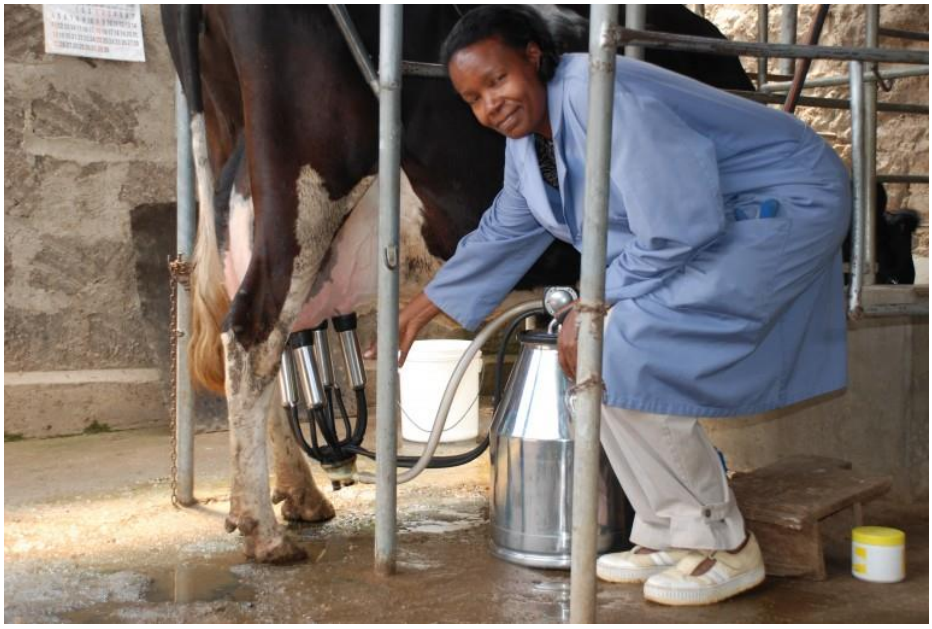
RESEARCH THESIS

Title: Accessibility of bucket milking machines to smallholder dairy farmers in Kiambu county Kenya to mitigate against milk losses and maintain quality



NJAU WANJAHI RIMUI

Van Hall Larenstein University of Applied Sciences the Netherlands

September 14, 2022

Accessibility of bucket milking machines to smallholder dairy farmers in Kiambu county Kenya to mitigate against milk losses and maintain quality

By

Njau Wanjahi Rimui

September 2022

This research was carried out as part of the SIA funded project “Food Waste Reduction and Food Quality Living Lab (FORQLAB)” of the professorship Climate Smart Dairy Value Chains

Consent Form

I **Wanjahi Njau** as of **27/09/2022** grants Van Hall Larenstein a free and non-exclusive licence to include this thesis report in the digital repository and to make it available to users based both at Van Hall Larenstein and elsewhere. This means that users can copy and adapt some or all of the paper.

This thesis may be consulted by you, provided you comply with the provisions of Van hall Larenstein and the following conditions of use:

- You will use the copy only for the purposes of research or private study
- You will recognize the author's right to be identified as the author of the thesis report and due acknowledgment will be made to the author where appropriate

Acknowledgments
I would like to thank the Netherlands government through the Orange Knowledge Programme (OKP) for granting me an opportunity to study. I would also like to acknowledge the VHL staff for the contributions in guiding me through the knowledge and skills I need in my future career.

I would like to thank my supervisor Robert Baars for his continued guidance and motivation throughout the research. This would never have been completed to the standard without your knowledge and support. Your hours of critiquing have been invaluable and I look forward to keeping in touch as I progress in life.

Special thanks to the extension staff at Githunguri Dairy Farmers Cooperative Society and Maurice Mativo Manager Kabete Dairy Farmers Cooperative Society for allowing me to collect data successfully. Finally, I give thanks to my family for continued support and encouragement

Dedication

This thesis report is dedicated to my Son Jayson Njau Wanjahi for his support

Contents

Acronyms

DVC	Dairy value chain
FIs	Financial institutions
GDFCS	Githunguri Dairy Farmers Cooperative Society
ILRI	International Livestock Research Institite
KDFCS	Kabete Dairy Farmers Cooperative Society
MFIs	Microfinance institutions
MM	Milking machines
SCC	somatic cell count
SM	Shelved machines
KCC	Kenya Cooperative Creameries
WM	Willing to purchase machines

Abstract

The use of milking machines has been available since the 1970s. Despite the fact that they improve milk quality the uptake has not been well received and only a few farmers have access to these existing technologies. The objective of this study was to investigate the opportunities to reduce milk losses in Githunguri and Kabete sub-counties by utilizing milking machines and ensuring access to finance among dairy farmers. A total of 30 respondents were asked were interviewed using a survey of which they were grouped into three that is farmers with milking machines, farmers who had shelved machines and those willing to purchase machines. Each group had 10 farmers. Observations were also used in tandem with the survey which was done on 30 farms during milking. Key face-to-face interviews of 12 respondents who were experts were also carried out.

It was found out that farmers with milking machines had a high milk production of 410 litres compared to those who shelved at 217 litres and those willing to purchase at 276 litres. Farmers with milking machines had fewer milk losses and did not loose milk due to spillage or spoilage. Most milk losses that occurred due to diseases such as mastitis may have been as a result of reduced adherence to hygiene. the study also found out that milking machines from Europe were mainly in use due to their quality while Turkish and Chinese machines had been shelved. There were no direct financial products related to milking machines. however, farmers had access to finance with cooperatives acting as intermediaries.

Based on these findings it can be concluded that farmers need to adopt to milking machines to improve on milk quality.

(Key words: milking machines; milk losses; milk quality)

1.0. Background

Kenya's dairy sector has an estimated 4% worth of the gross domestic product (GDP) 14% of the agricultural GDP and 44% of the livestock GDP (Faostat, 2020). The growth of the dairy sector is based on a rising national production (averaging 5.3% per year), processing volume (averaging 7% per year), and an yearly per capita milk consumption (averaging 5.8% per year) of around 110 liters (Rademaker *et al.,* 2016). Due to the rise in incomes driven by growth in the middle class the demand for milk and its products has been rising within the country (Gerosa and Skoet, 2012). Kenya has an estimated 4.3 million dairy cattle producing around 3.43 billion litres (Odera-Waitituh, 2017). Smallholder dairy farmers possess more than 80% of the dairy cattle and produce over 56% of total milk. They are raised in intensive and semi-intensive livestock production systems. The remaining 20% comes from large scale dairy farms and indigenous herds (Omore *et al.,* 1999). Friesians, Guernsey, Ayrshire, Jersey and their crosses are the main breeds usually kept for dairy production (Kibiego *et al*., 2015). Furthermore, exotic breeds are mated with the local East African Zebu (EAZ). Although, smallholder milk production is a feasible economic activity in Kenya, it is hampered insufficient quantity and quality feeds, limited access to breeding, illnesses, limited access to credit, and limited access to output markets (Okello et al., 2021)

Kenya produces about 3.4 billion liters of milk per year, 70% of milk is produced by dairy cows (Senerwa *et al.,* 2016). There are approximately 21 million cattle in Kenya of which 3 million are dairy cattle (Faostat, 2020). Milk in Kenya is produced from cattle, camels and goats.

