observations were made. Results of this intervention study revealed that there were significant changes in knowledge in both untrained and trained producers following training (Lindahl *et al*., 2018).

Smallholder farmers dominate Kenya's dairy sector, accounting for 95% of total milk production (Nyokabi *et al*., 2021). Nyokabi *et al*. (2021) assessed the milk quality and hygiene knowledge, attitudes and practices of smallholder dairy farmers in central Kenya using a cross-sectional study design. Data were collected through focus group discussions and a questionnaire. Furthermore, in a study, Mogotu *et al*., (2022) assessed the hygienic practices and microbial safety of milk supplied by smallholder farmers to processors in Bomet, Nyeri, and Nakuru counties in Kenya. Farmers' cleanliness and handling methods were evaluated through interviews and direct observations. The two studies established that dairy farmers had low knowledge and poor attitudes, which were associated with poor clean milk production despite doing both qualitative and quantitative designs, respectively.

In order to assess respondents' hygiene practices and awareness regarding bovine milk-borne zoonosis, in Bishoftu Town, Ethiopia, Lencho *et al*. (2018) conducted a questionnaire-based survey. In particular, smallholder dairy farmers level of awareness for anthrax, brucellosis and salmonellosis was low in Bishoftu Town, Ethiopia Lencho *et al*. (2018) such that only 19.84% knew anthrax 1.6%, knew salmonellosis and 6.35% knew brucellosis .

Similarly, in Zambia Phiri *et al*. (2021) revealed unhygienic tendencies among smallholder dairy farmers in three provinces of Zambia (Lusaka, Western and Southern) as potential microbial risk factors. Likewise, Paraffin *et al*. (2018) compared the perceptions of large-scale and small-scale farmers' safe milk production in Zimbabwe. Small-scale farmers were less concerned about milk safety (Paraffin *et al*., 2018). In both studies of Central African countries, it was found that milk from smallholder dairy farmers was produced under unsatisfactory hygienic conditions.

2.9 Gap in literature review

In the Blantyre Agriculture Development Division (BLADD), raw milk is a major contributor to nutrition and economic activities and must be produced under hygienic conditions to adequately yield the required benefits. Previous studies on knowledge, attitudes and practices (KAP) in BLADD focused on dairy farming particularly zoonotic diseases like brucellosis and rift valley fever (Kothowa *et al*., 2021; Kainga *et al.*, 2022). Another the study by Njombwa *et al*. (2021) sampled only fifteen dairy farmers, which was an inadequate sample size. Notably, Kothowa *et al*., (2021) found that 94.5% of 378 smallholder dairy farmers demonstrated poor understanding of basic hygiene principles, and their practices were inadequate, particularly because they were not aware of zoonotic diseases like Brucellosis. Furthermore, Njombwa (2021) identified several challenges that contributed to non-compliance, including limited access to water and inadequate cooling facilities. Therefore, this study was designed to build on previous studies (Kothowa *et al*., 2021 and Njombwa *et al*., 2021) to assess the knowledge, attitudes and practices employed by smallholder dairy farmers, including how raw milk produced complied with the Malawi Bureau of Standards and European Union Standards in a comprehensive manner.

CHAPTER THREE: METHODOLOGY

3.1 Study design

A descriptive cross-sectional study was carried out to understand smallholder farmers' the knowledge, attitudes, practices (KAP) and factor affecting of hygienic production of milk.

3.2 Study area

3.2.1 Study duration and location

The study was conducted in Malawi's Blantyre Agriculture Development Division between August and September 2023. This study focused on four districts where smallholder dairy production is widely practiced (Kothowa, 2021) which are Blantyre (15.8642 ^{0} S, 35.0488 ^{0} E), Thyolo (16.0457 ^{0} S, 35.28806 ^{0} E), Chiradzulu (15.8196 ^{0} S, 35.21621 ^{0} E), and Mulanje (15.9974 ^{0} S, 35.32466 ^{0} E) (Figure 3.1). The Blantyre Agriculture Development Division is located in the Shire Highlands, known for its mountainous terrain with elevations exceeding 1300 metres above sea level (Njombwa *et al*., 2021). The Thyolo Mountains border the region to the south-west while Mulanje Mountain rises to the east (Sindani, 2012). From the mountains and hills, numerous rivers flow towards the westward into the Shire River, in the east-south into the Ruo River and ultimately reaching Lake Chilwa in the east (Njombwa, 2019). This network of rivers carves out a vast landscape of valleys and plains, characterised by grasslands and scattered trees in the hills.

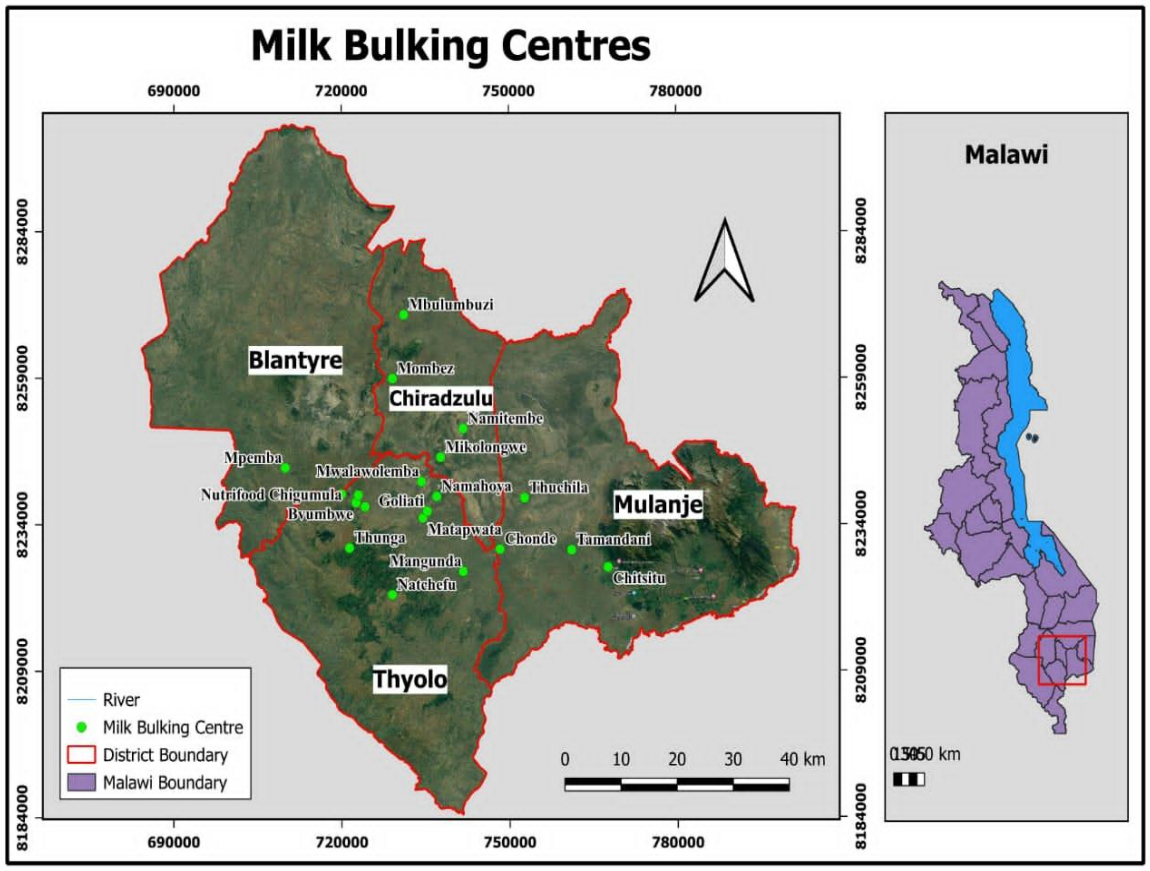

Figure 3.1: The location of milk bulking groups where questionnaire for knowledge, attitudes and practices including raw milk sampling was done in Blantyre, Chiradzulu, Mulanje and Thyolo Districts. Data source: QGIS.

3.2.2 Climate in Blantyre Agriculture Development Division

Blantyre, Chiradzulu, Mulanje and Thyolo districts generally have a cool climate. The Blantyre Agriculture Development Division experiences distinct seasons in June and July is cold-dry, while in September and October is hot-dry (DCCMS, 2024). In the 2023/24 rainy season Blantyre, Chiradzulu, Mulanje and Thyolo expected normal rainfall of 876.4mm, 556.7mm, 976.2mm and 765.8mm respectively (DCCMS, 2024). In addition, Chiperone winds provide mist and mild rains in June to August, reviving the dry grasslands (Baur *et al*., 2017). Most small dairy farmers, rely on rains for their pasture growth. Adequate rainfall maintains palatable and succulent grass, offering minerals and vitamins for promoting good animal health (Kothowa, 2021). Besides, the rains provide water for feeding animals and cleaning equipment and animal quarters,

contributing to diseases prevention (Baur *et al*., 2017). Heavy rains, however, can pose challenges like mud in cattle kraals and impassable roads, which affect hygienic milk production (Tariq, 2024).

Temperatures in the Blantyre Agriculture Development Division vary between 17 and 27 °C (DCCMS, 2024) which is crucial for dairy cattle. Some breeds, like Holstein-Friesians imported from temperate countries like Canada, would be heat stressed if raised in other regions of Malawi. The heat stressed animals consequently have reduced immunity, rendering them severely vulnerable to diseases (Knight-Jones *et al.*, 2016). The combination of temperature and rainfall patterns provide good pasture and a cooler environment which reduces the risk of certain diseases, making the Blantyre Agriculture Development Division a suitable region for dairy farming.

3.3 Study population

Smallholder dairy farmers (SHDFs) were the study population. In this study, a small-holder dairy farmer is one who owns less than five cows for dairy production and is involved in milk production activities. Smallholder dairy farmers in Blantyre Agriculture Development Division primarily keep Friesians, Jersey, Malawian Zebu and cross-breeds (Friesian-Zebu) for milk production (Sindani, 2012). The predominant dairy farming system in the Blantyre Agriculture Development Division is zero grazing, where cows are confined, and fed cut forage supplemented with concentrates (Kothowa, 2021). This system is necessitated by limited land availability in the area (Baur *et al*., 2017). Farmers face several challenges with zero grazing, including long travel distances for forage acquisition and limited access to protein supplements (Njombwa *et al*., 2021). Consequently, long distances contribute to reduced time for animal care and other farm activities, as well as potential forage quality degradation due to longer travel times (Baur *et al.*, 2017). Therefore, dairy farmers have to explore the promotion of collective forage production and have access to affordable motorised transport. In addition, there is a high cost of commercially available protein supplements and a lack of awareness about local alternative protein sources (Baur *et al*., 2017). Limited access to protein can be

improved by introducing locally produced protein or promoting collaborative buying of supplements at reduced costs through milk bulking groups.

Currently, cooperatives or private companies own milk bulking groups(MBGs) in the Blantyre Agriculture Development Division (Chalmers *et al*., 2019). Cooperative milk bulking groups are supported from Shire Highlands Milk Producers Association (SHMPA) to conduct triennial executive elections (Kothowa, 2021). Conversely, private milk bulking groups operate under the independent decision-making of their proprietors (Njombwa, 2019). Notably, all MBGs are authorised to deliver milk to processors (Revoredo-Giha *et al*., 2016).

3.4 Sample size determination and sampling

3.4.1 Sample size determination

The sample size was estimated, as described by Fisher *et al.*, (1991) $n = (z^2\ p\ q)/d^2$. This study considered a smallholder dairy farmer as a sampling unit. The assumption was that 50% of smallholder farmers follow hygienic production of milk; with precision of 5% at 95% confidence interval. Thus, population of $n = (z^2\ p\ q)/d^2$

Where n = calculated sample size,

z = standard normal deviation at 95% confidence interval =1.96,

P = proportion of dairy farmer with following hygienic production of milk (50%),

q= is complementary probability of p (1-P) smallholder dairy farmers failing to observe hygienic milk practices,

d = precision 5% = 0.05.

Calculation of sample size = $(1.96^2 \text{ x } 0.5\text{x}0.5)/0.5^2 = 384$

Recognizing the potential participants dropout (attrition), the study further calculated attrition rate at 10% as described by Kainga *et al.*, (2022). To account for this, calculated

sample size was multiplied by the attrition rate and 1. Where calculated sample size = 384

Attrition = $\frac{\text{Calculated sample size x Attrition rate}}{\text{(Attrition rate-1)}}$ = (384x10)/ (10-1) = 426

Attrition = 426 smallholder farmers.

Thus, sample size was increased by adding the expected number of drop outs, resulting to new sample size of 426 (384+42). This allocation employed the formula (x/N*426) where x is the population size of active smallholder farmers in each district and N represents the total number of active farmers in four districts. The sample sizes for Chiradzulu, Thyolo, Mulanje, and Blantyre districts were distributed among the population of active farmers in each district as 135,176, 80, and 35, respectively

3.4.2 Sampling

A Multi-stage sampling technique was utilised to select participants for a survey on knowledge, attitudes and practices (KAP) in Blantyre Agriculture Development Division (BLADD). The first cluster selected four districts out of seven district in Blantyre Agriculture Development Division using simple random technique. From each district a sub-cluster of milk bulking groups was selected based on the proportion of the farmers. At this stage, the sample size for participants was proportionally calculated for representativeness across four districts based on their smallholder dairy farmers' population.

An active milk bulking group meant the facilities that had functional cooling tanks and were selling raw milk to processors on behalf of farmers. The recruitment of participants KAP interviews and milk sample collection was conducted at the milk bulking groups' level, as it was convenient to capture many smallholder dairy farmers within the shortest time. After the KAP interviews, the research assistants sort consent for milk collection and permission for smallholder dairy farmers to participate in further observations of the hygienic production of milk at their dairy farms in the afternoon.

3.5 Inclusion criteria

Small holder dairy farmers who were recruited in the study had to satisfy the following criteria either

(1) Being an active smallholder dairy farmers (defined as someone who owned at least one lactating cow and delivered milk to milk bulking groups for marketing).
(2) Actively participating in milking routines at the farm.
(3) Furthermore, all participants had to be 18 years or older at the time of the recruitment.