Smallholder farmers are pressed to produce milk that meets food quality requirements in order to take advantage of the expanding demand for milk and its products Nyokabi *et al.,* 2019). This is due to demand of milk and its products driven by a high population, rising incomes and changing lifestyles. Improper milk handling, as well as poor hygiene and sanitation conditions in the milking environment, cause milk contamination. Contaminated milk may serve as a vehicle for pathogens such as bacteria, parasites, viruses and chemical residues that cause foodborne diseases and have a detrimental impact on the health nutrition of consumers (Amenu *et al.,* 2019). Compliance with milk and safety standards among farmers is low. They lack high risk investments to implements such quality practices. The study will help farmers to improve milk quality by adopting to existing technologies as milking machines that will go along way to ensure milk is handled in a safe and hygienic way thus less milk losses through rejection.

1.1. Overview of the milking process

Milking is a major operation that generates income on a farm. However, farmers face various challenges such as low productivity, poor hygiene and hand milking procedures. Hand milking is considered slow, tiresome and at times unhygienic thus dairy animals seek a risk of becoming exposed to diseases such as mastitis due to incomplete emptying of the udder. These challenges can be overcome by use of milking machines. However, the cost of these machines is high which is not suitable for small scale farms that have minimum mechanization, which hinders maximum productivity.

1.2. FORQLAB project

The problem owner is FORQLAB project, Githunguri Dairy Farmers Cooperative Society (GDFCs) and Kabete Dairy Farmers Cooperative Society (KDFCS). They are part of a consortium that contributes to reducing food losses in dairy value chains via the application of technical solutions and tools as well as improved chain governance in these food chains (FORQLAB, 2022). The consortium has four (4) kinds of

partners that are universities, the private sector, actor organizations supporting these chains and associate partners. Dairy processors experience difficulties to bear the risks of handling a highly perishable commodity like milk, especially from smallholder farmers, leading to large price fluctuations, increased spoilage and economic losses. Food waste reduction in the dairy value chain (DVC) requires interventions at farm/collection and processing levels. Technical interventions will help inform stakeholders on ways of reducing milk losses leading to income generation and improved food security.

1.3. Githunguri Dairy Farmers Cooperative Society

Githunguri Dairy Farmers Cooperative Society (GDFCS) is located in Githunguri town, Githunguri subcounty. It started as a milk collection centre of 31 farmers way back in 1961. The cooperative was established to assist small holder dairy farmers in Githunguri sub county, to market their milk. The cooperative has 84 collection centers and 7 cooling stations spread over the milk shed, which is primarily the Githunguri sub county's five wards. On a daily basis, the cooperative processes around 230,000 litres of milk. The Cooperative opened its own milk processing factory in 2004 to begin processing and distributing its own milk products under the Fresha Dairy Products brand.

1.4. Kabete Dairy Farmers Cooperative Society

Kabete Dairy Farmers Cooperative Society KDFCS is located at Wangige market, Kabete sub-county 20 kilometres from Nairobi. This was established in 1968 and mainly sold its milk to Kenya Cooperative Creameries (KCC) due to legislation. The cooperative has around 3000 members but only 950 are active. It draws its members from Nyathuna, Muguga, Kikuyu and Kabete wards. It has 35 milk collection centers and 2 cooling stations. The core business is milk collection, processing and marketing. The cooperative collects about 13,500 litres of milk/day of which 96% is pasteurized and sold directly to consumers via their milk bars while the rest is sold to traders, and only 4% of the milk is processed into yogurt.

1.5. Problem statement

Milking is an important process that determines whether a farm breaks even or not. However, smallholder farmers have to deal with challenges such as low productivity, poor sanitation and incomplete emptying of the udder. All these challenges are a result of insufficient adoption to technologies such as milking machines. The use of milking machines has been available since the 1970s in Kenya. However, there is little adoption of this technology due to the cost of investment and maintenance. A study by Ombuna (2018) shows that 95% of farmers milking by hand would like to acquire milking machines. This has hindered the quality of milk produced leading to losses both at the producer level and from processors due to high rates of milk rejection among small holder farmer who use hand milking as illustrated by Ombuna (2018).

Pambo (2015) notes that the lack of working capital limits farmers' access to technologies such as milking machines which are costly and a majority of smallholder farmers cannot afford to purchase. Furthermore, most microfinance institutions (MFIs) in Kenya lack a value chain approach that would aid smallholder farmers to adopt technologies, hence improving on productivity and quality of milk. In conclusion, this research aims at improving adoption of bucket milking machines by ensuring farmers have access to credit in an attempt to reduce milk losses.

1.3. Objectives

The main objective of this study is to contribute to milk loss reduction at the producer level in Githunguri and Kabete milk sheds, in Kiambu county by enhancing accessibility to milking machines and financial services.

1.4. Research questions

1. Which sensitization measures can be used to enhance adoption of milking machines for farmers with small herds but high milk production?

Sub questions

1) What are the current milk losses between farmers with milking machines and those without?
2) What kind of information is available on milking machines to farmers?
3) What preventive parameters are used to improve milk hygiene and safety within Kiambu county among farmers?

2. what is the role of financial institutions in ensuring farmers access to credit to invest in bucket milking machines?

Sub questions

1) what are the economic benefits derived from using milking machines?
2) Which financial products are provided by financial institutions for farmers to access capital for milking machines?
3) What knowledge do financial institutions have regarding milk machine technologies?
4) What is the farmer's opinion on using financial institutions in obtaining milking machines?

2.0. Literature review

2.1. Overview of the dairy sector in Kiambu county

Agriculture is the most important economic activity accounting for around 17% of the population's income. The most common enterprises among many households include dairy farming, poultry farming, pig farming and crop farming (Kiambu county government, 2013). According to Okello et al., (2010) there has been a shift in livestock production more so dairy and poultry due to an increase in demand for animal products due to low yields of cash crops mainly tea and coffee. Kiambu County among the top milk production areas, producing approximately 350 million litres per annum(County Government of Kiambu, 2018). Kiambu has several dairy processors namely; Brookside Dairies, Limuru fresh Milk, Githunguri Dairies, Kiambaa Dairies, and Pascha Dairies. Many households in Kiambu County are small-scale farmers that produce approximately 2-3 cows under intensive systems for milk production. Exotic cattle are reared by 67,014 households for dairy, while 10,511 rear indigenous cattle (Kiambu County Government, 2013; KNBS, 2019)

2.2. Description of the dairy value chain in Kiambu county

The dairy value chain in Kenya is comprised of many players, from farmers who are the primary producers to consumers. The dairy value chain is divided into two formal and informal, whereby formal milk is processed (pasteurized) before selling. The activities along the value chain include input supplying, producing, collection and bulking, processing, trading and consuming. In Kiambu, the dairy value chain is made up of actors, supporters, and influencers who are active in various activities and at diverse levels of the value chain. Input suppliers, milk producers, milk collection and bulking enterprises, processors, merchants, and consumers are among the actors who are directly involved in the chain; these are classified as direct actors. Drost and Van Wijk (2011) describe indirect actors, as chain supporters or chain influencers, who do not participate in the chain directly or commercially. They include financial service providers (banks and credit agencies), non-governmental organizations (NGOs), the government, extensionists, and scholars are among them:

Table 1: Chain actors and supporters

Name of stakeholder	Roles/ interests
Direct actors	
Input suppliers	They include AI providers, feed suppliers, drugs and dairy equipment
producers	Categorized as small scale, medium scale and large scale farmers. They produce milk and sell to cooperatives or informal traders
cooperatives	They collect milk via collection centres whereby bulking occurs and process at times
processors	Process and add value to milk before selling it to retailers
retailers	Include shops, supermarkets and either sell raw or processed milk
Supporters and influencers	
Research institutions	Training of manpower in animal health and production and assisting farmers adapt to new technologies
Financial institution	Include banks, microfinance institutions (MFIs) and saccos that access credit to farmers

National and county governments	Development of National Policies; formulation and evaluation of policies; facilitation of policy execution to create a conducive environment for other stakeholders to function; Extension and advisory services are provided to different stakeholders
NGOs	Educates farmers on feed conservation practices and coordinates numerous dairy-related programs in Kenya.

2.3. Milk contamination points

According to Kangethe et al., (2020) there are various factors contributing to milk contamination among farmers whereby poor hygiene on equipment (milking machines and containers) and the milking process are the major causes. Others include failure to clean udder before milking, not striping milk in a strip cup and mixing the milk, incomplete milking, leaving milk exposed after milking, unchilled milk after milking and also before transport. Diseases such as mastitis, tuberculosis, brucellocis and listeriosis can also cause milk contamination. Antibiotics are also a source of concern for contamination if milk is recommended for consumption without the prescribed withdrawal dates being ignored (Manyi-loh et al,).

Microbial contamination of milk is as a result of bacteria found in the cows udder (causes mastitis) or environment and may enter the milk via unhygienic handling and milking procedures. Contaminant bacteria such as *Escherichia coli* and *Salmonella spp* are an indicator of poor milk handling techniques.

2.4. Milk Losses

Milk losses at the farm are a result of poor handling which accounts to the largest proportion within the milk value chain in Kenya. Kenya loses 4.5% of its milk at farm level (Lore *et al.,* 2005). Milk is mainly lost in three forms which are spillage, spoilage and economic loss through "forced consumption" an occurrence in which evening and surplus milk is above normal household requirements. Land O lakes ((2008) during a case study in Njoro reported that small holder farmers mix evening and morning milk under poor storage condition. This leads to post harvest loses whereby milk is rejected by processors. Lore et al (2005), claims inadequate milk supply may be one of the causes and influencing factors of milk losses on the farm. This may be due to insufficient cooling, market rejection, lack of technical knowledge on safe milk handling and use of inappropriate containers.

2.5. Role of milking machines among smallholder farmers

Smallholder dairy farmers in Kenya face many challenges especially in terms of producing quality milk. Currently, milk somatic cell count (SCC) is of importance as a parameter for milk quality and is often investigated especially for quality milk-based payment systems (Atasever *et al.,* 2012). Whenever there is an increase in SCC milk quality is considered to be low. High SCC count is brought about by poor milk handling procedures where hygiene is not considered and microbes are able to access teats causing infections. This leads to low milk quality hence rejection within the cooperatives and losses to farmers. Milking machines can be used to intervene this situation as they operate under high hygiene standards thus less SCC count in milk hence maintaining milk quality.

2.6. Access to financial services

Working capital is needed to increase efficiency in smallholder dairy farms. Ongwech *et al*, (2022) notes that although there are many financial institutions willing to lend credit to farmers many have not been able to access this services, thus remaining as a major constraint. this hinders farmers from investing in existing technologies such as milking machines that would help in maintaining milk quality and reduce milk losses. Another reasons for not investing in milking machines is that farmers prefer to purchase fodder processing machinery, especially those who are members of a cooperative (wilkes *et al.,* 2019). This can be attributed by the training provided by extension officers whereby more training is on feed management rather than maintaining milk quality.

2.7. Farmers and finance

Smallholder dairy farmers from developing countries are faced with significant challenges to their output , development and sustainability (Tinsley and Agapitova, 2018). This include lack of affordable financial products and a limited supply knowledge of high-quality inputs, insufficient use of technology and market data, and a lack of market connections across the value chain. Smallholder farmers face an assortment of challenges when it comes to obtaining suitable and sufficient financial services. Credit supply and uptake are hampered by supply-side challenges such as a lack of flexible credit products as well as demand-side challenges such as a low capacity to service debt. Due to limited access to finance smallholder farmers tend to produce less milk with suboptimal inputs, resulting in lower yield (Saenger *et al.,* 2013). Due to this, their milk is less competitive in the market, and the threat for all other upstream value chain players is increased as a result of low quality and unpredictability of supply. Lower-income cash-strapped farmers are trapped in a debt cycle, forcing them to search for credit to repay previous loans. Traditional financing methodologies have failed to meet the needs of smallholder farmers in developing countries for appropriate financial services.

2.8. financial products

Financial products are instruments in which people can make a financial investment, borrow or save money (Murendo and Mutsonziwa, 2017). This can be issued by Financial Institution (FIs), governments or companies. Products are mainly negotiated agreements between two factions, the FIs on one hand and consumer or business on the other, that initiate a monetary relationship for a certain amount of time. Financial products can also be assets in which farmers use to buy other assets or expand a livestock shed.