3.6 Exclusion criteria

Smallholder farmers whose raw milk was for home consumption and who declined to be interviewed were excluded from the KAP survey. Large-scale commercial dairy farmers with herd size exceeding five cows were also excluded. In addition, smallholder dairy farmers from Matapwata Milk Bulking Group in Thyolo District were excluded because it was used for pretesting the survey questionnaires.

3.7 Data collection tools and procedures

3.7.1 Pretesting and administering of the electronic questionnaire

The questionnaire was developed by adopting instruments from existing studies such as (Nyokabi *et al*., 2021, Berhanu *et al*., 2021 and Gume *et al*., 2023). Questions were initially formulated in English, translated into Chichewa, one of the local language in Malawi and subsequently translated back to English for accuracy. The pretesting was conducted with twenty participants at Matapwata Milk Bulking Group in Thyolo District. The feedback from this exercise informed refinements to enhance the clarity, simplicity and understandability of the translated Chichewa questions. A team of trained assistant veterinary officers (AVOs) with a minimum of three years' experience in conducting surveys using electronic questionnaires administered on smartphones to farmers. Interviews were administered before or after milk sales at milk bulking groups where it was convenient for farmers (Figure 3.2).

Figure 3.2: The interviewer with one of the smallholder dairy farmer at Mpemba Milk Bulking Group.

3.7.2 Structure of the Questionnaire

The questionnaire had 35 questions structured into four sections: socio-demographic section, knowledge, attitudes and self-reported practices (Appendix 5).

Section 1: Socio-demographic Factors

A set of ten questions was asked to assess the socio-demographic factors of the smallholder dairy farmers influencing hygienic production of raw milk.

Section 2: Knowledge Questions

A set of five questions with three possible answers were asked to assess participants' knowledge on milk hygiene practices. The knowledge section had questions on animal housing, drinking of raw milk and storage milk as well as milk-borne pathogens and illnesses. Each correct answer was awarded one point, while a false or not sure answer

was given a zero point. Likewise, questions 2.4 and 2.5 were multiple choices questions and for each correct choice one point was awarded, while an incorrect choice was given zero points. Each participant could score between 0 and 7, with a higher score corresponding to a better knowledge of milk hygiene.

Section 3: Attitudes

A Likert scale with ten questions was used to assess the attitudes of participants towards milk hygiene. A four-item Likert scale was chosen to offer participants polarity between strongly disagreeing and strongly agreeing (Joshi *et al*., 2015). The attitude section assessed attitude through the following items: responsibility for good milk hygiene, milk contamination and facility maintenance. All questions had four possible answers: strongly agree, agree, disagree and strongly disagree, which were scored at 4, 3, 2, and 1 point, respectively. Only question 10 was scored in reverse. The calculated scored for attitudes ranged from 10 to 40. The higher the score, the more it implied a positive attitude towards clean milk production.

Section 4: Practices

The section on self-reported practices had ten questions focusing on the role of personal hygiene, hand washing practices, and strategies against milk-borne diseases and cross-contamination. Each question was scored with one mark for the right answer and zero for the wrong answer. The calculated total score for hygiene milk production will range from 0 to 10.

3.7.3 Scoring methods

In addition, each smallholder dairy farmer's (SHDF) score on knowledge, attitude and practices were summed up and expressed as a percent. Then an aggregate and composite score scheme were calculated for each smallholder dairy farmer. The aggregate score is the arithmetic average of knowledge, attitude and self-reported practice calculated for each dairy farmer. The score of at least 75% meant that the SHDF had passed the expected threshold to produce clean milk (Berhanu *et al.,* 2021). Furthermore, smallholder dairy farmers who scored an average of less than 75% on knowledge,

attitude and self-reported practices did not satisfy the aggregate scoring scheme. A composite score was determined by calculating each smallholder dairy farmer's individual score for knowledge, attitude and self-reported practice against a 75% cutoff. Smallholder dairy farmers who scored at least 75% in each section of knowledge, attitudes and self-reported practices were deemed satisfactory, while those who scored of below 75% in any category were considered unsatisfactory.

3.7.4 Observing hygiene practices at smallholder dairy farms.

The study employed a checklist (Appendix 6) adapted from previous studies by Orwa *et al*., (2017) and Mweeba, (2019). The study evaluated hygiene milking practices in four key areas: personal hygiene, animal management environments, milk handling and transportation. Ninety dairy farms were inspected across the four districts of Thyolo, Blantyre, Chiradzulu and Mulanje. The number of visits was distributed among the four districts proportionally according to the number of respondents in the questionnaire survey and inclusion criteria. Smallholder dairy farmers' hygienic practices were assessed using an eleven items checklist.

The assessment of animal housing environments involved evaluating the cleanliness of milking parlours and the availability of water sources. In addition, the roofing and flooring materials used on animal housing was also documented in the checklist. In terms of personal hygiene, observers focused on milkers' changing of clothes, handwashing practices and covering of milk. The research assistant further observed milk storage practices and the materials of containers for transporting raw milk from farms to milk bulking groups. Smallholder dairy farmers were instructed to record travel time from their farms to the milk bulking group using SD Standard Diagnostics Inc. ™ timers.

3.7.5 Raw milk sampling for *E. coli* analysis

To compare levels of *E. coli* contamination with established regulations set by Malawi Bureau of Standards and European Union standards, this study employed a simple

random sampling technique to select ninety (90) small holder farmers who met criteria for raw milk submission from database of knowledge, attitude and practices. Samples were collected at milk bulking groups, either before or after farmers sold their milk. Twenty-five (25) millilitres of raw milk samples were collected from farmers' milk container using a cup used at milk bulking groups and immediately transferred to sterile, tightly capped bottles. The bottles were labelled with unique serial numbers and date and time of collection to ensure proper identification and traceability using a permanent marker. The raw milk samples were then placed in an ice-cooled box and transported within four hours to the Malawi University of Business and Applied Sciences (MUBAS), Food Laboratory for analysis. The samples were stored at 2–8 °C and analysed within 48 hours.

3.7.6 Sample preparation and enumeration of *E. coli*

Sample preparation was done according to the ISO 6887-1 procedure (ISO, 2017). Samples were thawed at room temperature (18 °C) between half an hour and an hour. They were thoroughly mixed by shaking gently. A sterile pipette tip was used to pipette 1 ml of raw milk sample into a sterile falcon tube to containing 9 ml of distilled water. Next, subsequent serial dilutions were done from 1:100 to 1:10000. This was done to have dilution factor to calculate the final colony forming unit (CFU/ml). The raw milk samples were analysed in duplicate (Figure 3.3).

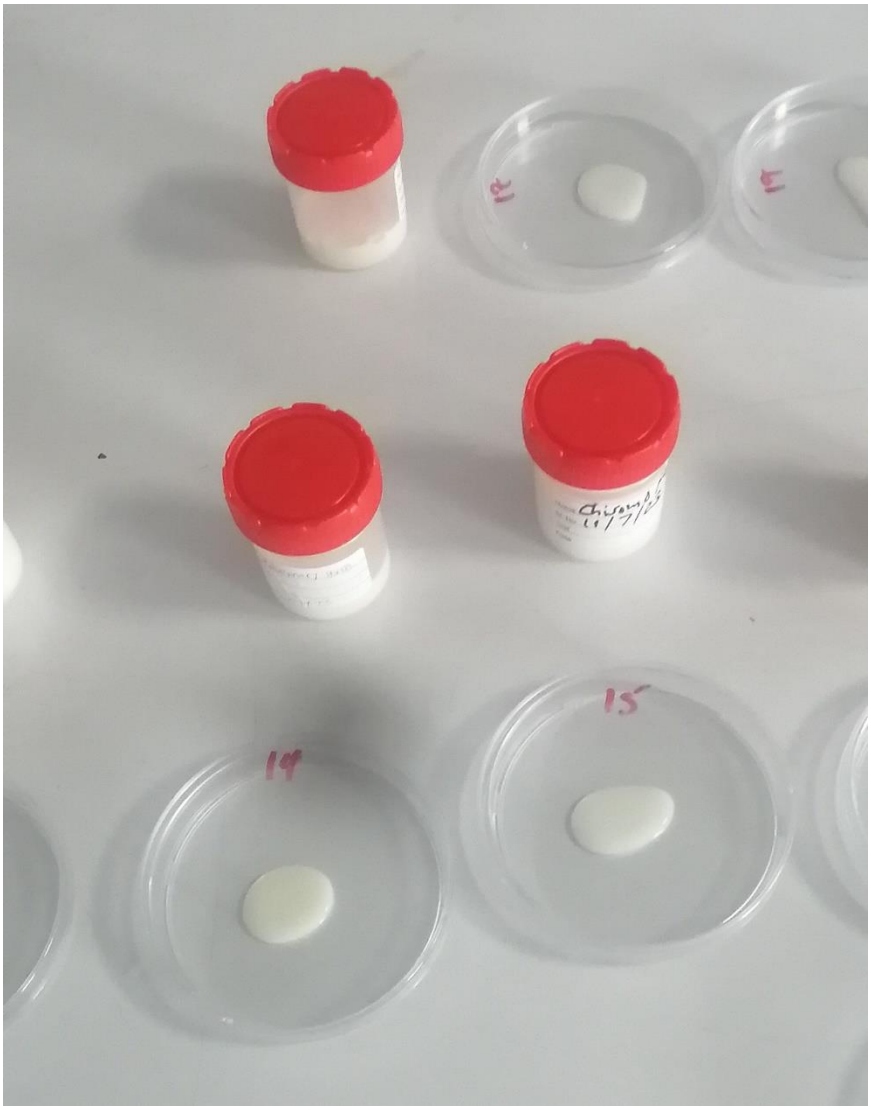

Figure 3.3: One millilitre of raw milk samples prepared in duplicate plates at Food Microbiology Laboratory, Malawi University of Business and Applied Sciences.

The violet red bile agar (VRBA) CM0107 (Oxoid, England) was prepared according to the Oxoid Limited, Hampshire, United Kingdom manufacturer's instructions using the pour-plate method. The enumeration of *E. coli* was done according to ISO 16649-1, 2018 protocol. One millilitre of raw milk was prepared in duplicate and about 22 ml of violet red bile agar (VRBA) CM0107 (Oxoid, England) was poured into plates (Figure 3.4.). Next, the plates were rocked gently, ensuring the sample and media were completely blended, eliminating any signs of raw milk. The prepared media was put in a Grant® water bath (Cambridgeshire, United Kingdom) at 48±1 °C until pour plating was

finished. The mixture was then allowed to solidify in cool air within twenty minutes, followed by inverting the plates and incubating at 37 ±1 °C between 18 and 24hrs.

Figure 3.4: Preparation of Violet red bile agar in Food Microbiology Laboratory, Malawi University of Business and Applied Sciences.

Violet Red Bile Agar (VRBA) CM0107 (Oxoid, England) was used for the enumeration of *E. coli*. The number of purple-pink or red colonies with reddish haloes called bile precipitate was counted and recorded in the laboratory book. After incubation, positive samples were counted visually to determine *E. coli* colony forming units (CFU) per ml. Dilutions with the total number of colonies on the plate were used for the calculation of CFU using the formula given below.

CFU/ml = number of colony counted on plate/ (volume plated (ml) x dilution factor).

3.7.7 Microscopic examination and Gram staining of *E. coli*

A single colony of each isolate was fixed on a clean microscope slide to examine for Gram stain, using oil immersion x100 objective and viewed under x 10 eyepiece thus total magnification of 1000 under Olympus microscope. The isolates that were red in colour, rod shaped suggestive of Gram negative bacteria (Ghali-mohammed *et al*., 2023).

3.7.8 Biochemical tests for identification *E. coli.*

Later on, the presumptive colonies were isolated from the Violet Red Bile Agar and subcultured on Nutrient Agar CM0003 (Oxoid, England). Colonies on Nutrient agar were inoculated using a 50 microlitres sterile plastic disposal loop, for rapid biochemical confirmation was performed using Bactident® Oxidase (© 2020 Merck KGaA, Darmstadt, Germany). The development of violet or pink on Bactident ® Oxidase (© 2020 Merck KGaA, Darmstadt, Germany) test strip indicated positive result. In the event of no colour development it was considered as *E. coli* negative result of raw milk.

A single colony of each bacterial isolate was taken on a 50 microlitres sterile plastic disposable loop and smeared on clean glass slide. Next, a drop of 3% hydrogen peroxide was flooded and mixed thoroughly. The presence of bubbles indicated a catalase test positive result while absence of bubbles after 30 seconds was interpreted as negative for *E. coli* respectively.

Indole test was performed by inoculating into peptone water broth a loopful of colony and incubating at 37 ±1 °C for 24 hours in incubator. After incubation, two drops of Kovac's reagent were added and `the presence of pink ring indicate a positive result. When there is no colour change it is an indication of negative test result.

Citrate utilisation test (Simmon's citrate slant) was employed to assist in identification of *E. coli.* A loopful of colony from nutrient agar was streaked onto a Simmon's citrate agar, then incubated at 37±1 °C for 24 to 48 hours. Change of colour of the medium to blue colour indicated a positive result. A green colour signified a negative for this test.

3.8 Data management and statistical analysis

Data from the questionnaire, observation checklist and laboratory results, previously stored in a Microsoft Excel® version 2010 spreadsheet, were exported into Statistical Package for the Social Sciences (SPSS)® version 26 for analysis. Within SPSS, the data underwent cleaning and coding procedures. Descriptive statistics, including medians, frequencies and percentages were employed to characterize the outcomes associated with social and institutional factors as well as aggregate scores which is an average for the sum of knowledge, attitude and practice. Smallholder dairy farmer with an aggregate score of 75% or higher were considered to have met the expected threshold for hygiene milk production. In contrast, those who scored below 75% were identified to improve one or more areas of knowledge, attitudes and practices. Analysis of variance (ANOVA) was employed but the run had unequal variances therefore, the alternative test of Kruskal Wallis H test was used to compare median across the districts in Blantyre Agriculture Development Division. A Chi-square test was employed to assess for associated factors of hygienic milk production among smallholder dairy farmers. The analysis in binary logistic regression may have been obscured by confounding, which could have led to non-significant results even after a true association exists.

3.9 Ethical considerations

The Animal Health Committee at the Department of Animal Health and Livestock Development, Ministry of Agriculture in Malawi, reviewed and approved the study protocol (reference DAHLD/AHC/01/2023/4). District council animal health offices granted permission to carry out the study in their jurisdiction area. The executive leadership, local chiefs and private owners of the milk bulking groups agreed that the study should proceed after explaining the purpose of the study. Only the research team members who were trained on KAP research procedures, confidentiality and autonomy of the farmers conducted the interviews, farm hygiene observations and raw milk collection. The principal investigator trained three research assistants from 22nd to 23rd August, 2023 at Matapwata Extension Planning Area, Thyolo District in Malawi. The interviewer read and explained the part of the information and consent form in

Chichewa. Interviews, farm hygiene observations and milk samples were only taken after farmer's verbal consent.

CHAPTER FOUR: RESULTS

4.1 Socio-demographic characteristics of smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division.

A total of 410 farmers participated in the KAP survey and their mean age was 41.7 (with a standard deviation of 12.2). Most participants were female, representing 60%. The highest number of study participants (42.9%) were recruited from Thyolo District, while the lowest number (7.6%) were from Blantyre District. The majority of the participants had formal education; the highest group attended primary school (61%), and some attended secondary school (25.4%), while a small number had no formal education (13.4%). The majority of dairy farmers (66.1%) had pre-training before starting farming. Most dairy farmers (57.1%) depend on the milk bulking group for their continuous lifetime learning, as shown in Table 4.1.

Table 4.1: Socio-demographic characteristics of 410 smallholder dairy farmers within Blantyre Agriculture Development Division, Malawi.

Demographic Characteristics	Category	Frequency n=410	Proportion (%)	95%CI
District	Thyolo	176	**42.9**	38.1-47.9
	Chiradzulu	125	30.5	26.1-35.2
	Mulanje	78	19.0	15.3-23.2
	Blantyre	31	7.6	5.2-10.6
Sex	Female	246	**60.0**	55.1-64.8
	Male	164	40.0	35.2-44.9
Education	Primary	250	**61.0**	56.1-65.7
	Secondary	104	**25.4**	21.2-29.9
	Tertiary	1	**0.2**	0.1-1.4
	No formal	55	13.4	10.3-17.1
Pre-training	Yes	271	**66.1**	61.3-70.7
	No	139	33.9	29.3-38.7
Source of lifetime education	MBG	234	**57.1**	52.1-61.9
	None	101	24.6	20.5-29.1
	Radio	2	0.5	0.1-1.8
	Television	27	6.6	4.4-9.4

	Other	46	11.2	8.3-14.7

4.2 Pre-training attendance and Knowledge, Attitudes and self-reported practices performance among dairy farmers in Blantyre Agriculture Development Division, Malawi

The results from knowledge, attitudes and practices survey, conducted among smallholder dairy farmers in Blantyre Development Division are presented in Table 4.2. The percentage of smallholder dairy farmers who attended Pre-training varied across districts, Mulanje had the highest attendance 84% (n=78), followed by Thyolo 68% (n=176), Blantyre 61% (n=31) and Chiradzulu 56% (n=125). Regarding knowledge, Mulanje smallholder farmers outperformed the other districts, with 74.4% followed by Thyolo 42.6%, whereas Chiradzulu and Blantyre had lower score 35.2 % and 35.4% respectively.

Farmers' attitudes towards hygienic milk production were overwhelmingly positive in most districts. Blantyre smallholder dairy farmers exhibited the most favourable attitudes 100%, while Mulanje and Thyolo followed closely at 96.2%. Chiradzulu had lowest percentage of smallholder dairy farmers with positive attitudes at 79.2%. In terms of practices, most Mulanje smallholder dairy farmers reported correct practices, while Chiradzulu and Blantyre had similar percent of (77.6 and 77.4) respectively. The calculations of aggregate and composite scores demonstrated that 88.5% of farmers from Mulanje has passed both aggregate assessment, while 71.8% were successful on composite scoring method.

Table 4.2: Smallholder dairy farmers' pre-training attendance and performance across Blantyre Agriculture Development Division.

Parameters		**District**			
		Blantyre	**Chiradzulu**	**Mulanje**	**Thyolo**
Percentage Score		**%**	**%**	**%**	**%**
Pre-training	Yes	61	56	84	68
	No	39	44	16	32
Knowledge	Passed	35.4	35.2	74.4	42.6
	Fail	64.6	64.8	25.6	57.4
Attitude	Positive	100	79.2	96.2	96.2
	Negative	0	20.8	3.8	3.4
Practice	Passed	77.4	77.6	91.0	60.8
	Fail	22.6	22.4	9.0	39.2
Aggregate	Passed	74.2	73.6	88.5	81.8
	Fail	25.8	26.4	11.5	18.2
Composite	Passed	22.6	27.2	71.8	22.7
	Fail	77.4	72.8	28.2	77.3

4.3 A comparison of hygiene knowledge in milk production among SHDFs across Blantyre Agriculture Development Division, Malawi

This study investigated differences in hygiene milk production knowledge across different districts within the Blantyre Agriculture Development Division (BLADD). The Kruskal-Wallis test was conducted to investigate whether district had significant effect on farmers' knowledge of hygienic milk production. The results indicate significant difference, χ^2 (3) =33.3, p = 0.001. The knowledge median score comparison between farmers from Blantyre and Mulanje showed a significant difference, with a test statistic of 11.7(p = 0.001, adjusted p = 0.004). Other district comparisons Blantyre-Chiradzulu, Blantyre-Thyolo, Chiradzulu-Thyolo, and Chiradzulu- Mulanje however, showed no significant differences (All adjusted p-values >0.05).

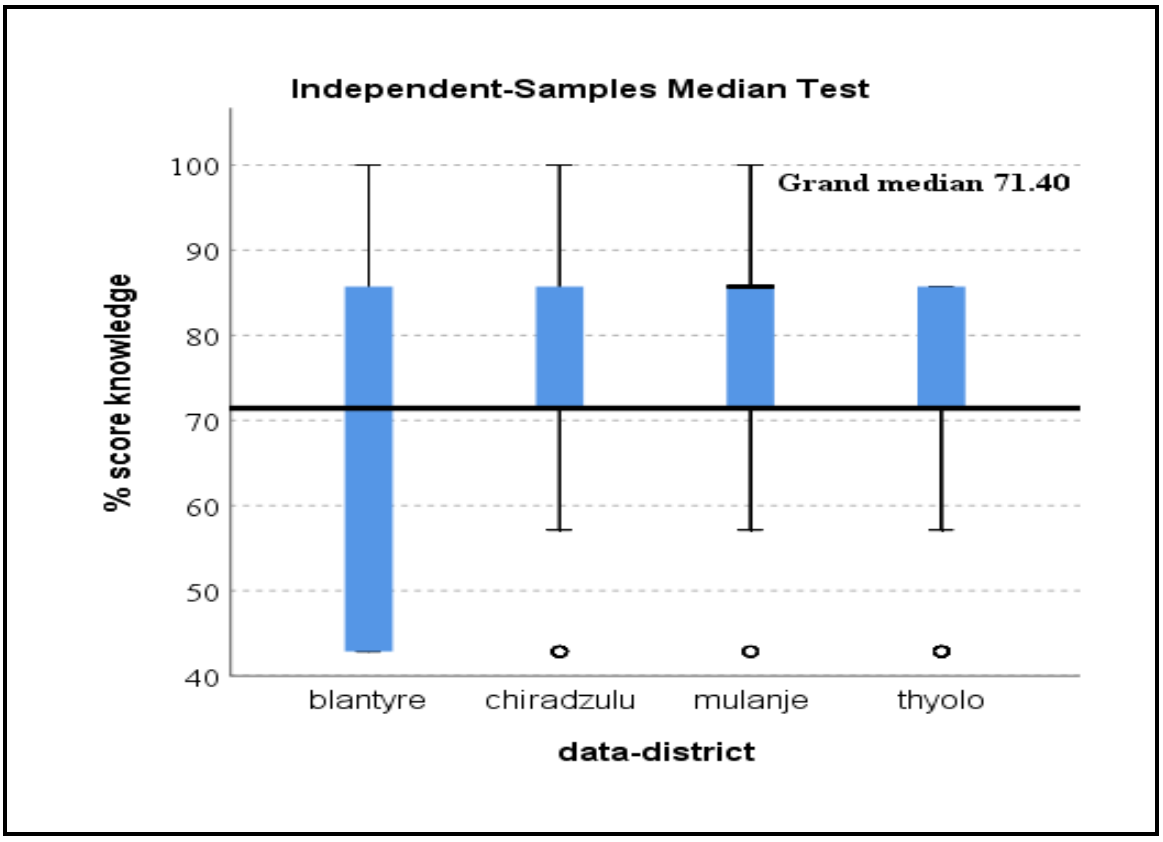

Figure 4.1: A comparison of hygiene knowledge in milk production among smallholder dairy farmers across Blantyre Agriculture Development Division (BLADD).

4.4 Attitude variations among 410 smallholder dairy farmers towards improving milk hygiene within BLADD, Malawi

This study investigated the influence district on farmers' attitudes toward hygienic milk production, a Kruskal- Wallis test was conducted. The overall median was 87.5% as displayed in figure 4.2 The results indicated significant differences, χ^2 (3) = 27.4, p<0.001.Post-hoc pairwise comparisons, adjusted using the Bonferroni correction, revealed notable of disparities in attitude scores between farmers from Chiradzulu-Mulanje (p = 0.001), Chiradzulu-Thyolo (p = <0.001), Chiradzulu-Blantyre (p = <0.001), and Mulanje-Blantyre (p =0.018).

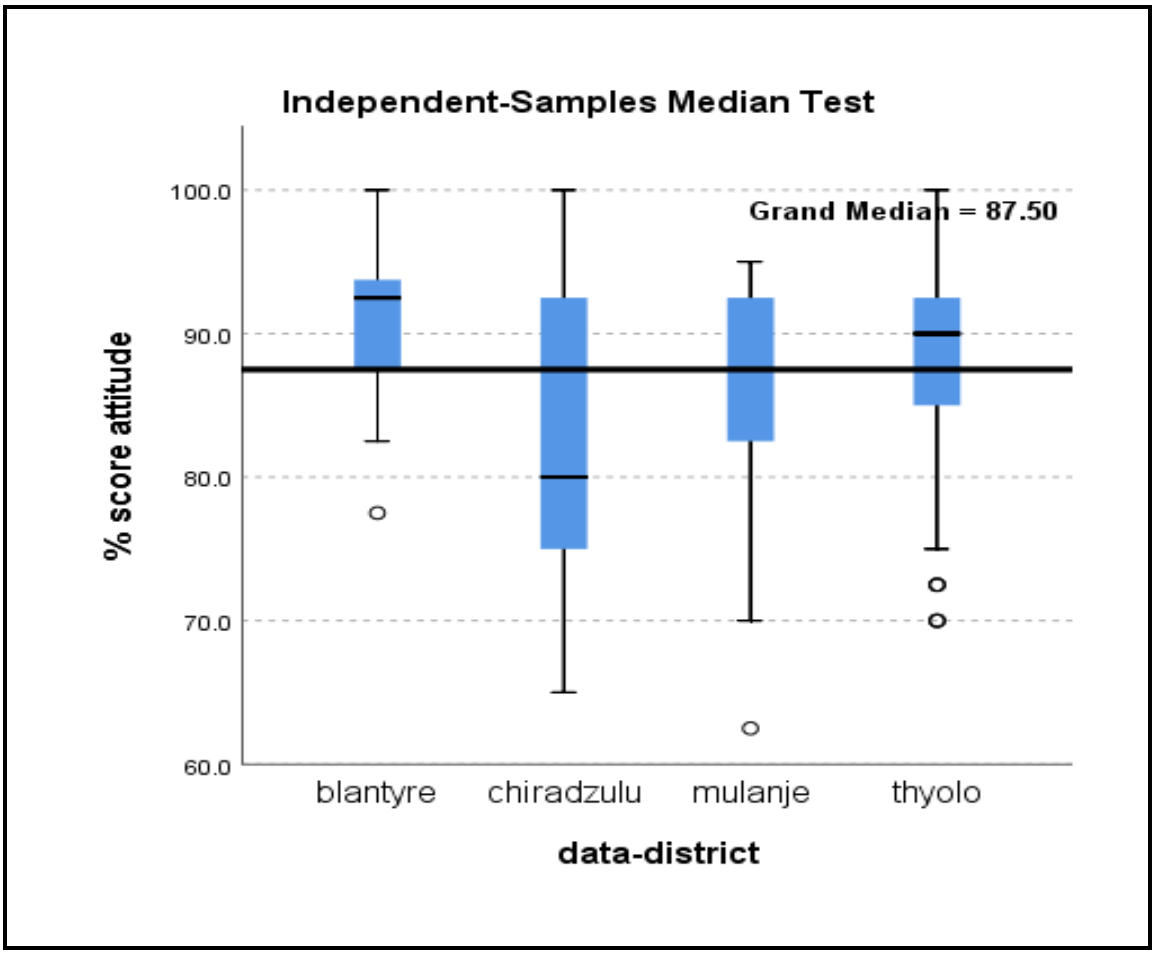

Figure 4.2: District-level variation in self-reported hygiene practices among dairy farmers in Blantyre Agriculture Development Division, Malawi.

4.5 District-level variation in self-reported hygiene practices among dairy farmers in Blantyre Agriculture Development

A Kruskal- Wallis test revealed significant differences in self-reported practices across four districts of Blantyre, Chiradzulu, Mulanje and Thyolo, χ^2 (3) = 29.3, p <0.001. Post-hoc comparisons, adjusted with the Bonferroni correction notable differences were identified smallholder dairy farmers between self-reported practices median score between farmers from Thyolo-Blantyre (p <0.001), Chiradzulu-Thyolo (p < 0.001) and Mulanje-Thyolo Districts (adjusted p = 0.001).