2.7. Conceptual framework

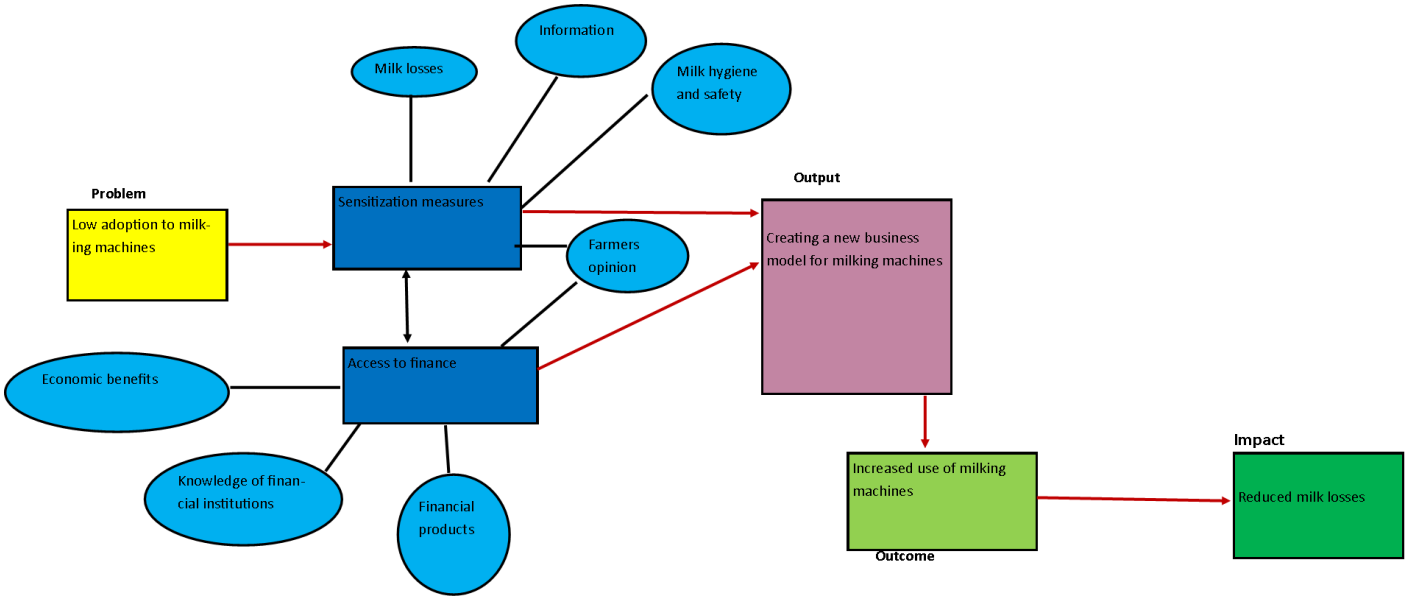


Figure 1: conceptual framework

3.0. Methodology

3.1. Area of study

The study was carried out in Githunguri and Kabete sub-counties located in Kiambu County. This area was selected as the dairy sector is well developed and vibrant.

The research was carried out on smallholder farmers under the umbrella of Githunguri Dairy Farmers Cooperative Society (GDFCs) and Kabete Dairy Farmers Cooperative Society (KDFCs) in Githunguri and Kabete sub counties in Kiambu county. Kiambu County is one of the 47 counties in the Republic of Kenya. The county lies between latitudes 00°25'and 10°20'S of the equator and longitude 360°31'and 370°15'E. It is a peri-urban county located in the central region that covers a total area of 2,543.5 km2 (County Government of Kiambu, 2018). Of this area, 476.3 km2 are under forest cover, 1,878 km2 are under cultivation, 649.7 km2 are non-arable, and 15.5 km2 are covered by bodies of water. Kiambu is divided into ten sub-counties and is home to an estimated 2.4 million people, according to the 2019 Kenya Population and Housing Census. Kiambu County borders Nairobi and Kajiado Counties to the south, Machakos to the east, Murang'a to the north and northeast, Nyandarua to the northwest, and Nakuru to the west.

Figure 2: Area of study

3.1.2. Definitions

Spillage: unintentional cause of allowing a liquid to flow over the edge of its container

Spoilage: The detoriation of milk and its products

Contamination: To make a product unfit by adding or unintentional mixing with harmful substances.

3.2. Data collection

3.2.1. Desk research

Desk research was used in reviewing relevant literature sources such as academic journals, books and credible online sources as google scholar among others. This was utilized in this research to develop a survey, observation checklist, interview checklist and also relating to previous studies for discussion of findings.

3.2.2. Target population, sample size and technique

The target population used were smallholder dairy farmers who are members of GDFCs and KDFCs. A stratified random sampling was used in conjunction with snowballing from two (2) sub counties (10 with milking machines, 10 who have shelved milking machines and 10 willing to purchase milking machines). This was done to ensure a representative of the whole population as possible are selected. In total 42 respondents were interviewed for this study.

Table 2: List of interviewees

Respondents	**Number**
1. Key informants	
Extension officers (cooperatives and government bodies)	4
Marketing officers	3
Finance officers	4
Research officer	1
2. Farmers survey	
farmers with milking machines	10
Farmers with milking machines (shelved)	10
Farmers without milking machines	10
Total respondents	**42**

3.2.3. Selection of key informants

Qualitative data was collected from key informant interviews. This was conducted using tailor made checklists and administered to different key informants. The respondent's interviewed were extension officers in GDFCS and KDFCS, subcounty veterinarians in Githunguri and Kabete sub counties, marketing representatives of Birrstar, Mediline and De Laval, and financial officers at K unity microfinance, Equity bank, GDC sacco society and Kabete sacco society, director of KDFCS and a livestock researcher at the International Livestock Research Institute (ILRI) .

3.2.4. Surveys

Face to face in-depth interviews were administered whereby a semi structured questionnaire was administered to 30 smallholder dairy farmers who were grouped as follows 10 with milking machines

(MM), 10 who had shelved machines (SM) and 10 who were willing to purchase milking machines (WM). This was done with the aid of extension workers from KDFCS and GDFCS. The questionnaire sought to collect both qualitative and quantitative data mainly from farmers who have a common interest in owning milking machines. The following information was collected:

1) Background information
2) Milk losses
3) Information on bucket milking machines
4) Farmers opinion
5) Financial products
6) Knowledge of financial institutions
7) Role of financial institutions

3.2.5. Observations

Observation as observed in appendix two (2) were conducted in all 30 small and medium farms for farmers who have milking machines (MM), shelved machines (SM) and willing to buy machines (WM). An observation checklist was used to check for environment on which milking procedures were practiced that is condition of the parlour, milking procedures and hygiene parametres. For farms with milking machines observations were made on how farmers use their equipment and whether they was them well after use. All visits were made at between 1300hrs to 1400 hrs East African time (EAT) which coincides with milking hours.

3.3. Data analysis

SPSS version 27 was used to analyze quantitative data and make representation in graph and tabular form. Comparison of means using ANOVA was used between and among three (3) groups that is farmers with milking machines (MM), farmers who had shelved machines (SM) and those willing to purchase machines (WM). ANOVA was also used to compare means of milk losses between and among groups in terms of milk losses for MM, SM and WM. For the test in milk losses and milk production a tukey post hoc test was used for comparison of means between groups. The Tukeys post hoc test was used to explore differences between groups while controlling the error rate.

Descriptive statistics were used calculate summaries of observations in farms between farmers groups MM, SM and WM, which were illustrated in form of graphs.

The audio records from the interviews were transcribed strictly for qualitative data. Green et al. (2007) described the data analysis process, which included reading and re-reading the transcripts to become acquainted with the data. Themes were identified and categorized based on the checklist. New themes were identified and added as appropriate.

3.4. Limitations of the study

Limitations encountered in this study included lack of admission by respondents on milk rejections at the cooperative. However, information was obtained by asking respondents whether they had encountered certain diseases for a one year period and how much milk they disposed as a result. Access to records was not allowed by majority of farmers. Some interviewees rejected both audio and video recordings and were comfortable in one taking notes. The data was also collected during the election period thus it was difficult to interview some respondents.

4.0. Results

4.1. Milk production between and within groups

The MM group produced more milk in comparison to the WM group and SM group who had the least amount of milk. They were no differences on milk sold to other consumers or traders, milk for home consumption and for calf feeding between the MM,SM and WM groups.

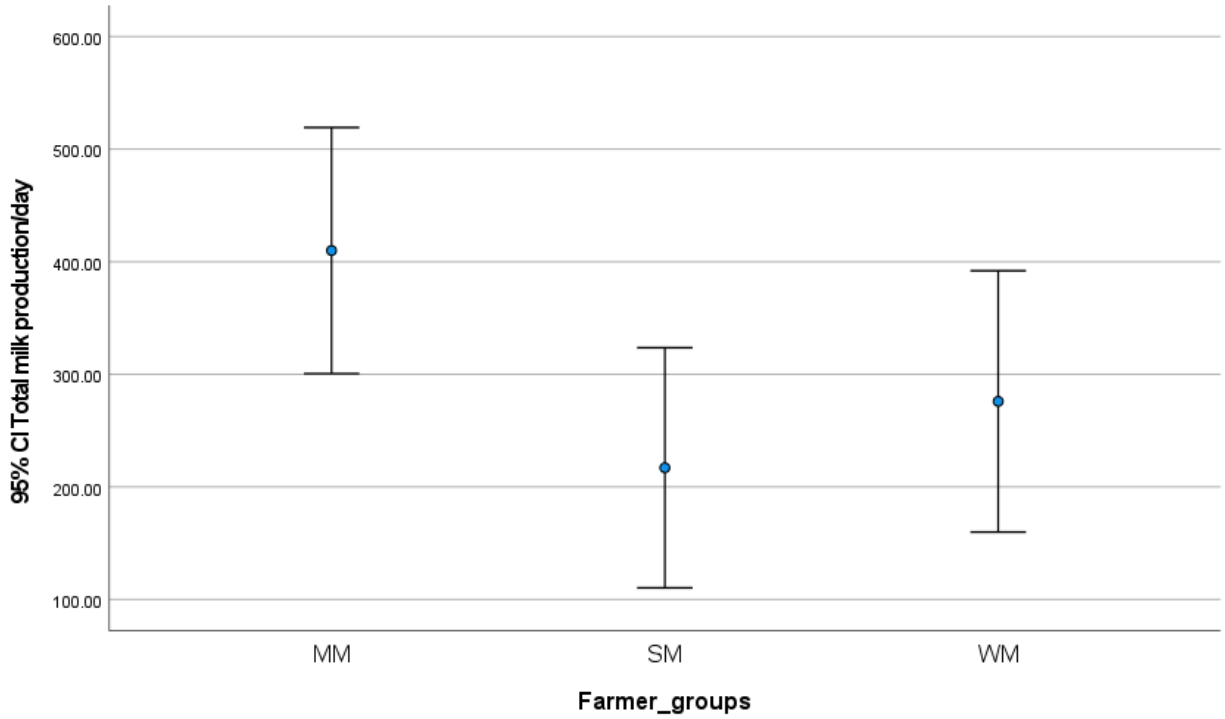


Figure 3: Means of total milk production in litres/day. CI=confidence interval, MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

Table 3: Means of total milk production and its uses in litres/day. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

	MM	**SM**	**WM**
Milk production/day (litres)	410[b]	217[a]	276[a]
Milk sold aside from cooperatives	9.13	15	13
Milk for home consumption	6.4	4.6	5
Milk for calf feeding	15.3	13.2	13.6
Milk for other uses	0	0	0

[a,b,] Means with different superscripts within effect differ (P<0.05)

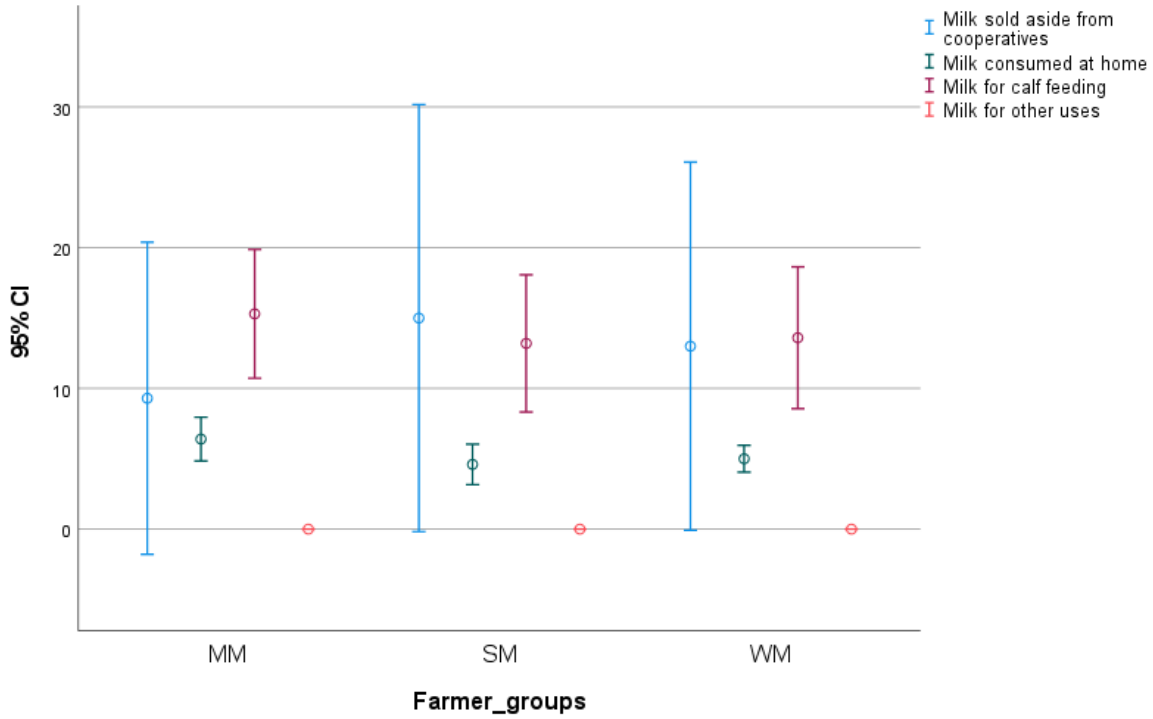


Figure 4: Means of milk sold aside from cooperatives, home consumption, calf feeding and other uses in litres/year. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.2. Milk losses

Farmers who shelved machines have a higher incidence for milk losses followed by those who are willing to purchase machines. Farmer with milking machines have the lowest incidences of milk losses. Farmers with milking machines did not suffer losses due to spillage, spoilage and contamination. Those with milking machines suffered milk losses only due to diseases. Apart from diseases farmers who acquire milking machines have minimum milk losses compared to their counterparts who have no machines.