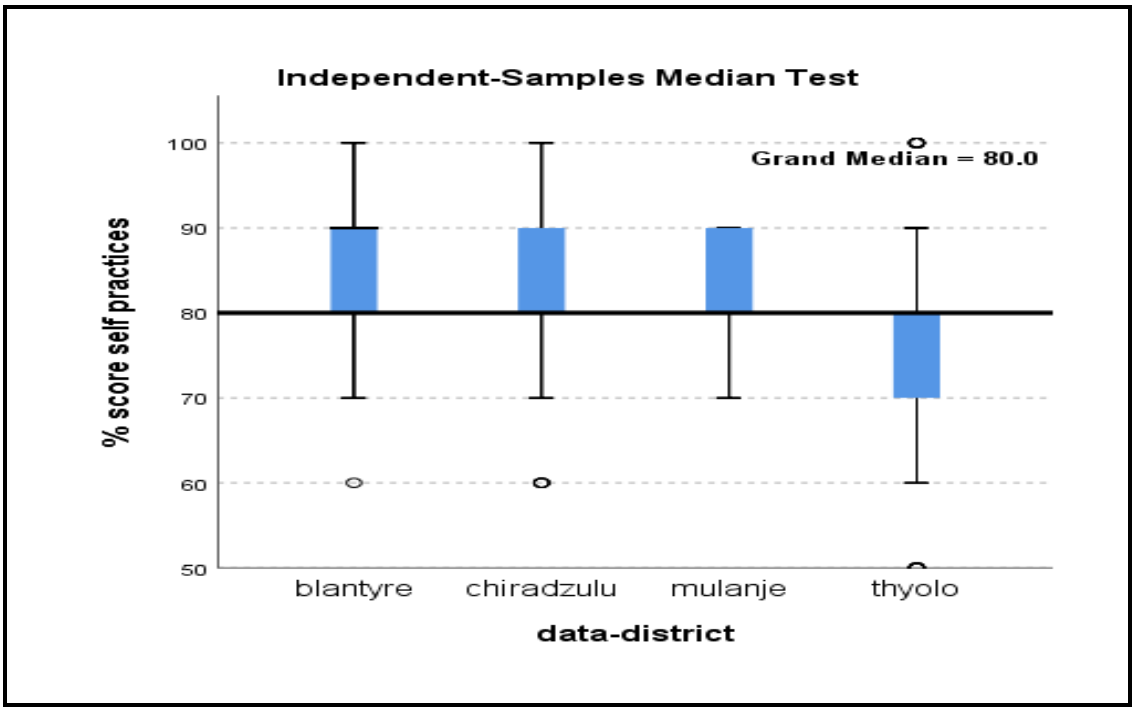

Figure 4.3: District-level variation in self-reported hygiene practices among dairy farmers in Blantyre Agriculture Development.

4.6 District-level performance of smallholder farmers assessed on hygiene milk production using aggregate score in Blantyre Agriculture Development Division, Malawi.

This study employed a Kruskal-Wallis test to examine the effect of district on farmers' aggregate score related to hygienic milk production. The analysis demonstrated significant difference in aggregate score percent across the four district of Blantyre, Chiradzulu, Mulanje and Thyolo in Malawi, χ^2 (3) = 30.6, p <0.001. Post-hoc comparisons, adjusted with the Bonferroni correction revealed differences between farmers from Chiradzulu-Mulanje ($p < 0.001$) and Mulanje-Thyolo ($p < 0.001$).

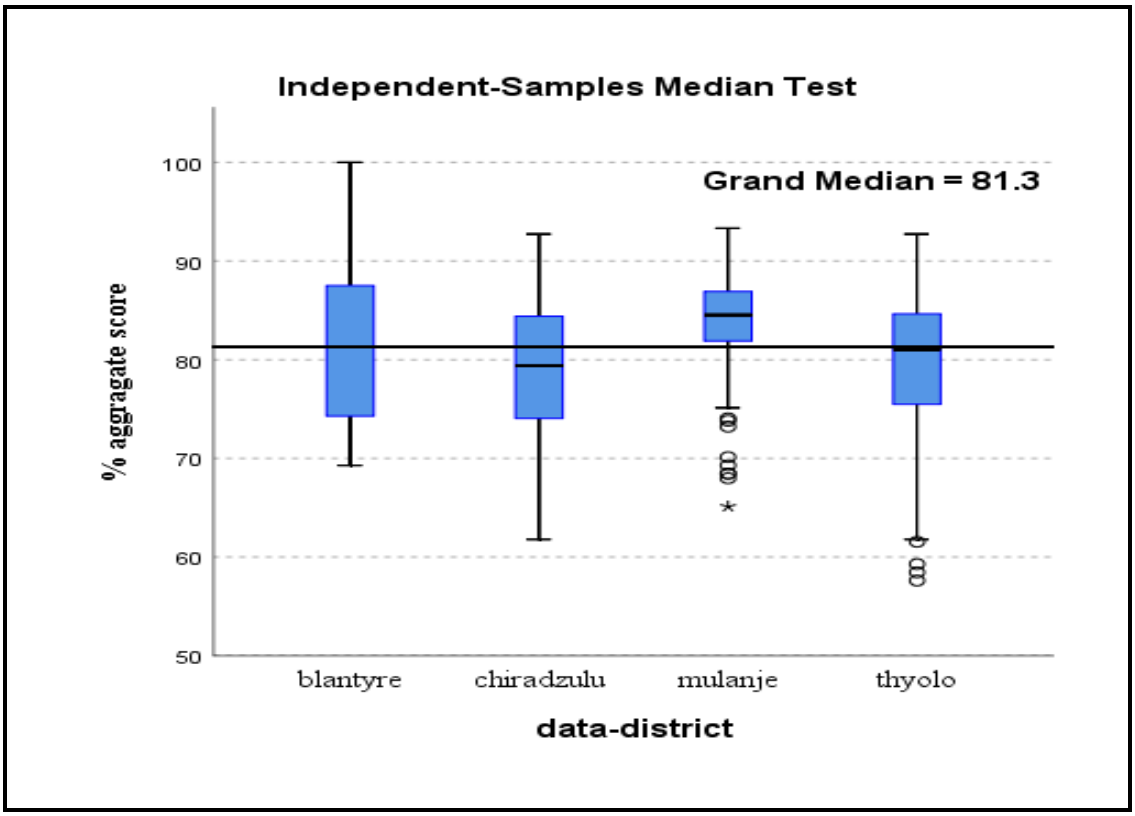

Figure 4.4: District-level performance of smallholder farmers assessed on hygiene milk production using aggregate score in Blantyre Agriculture Development Division, Malawi.

4.7 Compliance of *E. coli* presence in raw milk to Malawi Bureau of Standards in Blantyre Agriculture Development Division

The evaluation of compliance of *E. coli* with Malawi Bureau of Standards (MBS) within Blantyre Agriculture Development Division revealed gross rejection rate of raw milk samples depicted in Figure 4.5. Thyolo District recorded the highest of raw milk 93% (n = 23) contaminated with *E. coli* and did not meet Malawi Standard legal limit; followed by Blantyre at 90% (n = 10). Raw milk from Chiradzulu and Mulanje districts did not also conform to Malawi Bureau of Standard at 85% and 83% (n = 12) respectively. The overall compliance of smallholder dairy farmers' raw milk in Blantyre Agriculture development Division the established Malawi Standard of zero colony forming unit was 12.2%.

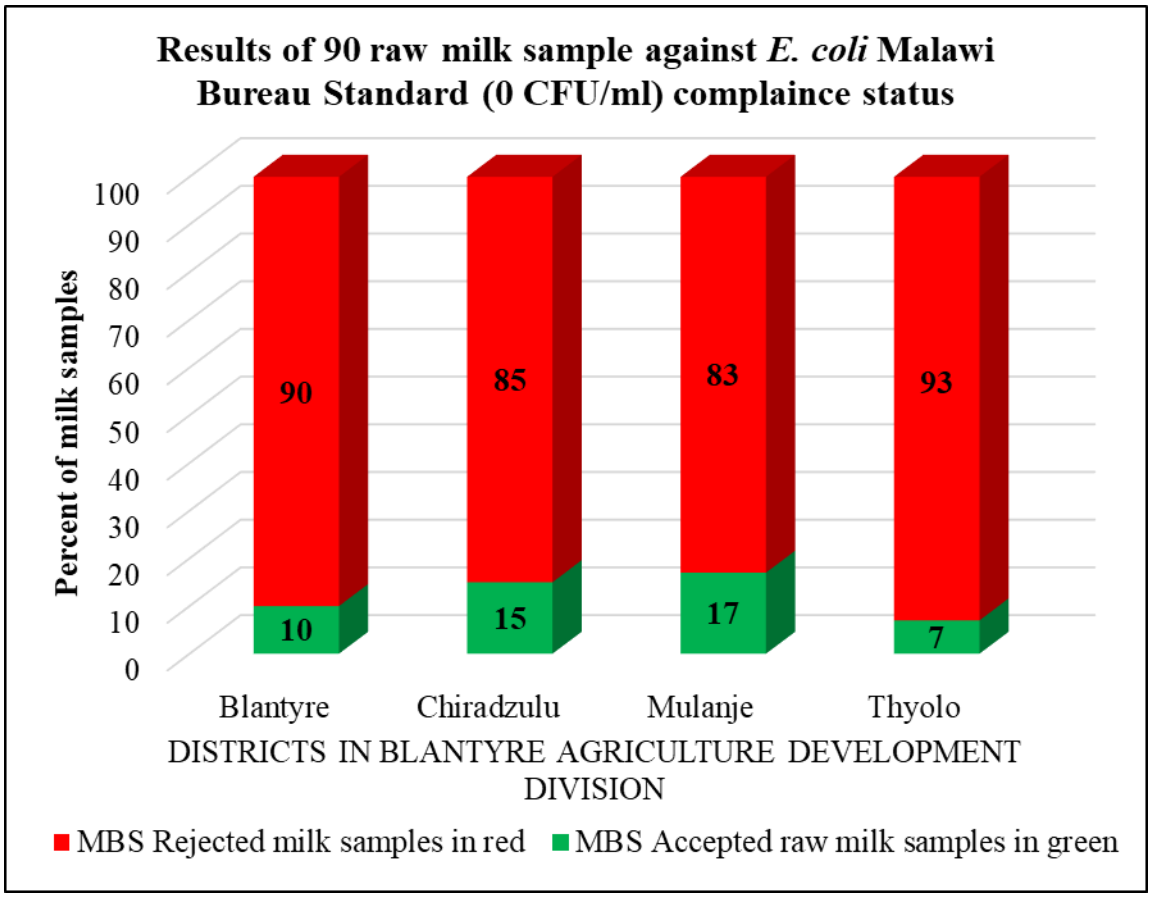

Figure 4.5: Results of ninety raw milk samples which complied with Malawi Bureau Standards supplied to processors in Malawi.

4.8 Compliance of *E. coli* presence in raw milk to European Union Standards in Blantyre Agriculture Development Division.

The compliance of raw milk samples from selected four districts was assessed against European Union Standards for *E. coli* at 100 CFU/ml. Overall, 56% (n = 90) in Blantyre were free of *E. coli* and conformed with European Union Standards. Raw milk from Blantyre had highest acceptance at 70% (n = 10) followed by Chiradzulu 59% (n = 39) while Mulanje 50% (n = 12) Thyolo 48% (n = 29 had low acceptance as shown in Figure 4.6.

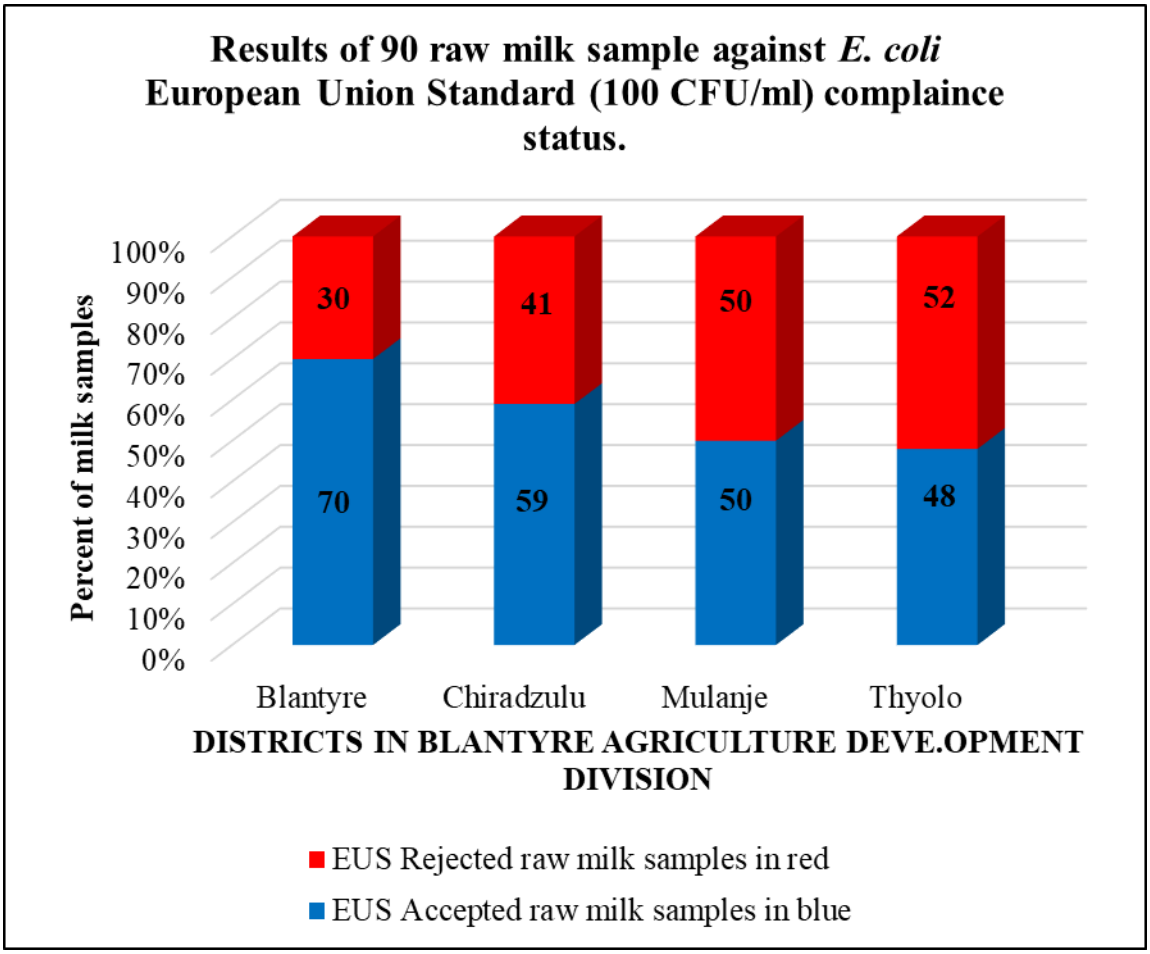

Figure 4.6: Results of ninety raw milk samples which complied with European Union standards supplied to processors in Malawi.