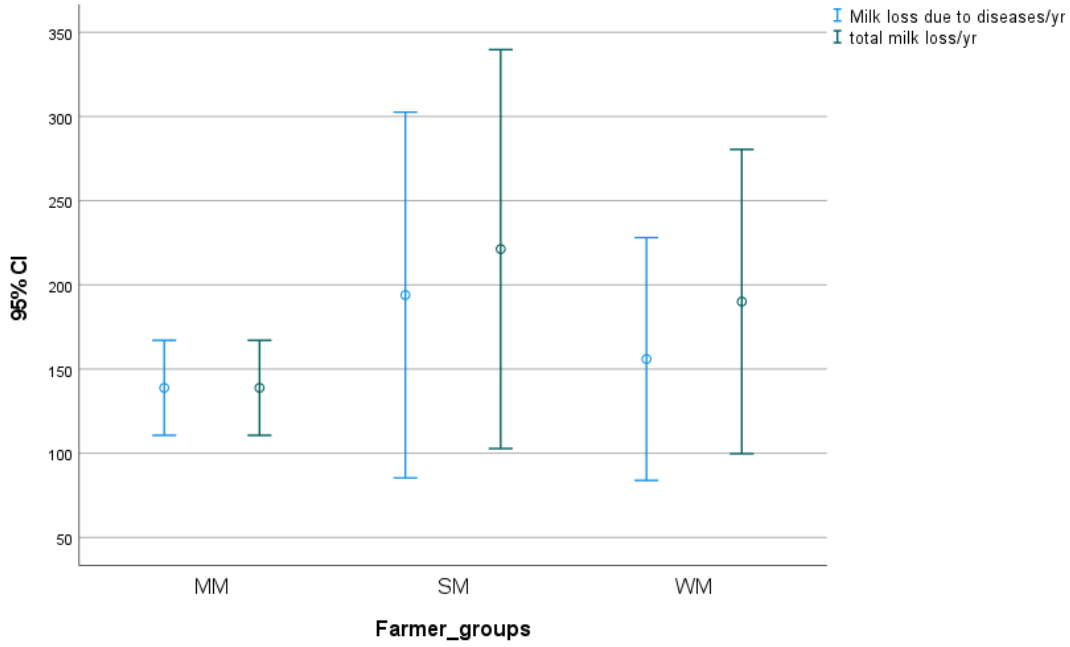


Figure 5: Means of total milk losses and milk losses due to diseases

Table 4: Means of total milk loss, milk loss due to diseases, spillage, contamination and spoilage in litres/year. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

	MM	**SM**	**WM**
Total milk loss	138.9[a]	221.3[b]	190.1[b]
Milk loss due to diseases	138.9	194	156
Milk loss due to spillage	0[a]	23.9[b]	31.9[b]
Milk loss due to contamination	0	3.4	2.2
Milk loss due to spoilage	0	0	0

[a,b,] Means with different superscripts within effect differ (P<0.05)

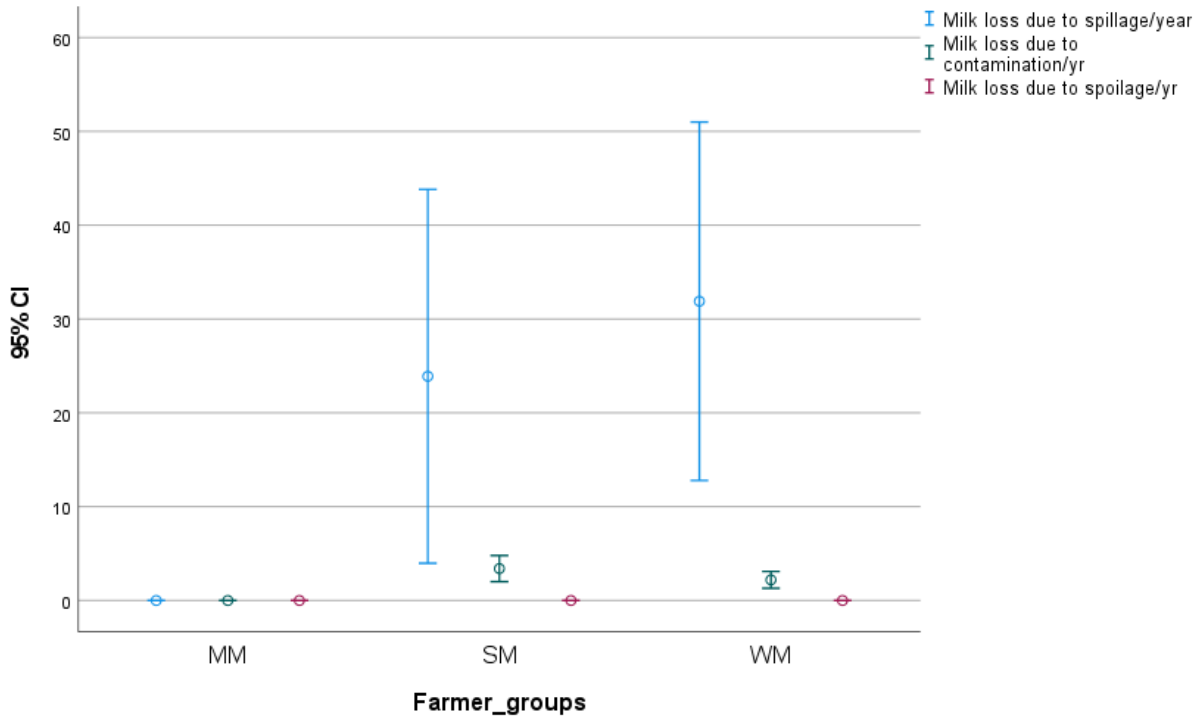


Figure 6: Means milk loss due to spillage, contamination and spoilage in litres/year. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.3. Farmer information on milking machines

Results show that farmers obtained their information from relatives or other farmers, trade fairs and agricultural shows and magazines and newspapers. The MM group obtained much of their information from newspapers and magazines. Relatives and other farmers were an important source of information for all groups that is MM, SM, and WM. Trade fairs and agricultural shows were important for farmer groups SM and WM. Relatives and other farmers remain an important source of information if farmers are to adopt to milking machines technologies.

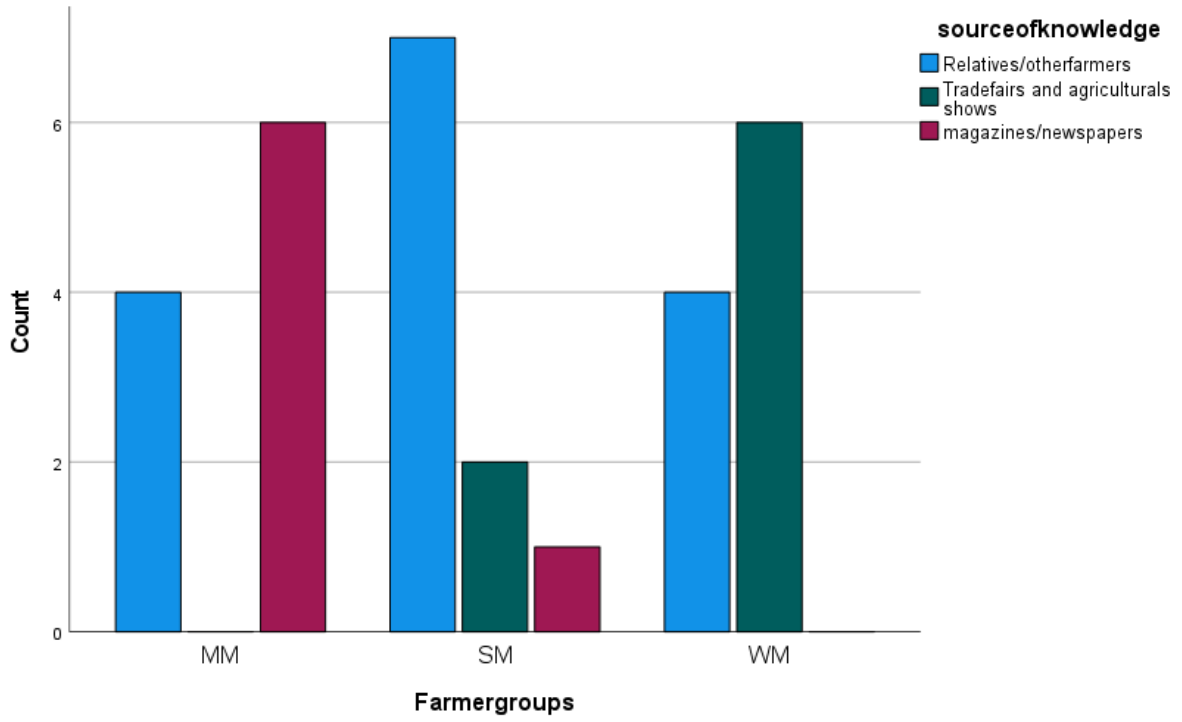


Figure 7: Source of knowledge on milking machines among farmer groups. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.3.1 Perception of milking machines among farmers

All farmers were asked to demystify myths and beliefs they had heard about milking machines from different sources. The following statements were brought to light by many respodents.

a) Milking machines milk blood from cows

b) Milking machines increase the rate of mastitis

c) Milking machines have an effect on udder shape and formation

d) Prolonged milking periods using milking machines causes teat erosions

e) Milk machines are costly to buy and maintain

f) Milk machines made for the African market were of archaic nature and should incorporate basic technologies.

4.3.2 Perception of milking machines as a source of mastitis

The SM and WM group had a majority believe that milking machines increased the prevalence of mastitis. However, those the MM group believed that they had no role in increase in prevalence of mastitis.

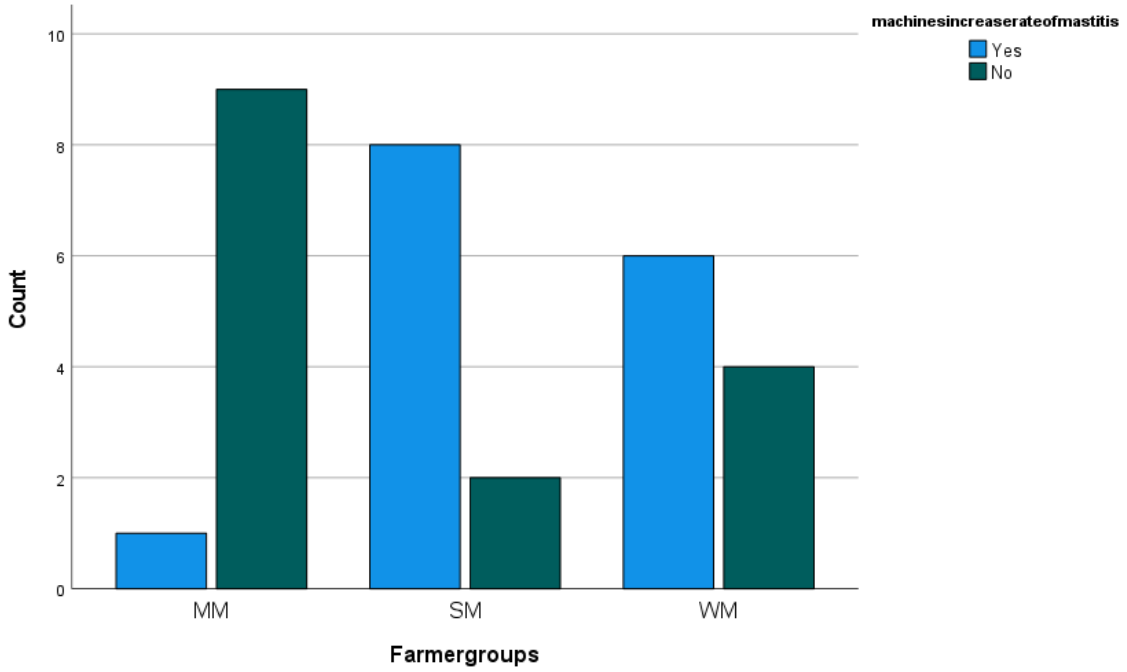


Figure 8: Perception of farmers on prevalence of mastitis using milking machines. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.3.3. Brands of milking machines as per manufacturing country

Functional machines were mainly manufactures from France, while Germany and India had the same number. Majority of the shelved machines had been manufactures in Turkey followed by China. Quality machines in terms of functionality are manufactured in Europe and partly in India. Machines manufactured in Turkey and China should undergo considerable improvements before farmers think of purchasing them. Kenya and the Netherlands were added to this survey since the project focused on interrelation between two countries. However, no farmer was using milking machines produced from both countries

Farmers who had shelved machines gave the following reasons for not using them

1) Machines could not be operated when the technical team left
2) Lack of spare parts
3) Increased prevalence of mastitis

4) Theft

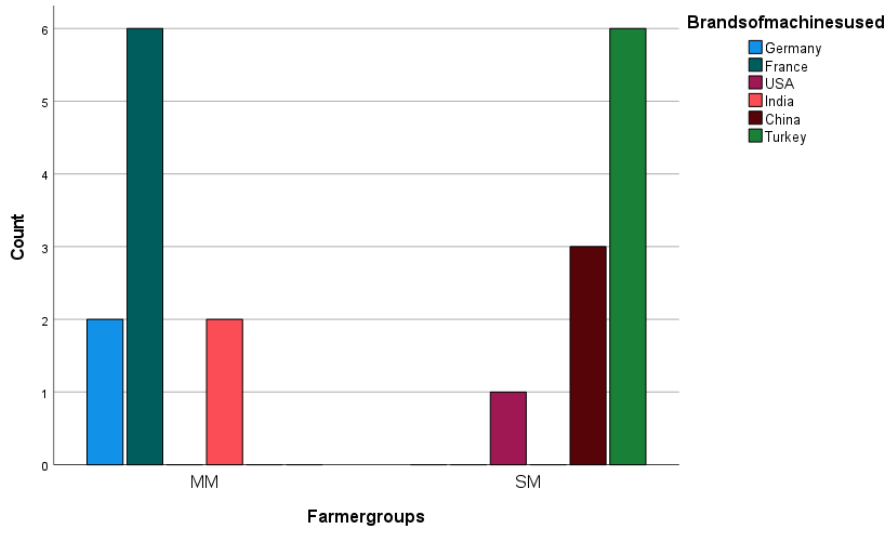


Figure 9: Countries in which milking machines were manufactured from. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

Table 5: Milking machines use and countries manufactured. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

Countries where milking machines are manufactured	MM	SM
France	6	0
Germany	2	0
India	2	0
Turkey	0	6
China	0	3
U.S.A	0	1
Netherlands	0	0
Kenya	0	0

4.4.Parameters applied for milk safety and hygiene among farmers

4.4.1. Hand washing before milking

The MM group use soap and water more often than the SM and WM group. Its expected from this data that the MM group produce more quality milk with less contamination due to hygiene measures put in place.