4.9 Risk factors for the determination of the hygienic production of raw milk.

4.9.1 Observed personal hygiene factors in ninety smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division

On personal hygiene factors assessed, all milkers in Blantyre and Mulanje districts wore personnel protective equipment during milking Table 4.3. Most small-scale farms in Blantyre 40% (n = 10), Thyolo 51.7% (n = 29) and Chiradzulu (19.5% (n = 39) had assigned farm worker for milking. All Small holder dairy farmer in Mulanje did not assign farm worker for milking and covered their milk.

Table 4.3: Observed personal hygiene factors in ninety smallholder dairy farmers in Blantyre Agriculture Development Division.

Personal hygiene factors	**Category**	**DISTRICT**			
		Blantyre n = 10	**Chiradzulu n = 39**	**Mulanje n=12**	**Thyolo n=29**
Percent score		%	%	%	%
Did SHDF put on working clothes when milking?	Yes	100.0	94.9	100.0	69.0
	No	0.0	5.1	0.0	31.0
Had assigned milker at farm	Yes	40.0	20.5	0.0	51.7
	No	60.0	79.5	100.0	48.3
Wash hand before milking	Yes	80.0	87.2	83.3	72.4
	No	20.0	12.8	16.7	27.6
Cover milk when milking	Yes	90.0	94.9	100.0	89.7
	No	10.0	5.1	0.0	10.3

4.9.2 Observed animal housing, waste management and environment factors in ninety small scale farms in Blantyre Agriculture Development Division, Malawi.

Three-quarters of dairy farms visited in Mulanje District had open roof on cattle kraal. The stone-paved or concrete floors were the most common in Mulanje 91.7% (n = 12) followed by Chiradzulu 87.2% (n = 39), Thyolo 86.2% (n = 29) and Blantyre 80% (n = 10). Most smallholder dairy farmers in Blantyre 90%, Chiradzulu 94.9% and Mulanje 83.3% relied on boreholes or tap water for their animals except for Thyolo where 44.8% depended on unprotected wells or rivers. All Mulanje smallholder dairy farmers cleaned their milking parlours before milking. The three districts of Blantyre had 80%, Chiradzulu at 79.5% and Thyolo at 79.3% slightly lower scores. Based on observations, most smallholder dairy farmers from Blantyre 50% and Mulanje 58.3% remove waste daily from kraals. The majority of participants reported cleaning or removing waste in the cattle housing on a daily basis in the Blantyre Agriculture Development Division as details in Table 4.4.

Table 4.4: Observed animal housing, waste management and environment factors in ninety small scale farms in Blantyre Agriculture Development Division.

Animal housing, waste management and environmental factors	**Category**	**DISTRICTS**			
		Blantyre n=10	**Chiradzulu n=39**	**Mulanje n=12**	**Thyolo n=29**
	Score percent	**%**	**%**	**%**	**%**
Type of floor	Stone paved/concrete	80.0	87.2	91.7	86.2
	Earthed	20.0	12.8	8.3	13.8
Type of roofing	Thatched/Iron	60.0	71.8	25.0	62.1
	Open	40.0	28.2	75.0	37.9
Source water	Borehole/tap water	90.0	94.9	83.3	55.2
	Unprotected well/rivers	10.0	5.1	16.7	44.8
Cleaned milk parlour before milking	Yes	80.0	79.5	100.0	79.3
	No	20.0	20.5	0.0	20.7
Waste removal frequency	Daily	50.0	46.2	58.3	44.8
	Weekly	50.0	53.8	41.7	55.2

4.9.3 Observed milk handling and transportation factors on small scale farms in Blantyre Agriculture Development Division, Malawi.

Most smallholder dairy farmers 90% (n = 90) in Blantyre Agriculture Development Division (BLADD) travel within two hours to reach and deliver raw milk to a milk bulking group. On equipment and materials used to milk and transport milk to the milk bulking groups, the majority of farmers 73.3 (n = 90) were used aluminium or stainless steel containers. The highest number of dairy farmer 40% (n = 10) who used plastic containers were from Blantyre District.

Table 4. 5: Observed milk handling and transportation factors on small scale farms in Blantyre Agriculture Development Division, Malawi.

Milk handling and transportation Factors	**Category**	**DISTRICTS**			
		Blantyre n = 10	**Chiradzulu n = 39**	**Mulanje n = 12**	**Thyolo n = 29**
Observation score		**%**	**%**	**%**	**%**
Type of milk container	Aluminum/ stainless	60	69.2	75	82.8
	Plastic	40	30.8	25	17.2
Travel time	Within 2hrs	80	89.7	100	96.6
	More than 2hrs	20	10.3	0.0	3.4

4.10 Factors associated with the hygienic production of raw milk

The association between the hygienic milk productions was examined through various parameters using Pearson's Chi-square as detailed in Table 4.6. There was a significant association between the hygienic production of milk and pre-training, source of information, waste management and cleaning of milk parlour before milking. The sex of the farmer, however, did not show an association ($\chi^2 = 1.65$, P value 0.27).

Table 4.6: The association of hygienic production of raw milk with various parameters**.**

Variable	***E. coli* results of dairy farmers' raw milk**				
	Score	**E.U *E. coli* threshold for raw milk**		**χ^2**	**P value**
		Acceptable (load =<2.00log10)	**Rejected (load >2.00log10)**		
Sex	Female	35	34	1.7	0.27
	Male	14	17		
Pre training	Yes	34	22	23.6	<0.001*
	No	16	19		
Source of information	MBG	31	11	15.0	<0.001*
	Radio	6	6		
	Other	7	5		

	None	6	18		
Waste management	Yes	31	12	11.6	0.001*
	No	17	30		
Cleans milk parlour before milking	Yes	5	12	4.8	0.028*
	No	43	30		

* Significant at P value=0.05

4.11 Predictors of the hygienic production of raw milk.

The significant predictors were dairy pre-training and aggregate score, which have been presented in Table 4.7. The farmers who were not offered Malawi government and partners' structured pre-training program increased five times likelihood of producing hygienic raw milk (OR=5.910, 95% CI: 1.997-17.489) compared to farmers who did not have structured pre-training (P-value = 0.001). Furthermore, the farmers who failed on the aggregate score were six times less likely to produce hygienic milk (OR=5.910, 95% CI: 1.997-17.489) than farmers who had passed an aggregate score of at least 75% (P-value = 0.001).

Table 4.7: Binary logistic regression of aggregate score, pre-training towards hygienic milk production of small dairy farmers in Blantyre Agriculture Development Division.

Factor	**Number of participant**	**OR**	**SE**	**P-value**	**95% CI (OR)**
Pre-training					
Yes	55	Ref.			
No	35	5.9	0.6	0.001	2.0-17.5
Aggregate score					
Passed	49	Ref.			
Failed	41	6.8	0.5	0.01	2.3-20.0

CI= Confidence Interval, OR= Odds ratio.

CHAPTER FIVE: DISCUSSION

The study set out to evaluate smallholder dairy farmers' knowledge, attitudes and practices (KAP) and factors affecting the hygienic production of raw milk in Malawi's Blantyre Agriculture Development Division. Smallholder farmers in the Blantyre Agriculture Development Division demonstrated excellent hygienic practices. The study revealed that over forty percent of the raw milk samples exceeded the *E. coli* threshold for the Malawi Bureau of Standards and European Union standards. Pre-training in dairy hygiene and the aggregate score significantly influenced hygienic milk production in Malawi's Blantyre Agriculture Development Division.

The study revealed disparities in medians hygienic milk production knowledge among smallholder dairy farmers (SHDFs) in selected Blantyre Agriculture Development Division districts, suggesting a potential challenge in ensuring consistent safe milk. Mulanje SHDFs demonstrably were most knowledgeable among Blantyre, Chiradzulu and Thyolo districts. This disparity is in agreement with the results of Berhanu *et al*., (2021), who found low knowledge among dairy farmers in Ethiopia. Both our studies and theirs employed simple random participant selection, despite having different methods of evaluating the dairy farmers. Notably, Berhanu *et al*. (2021) categorised knowledge into three levels: poor (≤50%), fair (51-69.9%) and good (>70%) while the present study grouped knowledge into two levels: excellent (≥75%) and poor (<75%). Besides, the current study adopted higher scores than previous related study scores because smallholder dairy farmers in Blantyre Agriculture Development Division require an in-depth understanding of hygiene knowledge to change their attitudes and practices consistently personnel hygiene, milking handling and sanitation measures to prevent milk contamination at the farms. Njombwa (2019) conducted a similar study in all three agriculture ecological zones (AEZ) of Malawi, which also indicated that farmers were knowledgeable about milk contamination. However, methodological differences, including a smaller sample size (n = 15) and different approaches to knowledge assessment, limit direct comparisons with the current study. A possible explanation for variation in knowledge might be arising differences in number of

farmers who were offered pre-training. Consequently, low knowledge of hygienic raw milk production affect compliance with raw milk standards.

The present study found excellent self-reported practices among smallholder dairy farmers across four districts: Blantyre, Chiradzulu, Mulanje and Thyolo. This suggests that assistant veterinary officers' mentorship and training services to dairy farmers could have assisted in the construction of improved animal housing and milking parlours, which were important in securing hygienic milk production (Kainga *et al.*, 2022). Unfortunately, this could not be translated into reduced milk contamination, probably due to practical challenges in implementing and maintaining hygienic milk practices. These challenges might include insufficient access to potable water or a lack knowledge about removing cattle dung daily.

In the study, it was found that the majority of the milkers 81.1% (n = 90) were washing their hands before milking, a practice which is a positive step towards preventing contamination of raw milk by pathogenic bacteria such as *E. coli.* In contrast, Shanta *et al*. (2021) reported lower 41.5% handwashing practices among dairy farmers in Bangladesh due to large herd size and limited awareness of hygienic milk production. Surprisingly, raw milk from Blantyre Agriculture Development Division had contaminated with *E. coli*. Therefore, extension workers must encourage smallholder dairy farmers to be washing hands consistently for hand hygiene technique to be efficient and effective, in removing bacteria such as *E. coli.* This supports similar studies by Orwa *et al*. (2017) in Kenya and Andrew *et al*. (2021) in Zanzibar who found that personnel was the highest source of raw milk contamination at small scale farms. For milk safety can be enhanced, it is imperative to provide ongoing training on proper handwashing techniques and promote a culture of hygiene among smallholder dairy farmers. This may necessitate and stricter regulations from competent authorities as the case of Malawi Bureau of Standards to protect public health. Strengthening handwashing among smallholder dairy farmers could reduce contamination levels, contributing to hygienic milk production.

Furthermore, it was observed that some animal quarters 52.2% (n = 90) in Blantyre Agriculture Development Division were filthy due to the accumulation of cow dung, urine and feed remnant which was not cleaned in the kraals within a day. It was simple, therefore, for the milker's hands or milk to become contaminated. The observation is consistent with findings of Nyokabi *et al*. (2021) study done in Kenya, which reported also that farmers did not adhere to proper animal housing cleaning and manure dumping distance. A reasonable approach to address the issue of unsanitary animal quarters is application of both social network and diffusion of innovation theories by veterinary officers and farmers associations. The Shire Highlands Milk Producers Association (SHMPA) should identify influential farmers with clean kraals to promote innovative management techniques like composting and biogas production (Takahashi *et al*., 2016). Furthermore, diffusion of innovations may be used to support raising awareness of importance of having clean kraals (Green *et al*., 2009). Ultimately, the success of hygienic milk production could be achieved through dairy farmers' consistent cleaning of animal housing daily and adhere to proper manure disposal.

The low compliance for *E. coli* contamination threshold, as set by local Malawi Bureau of Standards zero colony-forming units per millilitre. Coincidentally, Njombwa, (2019) also reported a high prevalence of *E. coli* at 73.3% (n = 15) in their analysis of four agricultural ecological zones in Malawi. In addition, Sindani reported higher presence of *E. coli* in raw milk samples from smallholder farmers in Malawi which is also similar to present study. Previous studies on raw milk from smallholder dairy farmers in developing countries had frequently reported *E. coli* as a contaminant of raw milk.(Berhe et al., 2020, Andrew et al. 2021; Mogotu *et al*., 2022). This could be because *E. coli* is abundant in cattle and the environment where milking is taking place (Orwa *et al*.2017). This could contribute to high prevalence of *E. coli* and higher counts in the milk sample (Mogotu *et al*., 2022). Therefore, Malawi Bureau of Standards in collaboration with veterinary officers should be conducting risk based assessment on the occurrence *E. coli* to identify and address sanitation issues at small scale dairy farms.

Another result from the analysis of ninety raw milk samples from the four districts that participated in this study in Blantyre Agriculture Development Division were above the recommended European Union's legal limit (*E. coli* 100 CFU/ml) for raw milk. This is consistent with Gume *et al*., (2023) study in Ethiopia which reported the highest *Escherichia coli* count from 28% of fifty raw milk samples from smallholder dairy farmers. Consumption of at least 100 colony forming units of *E. coli* per ml can lead to serious health problems especially in vulnerable population like children, the elderly and immuno-compromised individuals (Grace *et al*., 2020). Apart from *E. coli* abundance in milking environment, failure to supervise farmworkers could contribute to the contamination of milk. This is in agreement with the study by Knight-Jones *et al.* (2016) in Zambia, which found that smallholder dairy farmers were inconsistently supervising farm workers. *Escherichia coli* counts are important to the dairy industry and consumers as high counts contribute to spoilage and unsafe milk in milk value chain. As mentioned in the literature review, the European Union standard could have been established with a higher count (100 CFU/ml) and are able to achieve lower rates because regulations are enforced through risk-based audits and penalties imposed on non-compliant smallholder farmers (Berge *et al*., 2020). Another explanation could be that farmer in European Union have access to better infrastructure and technology such as modern milking machines and hygienic milking parlours (Grace *et al*., 2020). Smallholder farmers and consumers in developing countries are more aware of food safety regulations which leads to greater compliance with laws and a demand for high quality dairy products (Baur *et al*., 2017). These results suggest the need for prerequisite training and good animal husbandry to improve overall compliance.

Another observation was that dairy farmers lacking structured pre-training in hygienic milk production were significantly less likely to achieve hygienic milk standards compared to pre-trained farmers. This aligns with the findings of Lindahl *et al*. (2018), who demonstrated the positive impact of structured training interventions on milk hygiene practices between trained and untrained smallholder dairy farmers in northeast India. Interestingly, despite lacking formal and structured training, some farmers in the current study exhibited excellent practical skills and positive attitudes toward hygienic

milk production. This suggests the possibility of alternative learning, such as peer learning at milk bulking groups or self-directed learning from radio and television, contributing to improved hygiene practices over time.

This study introduced a novel aggregate score for assessing Knowledge, Attitudes and Practices (KAP) among smallholder farmers, addressing the limitations of existing methods that often focused on individual components. This scoring system incorporates knowledge, attitudes and practices into a single metric, revealing hidden patterns not evident in individual scores. Previous studies have often utilised individual KAP scores to assess the hygienic milk production of the farmers (Lindahl *et al*. 2018, Njombwa, 2019; Nyokabi *et al*. 2021). For example, Lindahl *et al*. (2018) found low knowledge milk zoonotic diseases in the Assam Region in India among smallholder dairy farmers. However, this study may have missed important nuances and interactions between knowledge, attitudes and practices. Consequently, any deficiencies in any of the components of the KAPs can have a devastating impact on hygienic milk production. A farmer with positive attitudes and excellent practices may still struggle to produce hygienic milk that meets legal limits for Malawi or the European Union. Future KAP studies could explore the application of the aggregate and composite scoring method in different dairy farming to examine other relevant factors.

This study encountered notable limitations that may have influenced the quality of the results. Due to limited resources, some hygienic raw milk production factors could not be evaluated such as observing milking techniques and animal health. Furthermore, the potential for recall bias among certain participants may have influenced the accuracy of responses of knowledge and self-reported practices, hence introducing a degree of uncertainty into the final results. These limitations underscore the need for a cautious interpretation of the results and highlight areas for improvement in future research.

In summary, the study revealed positive attitudes and excellent practices among smallholder dairy farmers in the four districts of Blantyre, Chiradzulu, Mulanje and Thyolo. However, the results of *E. coli* from raw milk samples analysed showed low compliance with Malawi and EU standards. The risk of contamination with *E. coli* was

high, which is worrisome considering that milk is regarded as food, especially for children in Malawi. Interestingly, cleanliness of milking parlour, waste management, structured pre-training and aggregate score were significant contributing factors to the hygiene production of milk in the study. It is therefore important that district veterinary officers, dairy farmers and processors in Malawi's dairy sector invest in structured pre-training and use an aggregate score scheme to contribute to the improvement of hygienic milk production to secure public health benefits.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

This study found that smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division (BLADD), had positive attitudes and excellent practices. However, their knowledge was inadequate and raw milk produced could not consistently meet established limits of *E. coli* in Malawi or European Union Standards. The contributing factors to hygienic milk production includes waste management and cleanliness of milking parlour. In addition, pre-training and aggregate score has influence on smallholder dairy farmers' knowledge on hygienic milk production.

This study provides an insight to specific farmers' inadequate knowledge on removal daily removal of waste, limited infrastructure like potable water in Thyolo district and weak monitoring of raw milk standards. Therefore, consumption of raw milk produced by smallholder dairy farmers in Blantyre Agriculture Development Division (BLADD) poses a significant public health risk. Unpasteurised or inadequately boiled milk from BLADD can harbor *E. coli* that can lead to milk-borne infections to the local community.

6.2 Recommendations

1. The Department of Animal Health and Livestock Development in Malawi, in collaboration with dairy processors and cooperatives should establish a fund for structured pre-training workshops and continuous on farm targeted mentorship on hygiene production of milk for small holder dairy farmers. The Department of Animal and Livestock Development should develop a training manual for smallholder dairy farmers followed by annual refresher training for all smallholder dairy farmers on hygiene milk production. Smallholder dairy farmers' training manual should be and translated into local languages like Chichewa with visual cues to enhance learning and knowledge retention.

2. The Ministry of Agriculture and Ministry of Health in Malawi should take the lead in fostering working collaboration to develop and implement awareness and

trainings based on one health approach at milk bulking groups. The focus of the programs should be common zoonotic diseases, providing practical skills on personnel hygiene, animal welfare and hygienic milking techniques and demonstration of traditional pasteurisation methods.

3. In addition, district councils should support smallholder farmers with enough potable water, especially in Thyolo. The dairy farmers should be taught the importance of using potable water for sanitising animal houses, milker's hands and milking equipment.

4. Aggregate or composite scores should be considered when setting thresholds in future KAP studies to identify farmers with good knowledge, positive attitudes and excellent practices. Aggregate scoring is an average of knowledge, attitudes and practices while composite scoring encourages an in-depth understanding of hygiene knowledge to change their attitudes and practices consistently. Both scoring methods provide a holistic assessment, revealing how farmers with excellent practices may still have knowledge gaps and produce raw milk not meeting standard requirements. Smallholder dairy farmer associations and veterinary officers in Malawi can use these scoring methods as tools to identify areas where individual farmer need targeted support. This targeted assistance could be training programs or infrastructure such as access to potable water. Overall, aggregate or composite scores are valuable tools for assessing farmers' performance and guiding interventions to improve hygienic milk production.

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APPENDICES

Appendix 1: Participants' information sheet: English Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

Introduction:

My name is Enock Chilambula or/and my research assistant's name_____. I am a Malawian studying at the University of Zambia, School of Veterinary Medicine particularly Master of Food Safety and Risk Analysis. I am inviting you to participate in the study.

Purpose of the study

This study part of my practicum for my training in master of food safety and risk analysis which I am doing at the University of Zambia. The purpose of the study is to assess the knowledge, attitudes and practices of hygiene milk production among smallholder farmers in Blantyre Agriculture Development Division. In the process will learn how you take care of the dairy cows, housing management, feeding and water, milking, transportation and your general information.

Potential participants are active smallholder dairy farmers from Thyolo, Chiradzulu and Mulanje districts. You have been invited because you are an active farmer who is living in the study area.

I am expecting the interview to take your twenty minutes.

Procedures

If you agree to participate in this study:

- You will be asked questions in private and secure place. I will use the tablet or phone to access questions. No recording or information taken will be linked to your personal details as questionnaires will be identified by numbers.

Compensation

You may wish to know that there is no payment for participating in this study.

Risks/Burdens

I have not thought of any physical harm and risk in participating in this study. I am aware that some information you may tell me may be personal or maybe sensitive to other stakeholders therefore I am assuring you that I will take full responsibility to protect this information. This information will be secured and used for the purpose of this study only.

Benefits/Ancillary Care

Your participation to this study will contribute to generation of new information regarding level of knowledge, attitudes and practices in clean milk production. Your selfishness efforts will benefit current and future smallholder dairy farmers in Blantyre Agriculture Development Division.

Protecting Data and Confidentiality

The collected data will be locked and secured with passwords available to principal investigator. I will destroy all data after three years after typing the information. I will back up the information in personal Google drive accessed with password.

What happens if you do not want to participate in the study?

Your decision not to participate in the study will not affect the normal services you get at this facility. You are free to withdraw at any time if you decide to participate in this study. You are free not to answer questions that you may feel to be so personal.

Who do I call if I have questions or problems?

In case you have any questions call:

Principal investigator:

Enock Chilambula,
Mwanza District Hospital, P.O. Box 80, Mwanza, +265999175230,
Email: cechilambula@gmail.com.

Concerns and complaints: Dr. John Kothowa, The Regional Veterinary Office**,** P.V.H.O Premises

Or you can also write or call to: Dr. Gilson Njunga, Animal health committee under the Department of Animal Health and Livestock Development (DAHLD) in Ministry of Agriculture and Food Security. gilsonnjunga@gmail.com.

Appendix 2: Participants' information sheet: Chichewa Version

Mawu oyambira:

Ndine Enock Chilambula kapena / ndipo dzina la wondithandizira ndi_____. Ndine m'Malawi yemwe amaphunzira ku Yunivesite ya Zambia, sukulu ya Vetenale. Chidwi changa ndikumvetsa za chitetezo ndikuwunika ziwopsezo n'chakudya. Ndikukupemphani kuti mutenge nawo mbali m'ndondomeko yowona kakamidwe kaukhondo kamkaka.

Cholinga cha Ndondomeko

Ndondomekoyi ndigawo la maphunziro anga luso la chitetezo ndikuwunika ziwopsazo n'chakudya. Cholinga cha ndondomekoyi ndikuwunika chidziwitso, malingaliro ndi makamidwe a mkaka mwaukhondo pakati pa alimi ang'onoang'ono omwe ali mgawo la chitukuko ulimi la Blantyre. Tifuna kumva ndi kuphinzira kwa alimi momwe mumasamalira ng'ombe zamkaka, kasamalidwe ka makhola, kudyetsa ndi kumwetsa madzi, nthawi yomwe mutenga kuti mugulitse mkaka ndi zambiri zanu. Omwe atenga nawo mbali ndi alimi ang'onoang'ono amkaka ochokera maboma Thyolo, Chiradzulu ndi Mulanje. Mwaitanidwa chifukwa ndinu mlimi yemwe amakhala m'derali.

Ndikuyembekezera kuti kuyankhulana kwathu kutenga mphindi makumi awiri (20 minisi).

Machitidwe a Ndondomekoyi

Ngati mukuvomera kutenga nawo mbali pa kafukufukuyu:

•Mudzafunsidwa mafunso pamalo achinsinsi komanso otetezeka. Ndigwiritsa ntchito foni kuti ndipeze mafunso. Ndondomekoyi ndiyachinchinsinsi choncho maina anu kapena zoyankhula zanu zizakhala zotetedwa mpaka nthawi yotsindikidza zotsatira.

Ubwino wotenga nawo ndondomekoyi

Ndondomekoyi idzathandizira kupeza mulingo wachidziwitso, malingaliro ndi machitidwe pakukama mkaka mwaukhondo. Izi zimathandiza adindo kuthandiza alimi ang'onoang'ono popedza thandizo lamaphunziro kapena zipangizo moyenera kuti mkaka udzikhala waukhondo ndi wopanda chiwopsedzo.

Dziwani kuti palibe ndalama dziperekedwa kwa alimi potenga nawo mbali mundondomekoyi.

Zowopsa ndi nkhawa zina

Sindinaganizire za kuvulaza komanso chiopsezo chotenga nawo mbali ndondomekoyi. Ndikudziwa kuti zina zomwe mungandiuze zitha kukhala zachinsinsi n'chifukwa chake ndikukutsimikizirani kuti ndidzatenga udindo wonse kuteteza izi.

Foni ndi makina a komputa wonse tikugwilitsa ndintchito ndidzotetedwa ndi pinikode omwe amapezeka kwa wofufuza wamkulu.

Chimachitika ndi chiyani ngati simukufuna kutenga nawo mbali ndondomekoyi?

Pomaliza dziwani kuti muli ndi ufulu kutenga nawo mbali ndondomekoyi mosakakamidzidwa kapena kuwoopsedzedwa. Mutha kundifunsa pomwe simumvetse komanso kusayankha mafunso ena. Lingaliro lanu loti musatenge nawo mbali ndondomekoyi silikhudza nthandizo lomwe mumapeza pamalo pano.

Ngati muli ndi mafunso, Imbani:

Principal investigator:

Enock Chilambula, Mwanza District Hospital, P.O. Box 80, Mwanza, +265999175230, Email: cechilambula@gmail.com.

Mutha kupeleka madando okhudza ndondomekoyi:

Dr. John Kothowa, the Regional Veterinary Office. P.V.H.O Premises

Kapena lemberani mkulu wona chisamaliro cha ziweto

Dr. Gilson Njunga

Animal Health Committee under the Department of Animal Health and Livestock Development (DAHLD) in Ministry of Agriculture and Food Security. gilsonnjunga@gmail.com.

Appendix 3: Informed consent English Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

Hello! My name is _____ I am student at School of Veterinary Medicine, the University of Zambia. As part of my master's degree in food safety and risk analysis, I am conducting a survey on knowledge, attitudes, and clean milk production in the Blantyre Agriculture Development Division. The information I will get from you, will help to understand the level of knowledge, attitudes and clean milk production practises therefore foster intervention programmes in the dairy sector. The questions usually take **20 minutes**. All answers you give will be confidential and will not be shared with anyone other than members of our survey team. You have been invited to participate because you are registered farmer at this milk bulking group. Your views are important in this survey. If I ask you any question you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time.

In case you need more information about the survey, you may contact people listed on the information sheet given to you.

What does your signature (or thumbprint) mean on the consent form?

Your signature (thumbprint) means:

- You have been informed about the study' purpose, procedures, possible benefits and risks.You have been given the chance to ask questions before you sign.
- You have voluntarily agreed to in the study.

Do you have any questions? May I begin the interview now?

---------- ----------/----------/2023

Name of participant in capital letters Signature of participant Date

---------- ----------/----------/2023

Name of Research assistant Signature of research assistant Date

Ask the participant to mark a 'left thumb print' if s/he cannot sign above.

Appendix 4: Consent Form Chichewa Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

Kalata ya chiloledzo

Moni! Ine ndi_____. Ndine wophunzira kusukulu ya vetenale, yunivesite ya Zambia. Monga gawo la maphunziro anga pankhani yachitetezo cha chakudya, ndili kufufunza zokhudza chidziwitso, malingaliro, ndi kupanga mkaka koyera mu gawo la chitukuko cha ulimi la Blantyre. Zomwe ndipeza kuchokera kwa inu, zindithandiza kumvetsetsa kuchuluka kwa chidziwitso, malingaliro ndi njira zopangira mkaka zoyera. Mafunso nthawi zambiri amatenga mphindi 20.

Mayankho onse omwe mudzapereka adzakhala achinsinsi. Mwapemphedwa kutenga nawo mbali chifukwa ndinu mlimi wamkaka. Mayankho anu ndiofunikira pa m'ndondomekoyi. Ngati ndikufunsani funso liri lonse lomwe simukufuna kuyankha, ingondidziwitsani ndipo ndipitiliza ndi mafunso otsatira kapena mutha kuyimitsa kuzokambirana zathu.

Ngati mukufuna zambiri za kafukufukuyu, mutha kulumikizana ndi anthu omwe atchulidwa patsamba lachidziwitso lomwe mwapatsidwa.

Siginecha yanu (chidindo) ikutanthauza:

- •Mwadziwitsidwa ndicholinga, kachitidwe, ubwino wa ndondomekoyi.
- •Mwapatsidwa mwayi wofunsa mafunso musanasainire.
- •Mwavomera mwakufuna kwanu ndondomekoyi.

Kodi muli ndi mafunso?

Kodi mwapanga chiganizo chotenga mbali m'ndondomekoyi?

----------	----------	----/----/2023
Name of participant in capital letters	Signature of participant	Date
----------	----------/----/2023	
Name of Research assistant	Signature of research assistant	Date

Ask the participant to mark a 'left thumb print' if s/he cannot sign above.

Appendix 5: Questionnaire English Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

Questionnaire number: ----

Demographic Data

1.1 District	**1.** ○Thyolo **2.** ○Chiradzulu **3.** ○Mulanje **4.** ○Mulanje
1.2 Milk Bulk Group	**----**
1.3 Sex of farmer	**1.** ○Female **2.** ○Male
1.4 How old are you?	**----**
1.5 What is your level of education?	**1.** ○ None **2.** ○ Primary School **3.** ○ Secondary School **4.** ○ University/tertiary
1.6 What is your marital status?	**1.** ○ Married **2.** ○ Single **3.** ○ Widow/Widower **4.** ○ Divorced
1.7 How much milk do you consume per day?	**----**
1.8 How long have you been in dairy farming?	**----**
1.9 Did you ever attend any formal initial training before starting the dairy farming?	**1.** ○Yes **2.** ○No
1.10 What is source of your lifetime training?	**1.** □ Training at MBGs **2.** □ TV **3.** □ Radio **4.** □Other specify--

2.0. Knowledge Section

2.1. What is the right floor for cattle?	**1.** ○ Earthen **2.** ○ Stone paved **3.** ○ Concrete
2.2. What is required top cover of cattle housing?	**1.** ○Thatched cover **2.** ○Iron cover **3.** ○Open
2.3. Can consumption of raw milk transmit or cause disease?	**1.** ○Yes **2.** ○Not sure **3.** ○No
2.4. If yes, which of the following infections or diseases are transmitted through milk consumption.	**1.** □ Bovine tuberculosis **2.** □ Malaria **3.** □ Brucella **4.** □ Diarrhoeal diseases.
2.5. What milk storage conditions can increase the multiplication of germs?	**1.** □ Storing at any room temperature **2.** □ Cool place/in container with cold water **3.** □ Refrigerator

3.0. Attitudes section

Score key: 1 = strongly agree; 2 =agree; 3 =disagree and 4=strongly disagree

No	Question	1	2	3	4
1	Do you agree/ disagree that washing udder of cows soap and water before milking prevent contamination of milk?				
2	Do you agree/ disagree that hand hygiene is necessary to prevent milk contamination?				
3	Do you agree/disagree that there is risk of disease when under five children are given raw (unboiled) milk for consumption?				
4	Do you agree/disagree that diary animals need potable water?				
5	Do you agree/disagree that feeding cattle after milking prevent mastitis?				
6	Do you agree/disagree that mixing old and new stock of milk is risk for milk contamination?				

7	Do you agree/disagree that producing clean milk is farmers' responsibility?				
8	Do you agree/ disagree that continuous lifetime training about clean milk production is important to farmer?				
9	Do you agree/ disagree that milk adulteration with water is risk factor of contamination?				
10	Do you agree/disagree a sick milker (diarrhoea) should be milking animals?				

4. Self- Reported Clean Milk Practices

1. What type of milk container is used by farmer?	**1.** ○ Aluminum/Stainless steel **2.** ○Plastic
2. Do you change clothes when milking?	**1.** ○Yes **2.** ○ No
3. Do you continue working when you are sick?	**1.** ○Yes **2.** ○ No
4. Do you wash hand before milking?	**1.** ○Yes **2.** ○ No
5. If yes, why do you wash hands?	**1.** ○Avoid cholera **2.** ○Avoid covid19 **3.** ○Reduce germs
6. How long do you travel from home to milk bulking group?	**1.** ○ Within 2hrs **2.** ○2-4hrs **3.** ○ More than 4hrs
7. Where do you source water for the dairy cattle?	**1.** □ River **2.** □ Unprotected well **3.** □ Borehole **4.** □ Tap water
8. How often do you clean udder when milking?	**1.** ○ Before milking **2.** ○ After milking **3.** ○ Before and after milking **4.** ○ Not at all
9. What do you use to clean the udder?	**1.** ○ Water **2.** ○ Soap and water **3.** ○ Chlorine and water

	4. ○Sucking of calf
10. How often do you clean/remove waste from cattle housing?	**1.** ○ Daily **2.** ○ Weekly **3.** ○ Monthly **4.** ○ More than a month

Thank for your participation!

Appendix 6: Observation Checklist English Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

Questionnaire Number: ----

1.0 Verbal consent for milk samples and farm observation.

Now that you have participated in the section of KAP survey. How do you feel? Next, we are asking you to grant us permission to collect 25mls from your container to test for *E.coli.*

Can we proceed to collect milk? **1.** ○Yes **2.** ○No

Lastly, we are requesting you to grant us permission to visit your farm and observe how you implement hygienic practices.
Do you we proceed to visit you in the afternoon? **1.** ○Yes **2.** ○No

2.0 Demographic Data

1.1 District	**1.** ○Thyolo **2.** ○Chiradzulu **3.** ○Mulanje **4.** ○Blantyre
1.2 Milk Bulk Group	----
1.3 Sex of farmer	**1.** ○Female **2.** ○Male
1.4 How old are you?	----
1.5 What is your level of education?	**1.** ○ None **2.** ○ Primary School **3.** ○ Secondary School **4.** ○ University/tertiary
1.6 What is your marital status?	**1.** ○ Married **2.** ○ Single **3.** ○ Widow/Widower **4.** ○ Divorced
1.7 How milk do reserve for home use?	----
1.8 How much milk do you consume per day?	----
1.9 Do you boil milk?	**1.** ○Always

	2. ○Not always
1.10 How long have you been in dairy farming?	**----**
1.11 Did you ever attend any formal initial training before starting the dairy farming?	**1.** ○Yes **2.** ○No
1.12 What is source of your lifetime training?	**1.** □ Training at MBGs **2.** □ TV **3.** □ Radio **4.** □Other specify--

3.0 Observation of hygiene production of raw milk practices

1. What type of milk container is used by farmer?	**1.** ○ Aluminum/Stainless steel **2.** ○Plastic
2. Did farmer change clothes when milking?	**1.** ○Yes **2.** ○ No
3. Did you have specific assigned milker?	**1.** ○Yes **2.** ○ No
4. Did farmer wash hand before milking?	**1.** ○Yes **2.** ○ No
5. Did the milker cover milk when milking?	**1.** ○Yes **2.** ○ No
6. How long do you travel from home to milk bulking group?	**1.** ○ Within 2hrs **2.** ○2-4hrs **3.** ○ More than 4hrs
7. Where do you source water for the dairy cattle?	**1.** □ River **2.** □ Unprotected well **3.** □ Borehole **4.** □ Tap water
8.Did farmer clean always milk parlour before milking	**1.** ○Yes **2.** ○ No
9. What is the type of roof of kraal?	**1.** ○cover **2.** ○ open
10. What is the type of floor of kraal?	**1.** ○paved **2.** ○ unpaved
11. How often do you clean/remove waste from cattle housing?	**1.** ○ Daily **2.** ○ Weekly **3.** ○ Monthly **4.** ○ More than a month

Thank for your participation!

Appendix 7: Questionnaire Chichewa Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

Questionnaire Number: ----

1.0 Demographic Data

1.1 Boma	**1.** ○**Thyolo** **2.** ○**Chiradzulu** **3.** ○**Mulanje** **4.** ○**Mulanje**
1.2 Dzina la Deile (Milk Bulk Group)	----
1.3 Chongani ngati mlimi ndi wamkazi kapena mwamuna	**1.** ○Mkazi **2.** ○Mwamuna
1.4 Kodi muli ndi zaka zingati zakubadwa?	----
1.5 Kodi maphunziro anu ndi otani?	**1.** ○ Sadapite kusukulu **2.** ○ Pulayimale sukulu **3.** ○ Sekondale sukulu **4.** ○ Yunivesite
1.6. Kodi banja lanu ndi liti?	**1.** ○ Wokwatira **2.** ○ Mbeta **3.** ○ Wamasiye **4.** ○ Ukwati udatha
1.7 Kodi mumamwa mkaka wochuluka bwanji patsiku?	----
1.8 Kodi mwachitapo ulimi wang'ombe za mkaka kwanthawi yaitali bwanji?	----
1.9 Kodi mudachitapo maphunziro aukhondo wamkaka musanayambe ulimiwu?	**1.** ○Eya **2.** ○Ayi
1.10 Kodi mumaphunzira za ukhondo wa mkaka ndi pakhola kudzera -------?	**1.** □ gulu la alimi laku deile **2.** □ TV **3.** □ wayilesi **4.** □ other specify------

2.0 Knowledge Section

2.1. Kodi khola labwino pansi pake mpotani?	**1.** ○ ladothi **2.** ○ potsanja miyala **3.**○ lowaka ndi simenti/konketi
2.2. Kodi khola la ng'ombe lovomedzeka limafunika denga lotani?	**1.** ○la udzu **2.** ○la malata **3.** ○losafolera
2.3. Kodi kumwa mkaka waiwisi kumatha kufalitsa kapena kuyambitsa matenda?	**1.** ○Eya **2.** ○Sindikudziwa **3.** ○Ayi
2.4. Ngati inde, mwamatenda otsatirawa tchulani omwe tingatenge kudzera m'mkaka?	**1.** □ chifuwa cha TB **2.** □ malungo **3.** □ bulusela **4.** □ Matenda otsegula mmimba
2.5. Tchulani machitidwe omwe angachulukitse majeremusi kapena kuwononga mkaka posunga?	**1.** □kusunga nyumba **2.** □ kusunga mmadzi wodzizira bwino **3.** □ kusunga mufuliji

3.0. Attitudes Section

Score key: 4 = strongly agree; 3 =agree; 2 =disagree and 1=strongly disagree

No	Question	1	2	3	4
1	Kodi mukuvomereza kapena simukuvomereza kuti kusuka mawere a ng'ombe ndi madzi ofunda kumachepetsa kuwonogeka kwa mkaka?				
2	Kodi mukuvomereza / kusagwirizana kuti ukhondo wam'manja ndikofunikira pokama mkaka kuti usawononge ke?				
3	Kodi mukuvomereza /simuvomereza kuti pali chiopsezo cha matenda pomwe ana osakwana zaka asanu amapatsidwa mkaka wosawiritsa kuti amwe?				
4	Kodi mukuvomereza /simuvomereza kuti ng'ombe zamkaka zimafunikira madzi aukhondo akumwa?				

5	Kodi mukuvomereza /simuvomereza kuti kupatsa chakudya ng'ombe mukakama kumateteza matenda kumawele a ng'ombe?				
6	Kodi mukuvomereza / simuvomereza kuti kusakaniza mkaka wakale ndi watsopano ndi chiopsezo cha kuwonongeka kwa mkaka?				
7	Kodi mukuvomereza /simuvomereza kuti kupanga mkaka waunkhondo ndi udindo wa alimi?				
8	Kodi mukuvomereza / simukuvomereza kuti kuphunzira ulimi wa mkaka waukhondo ndi kofunikira kuti munthu akhale mlimi wopewa matenda?				
9	Kodi mukuvomera/simuvomereza kuti mchitidwe wothira madzi ku mkaka uthakuyambitsa matenda?				
10	Kodi mukuvomereza /simuvomereza kuti munthu yemwe amakama mkaka ngati wadwala (kutsegula m'mimba) ayenera kupitidza kugwira ntchito yokama ndikutengera mkaka kudeile?				

5.0. Self- Reported Clean Milk Practices

1. Kodi mlimi akugwilirisa ntchito tchani la mtundu wanji? *(onani)*	**1.** ○Aluminum/stainless steel **2.** ○ plastic
2. Kodi mumasintha zovala mukamakama?	**1.** ○Eya **2.** ○ Ayi
3. Kodi mumakupitiliza kugwira ntchito pamene mukadwala	**1.** ○Eya **2.** ○ Ayi
4. Kodi mumasamba m'manja musanakame?	**1.** ○Eya **2.** ○ Ayi
5. Ngati inde, chifukwa chani mumasamba manja?	**1.** □ Kupewa Cholera **2.** □ Kupewa **kolona (covid19)** **3.** □ **Kuchepetsa majeremusi**
6. Kodi mumatenga nthawi yayitali bwanji kuchokera kunyumba kupita ku deile?	**1.** ○ osapitira maola awiri (<2hr) **2.** ○ maola awiri mpaka anayi 2-4hrs **3.** ○ kupilira maola anayi (>4hrs)
7. Kodi madzi a ng'ombe zamkaka mumawatunga kuti?	**1.** □ Kumtsinje **2.** □ Chitsime chosatetezedwa **3.** □ Njigo **4.** □ Madzi apampopi
8. Kodi mumatsuka mawere a ng'ombe kangati	**1.** ○ Musanakame

mukamakama mkaka?	**2.** ○ Mukatha kukama **3.** ○ Musanakame komanso pomaliza **4.** ○ Ayi, sitisuka
9. Kodi mumatsuka mawere ndichiyani musanayambe kukama mkaka?	**1.** ○ Ndimadzi **2.** ○ Sopo ndi madzi **3.** ○ Klorini ndi madzi **4**. ○ Ndi mwana wa ng'ombe
10. Kodi mumachotsa ndowe m'khola la ng'ombe kangati?	**1.** ○ Tsiku liri lonse **2.** ○ Pasabata **3.** ○ Pamwezi **4.** ○ Kupitilira mwezi

Zikomo chifukwa chotenga nawo mbali!

Appendix 8: Observation Checklist Chichewa Version

EVALUATION OF SMALLHOLDER DAIRY FARMERS' KNOWLEDGE, ATTITUDES, PRACTICES (KAP) AND FACTORS CONTRIBUTING TO HYGIENIC PRODUCTION OF RAW MILK IN MALAWI'S BLANTYRE AGRICULTURE DEVELOPMENT DIVISION

1.0 Verbal consent for milk samples and farm observation.

Tikukuthokoni potenga gawo loyamba la kafukuyi. Tifotokozeleni mwachidule wayenda bwanji kafukufukuyi? Choncho potilira ndikafukufukuyi tikupemphani kuti mwakufuna kwanu mutipaseko mkaka theka la kabotolo aka ndilinga choti tikapime kuti tithe kudziwa ukhondo wamkaka wanu? Muli womasuka kupeleka mkakawu pano 1. ○Eya 2. ○ Ayi

Mugawo lomaliza: mmodzi mwa ife adzakulondolani kunyumba kwanu kuti akawone mmene musungira ng'ombe zanu.
Kodi muliwokondwa kuyendeledwa ndimmodzi mwaife ndicholinga chowona za ukhondo wa ng'ombe zamkaka. **1.** ○Eya **2.** ○ Ayi

2.0 Demographic Data

1.1 Boma	**1.** ○**Thyolo** **2.** ○**Chiradzulu** **3.** ○**Mulanje** **4.** ○**Blantyre**
1.2 Dzina la Deile (Milk Bulk Group)	**----**
1.3 Chongani ngati mlimi ndi wamkazi kapena mwamuna	**1.** ○Mkazi **2.** ○Mwamuna
1.4 Kodi muli ndi zaka zingati zakubadwa?	**----**
1.5 Kodi maphunziro anu ndi otani?	**1.** ○ Sadapite kusukulu **2.** ○ Pulayimale sukulu **3.** ○ Sekondale sukulu **4.** ○ Yunivesite
1.6. Kodi banja lanu ndi liti?	**1.** ○ Wokwatira **2.** ○ Mbeta **3.** ○ Wamasiye **4.** ○ Ukwati udatha
1.7 Kodi mumamwa mkaka wochuluka bwanji patsiku?	**----**
1.8 Kodi mwachitapo ulimi wang'ombe za mkaka kwanthawi yaitali bwanji?	**----**

1.9 Kodi mudachitapo maphunziro aukhondo wamkaka musanayambe ulimiwu?	**1.** ○Eya **2.** ○Ayi
1.10 Kodi mumaphunzira za ukhondo wa mkaka ndi pakhola kudzera -------?	**1.** □ gulu la alimi laku deile **2.** □ TV **3.** □ wayilesi **4.** □ nenani ------

3.0 Observation of hygiene production of raw milk practices

1.0 Kodi mlimi akugwilirisa ntchito tchani la mtundu wanji? *(onani)*	**1.** ○Aluminum/stainless steel **2.** ○ Plastic
2.0 Kodi mlimi asintha zovala mukamakama?	**1.** ○Eya **2.** ○ Ayi
3.0 Kodi muli ndiwokama mkaka wapadera?	**1.** ○Eya **2.** ○ Ayi
4.0 Kodi mlimi anasamba m'manja sanakame?	**1.** ○Eya **2.** ○ Ayi
5.0 Kodi mkaka udavundikilidwa pa nthawi yokama?	**1.** ○Eya **2.** ○ Ayi
6.0 Kodi mumatenga nthawi yayitali bwanji kuchokera kunyumba kupita ku deile?	**1.** ○ osapitira maola awiri (<2hr) **2.** ○ maola awiri mpaka anayi 2-4hrs **3.** ○ kupilira maola anayi (>4hrs)
7.0 Kodi madzi a ng'ombe zamkaka mumawatunga kuti?	**1.** □ Kumtsinje **2.** □ Chitsime chosatetezedwa **3.** □ Njigo **4.** □ Madzi apampopi
8.0 Kodi malo wokalimira adali owoneka akhondo? Chonga eya ngati adasesedwa/kapena kukolopa.	**1.** ○Eya **2.** ○ Ayi
9.0 Kondi denga lakhola ndilotani	**1.** ○lofoledwa **2.** ○ losafolera
10.0 Kodi pansi pa khola ndipotani?	**1.** ○la concrete/miyala. **2.** ○ Pali dothi.
11.0 Kodi mumachotsa ndowe m'khola la ng'ombe kangati?	**1.** ○ Tsiku liri lonse **2.** ○ Pasabata **3.** ○ Pamwezi **4.** ○ Kupitilira mwezi

Zikomo chifukwa chotenga nawo mbali!

Appendix 9: Standard operating procedure for *E. coli* testing Bactident oxidase.

Principle

Cytochrome oxidase is an enzyme of the iron porphyrine group, which is very widely distributed in nature. It oxidises the reduced cytochrome c and thus transforms itself into the reduced and inactive form. In the presence of molecular oxygen, the cytochrome oxidase can oxidise 1-naphth+dimethylparapherenylene (diamine) with the formation of the condensation molecule indophenol blue, which is the basis for the classification and identification of bacteria.

Materials

1. 70% alcohol.
2. Bottle of a strip of Bactident oxidase reagent
3. Sterile plastic loop 50 µl
4. Culture media of *E. coli* on nutrient agar.

Safety precautions

- Disinfect test strips after use and any spills with 70% alcohol.

Procedure

1. With a sterile plastic loop, take 50 µl of a separate, well-grown colony from the nutrient agar.
2. Apply the colony to the reaction zone and spread with an inoculating loop.
3. After approximately 30 to 30 seconds, read the results against the colour scale.

Interpretation of results

Positive for the reaction zone colour change to blue to blue violet

Negative for reaction zone: no colour change, absence of *E. coli.*

Appendix 10: Other complimentary biochemical test used to identify *E .coli*

Catalase test

A single colony of each bacterial isolate was taken on 50 microlitres sterile plastic disposal loop and smeared on clean glass slide. Next, a drop of 3% hydrogen peroxide was flooded presence of gaseous bubbles indicated a catalase test positive result.

Indole test was performed by inoculating into peptone water broth a loopful of colony and incubating at 37 ±1 °C for 24 hours in incubator. After incubation, two drops of Kovac's reagent were added presence of pink ring indicate a positive result.

Citrate utilisation test (Simmon's Citrate slant) was employed to assist in identification of *E. coli.* A loopful of colony from nutrient agar was streaked onto a Simmon's citrate agar, then incubated at 37±1 °C for 24 to 48 hours. Change of colour of the medium to blue colour indicate a positive result.

Appendix 11: Standard operating procedure for preparation of violet red bile agar.

Principle

A lactose- containing selective medium for the detection and enumeration of coliform organisms in dairy products.

Materials

1. Balance
2. Heat resistant gloves.
3. Distilled water.
4. Violet red bile agar
5. Sterile media plates
6. Bunsen burner.
7. Two 500ml conical flasks
8. Water bath

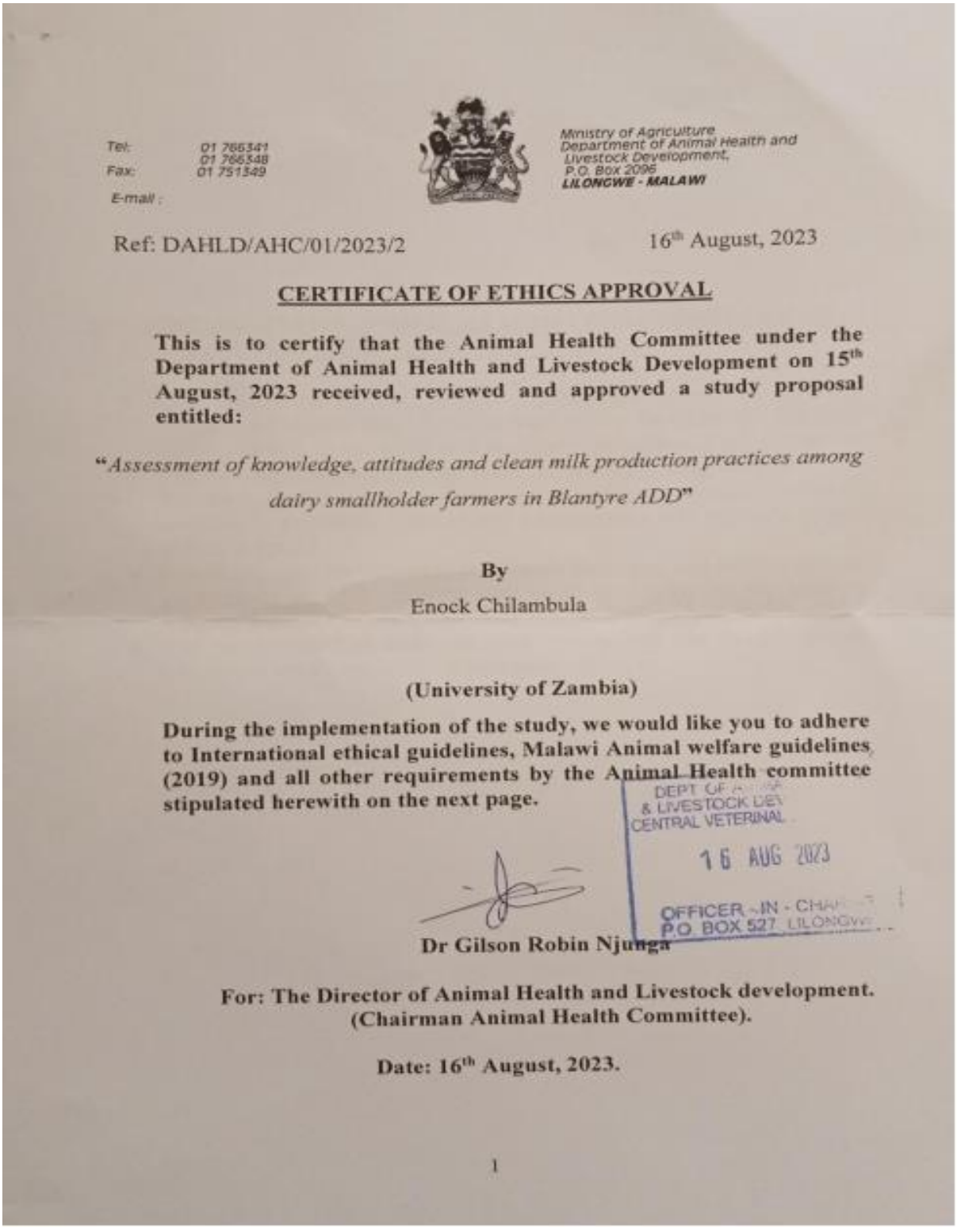
Safety precautions

- Use heat resistant gloves to handle hot items

Procedure

1. Weigh dehydrate violet red bile agar to desirable quantity.
2. Suspend 38.5g in 500ml of distilled water. Bring to boil and removal when mixture has just boiled for few seconds ensure that the agar has dissolved completely by mix well before pouring. Remember no sterilisation is required.
3. Place freshly prepared media in 48±1°C and used it within three hours.
4. Mix with raw milk until no traces of raw milk are visible.

Appendix 12: Ethical clearance certificate.



Tel: 01 766341
01 766348
Fax: 01 751349
E-mail :

Ministry of Agriculture
Department of Animal Health and Livestock Development,
P.O. Box 2096
LILONGWE - MALAWI

Ref: DAHLD/AHC/01/2023/2

16th August, 2023

CERTIFICATE OF ETHICS APPROVAL

This is to certify that the Animal Health Committee under the Department of Animal Health and Livestock Development on 15th August, 2023 received, reviewed and approved a study proposal entitled:

"*Assessment of knowledge, attitudes and clean milk production practices among dairy smallholder farmers in Blantyre ADD***"**

By

Enock Chilambula

(University of Zambia)

During the implementation of the study, we would like you to adhere to International ethical guidelines, Malawi Animal welfare guidelines (2019) and all other requirements by the Animal Health committee stipulated herewith on the next page.

DEPT OF ANIMAL & LIVESTOCK DEV
CENTRAL VETERINAL
16 AUG 2023
OFFICER-IN-CHA
P.O BOX 527 LILONGWE

Dr Gilson Robin Njunga

For: The Director of Animal Health and Livestock development.
(Chairman Animal Health Committee).

Date: 16th August, 2023.

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REQUIREMENTS FOR ANIMAL HEALTH COMMITTEE ETHICAL APPROVAL FOR YOUR STUDY PROPOSAL

- Chief Animal Health and Livestock Development Officers on behalf of Program Managers from Blantyre Agriculture Development Division where you will do the study will monitor your study and any deviations from the approved proposal may result in your study being stopped.
- You are expected to complete your studies within the specified period as specified in your study protocol and any extension will require a review of your proposal
- Ensure that only the registered staff under Veterinary and Para-veterinary practitioners act 53:04 of 2003 shall be allowed to collect any samples from the animals
- You are expected to share the study results with the Animal Health Committee upon completion of your study.