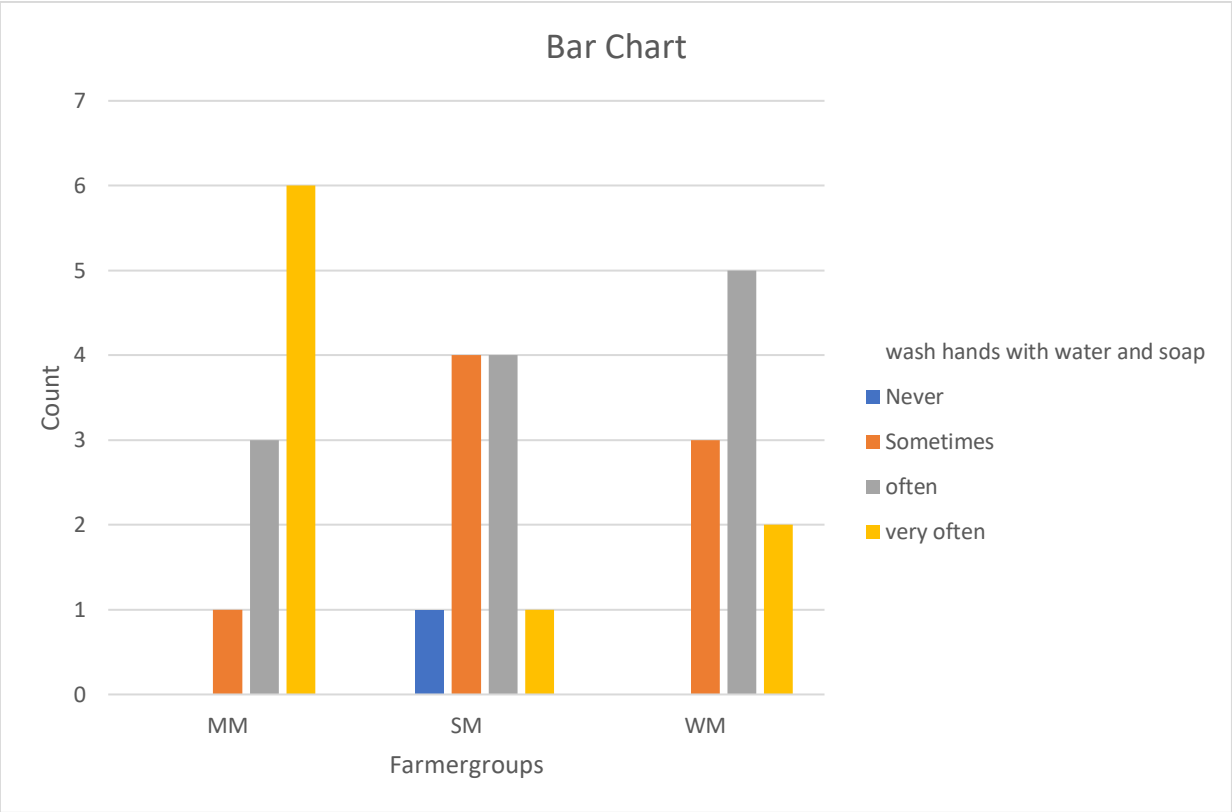


Figure 10: Frequency of hand washing before milking. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

In relation hand washing above the MM group had wash sinks equipped with soap thus the high rate of washing hands before milking. Despite, a majority of those in the SM group having wash sinks hygiene measures were not strictly adhered too. The WM group have no wash sinks. However, they try to adhere to hygiene by putting a watering can but at times forget to wash hands.

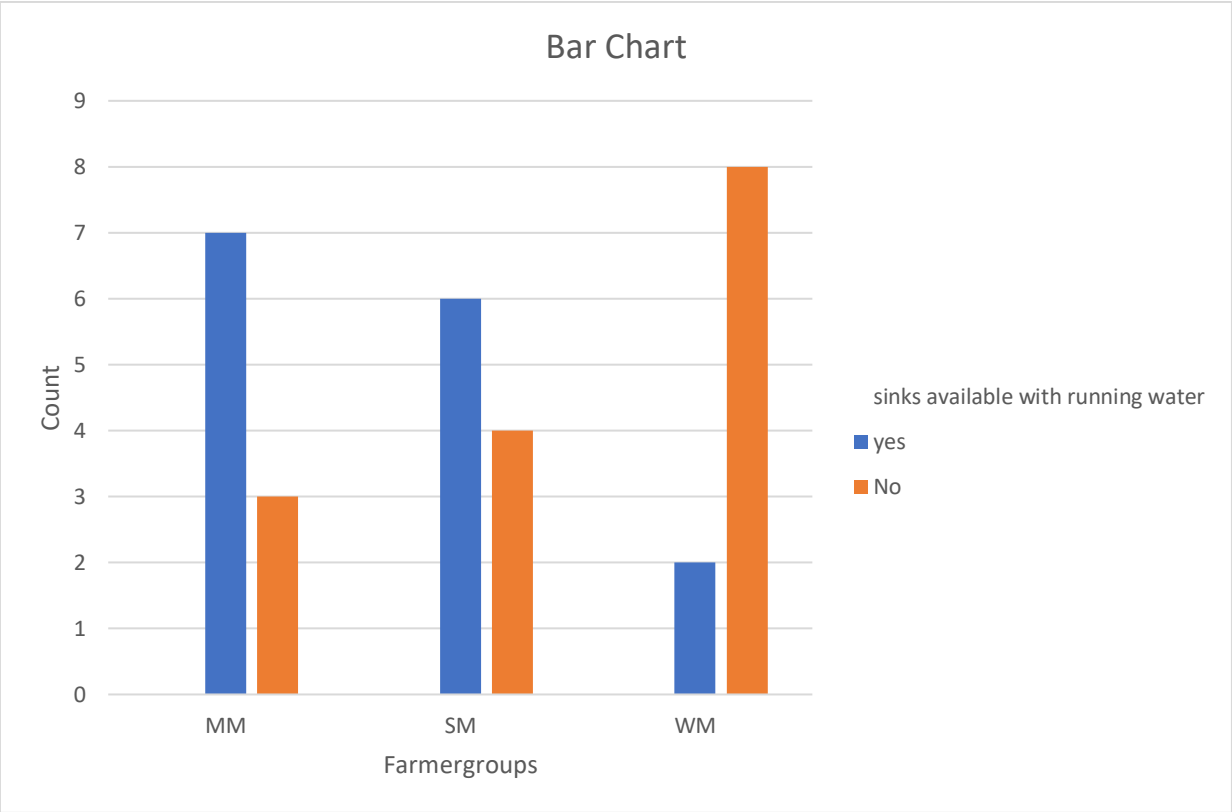


Figure 11: Farmers who owned hand washing sinks near the milking parlour. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.4.2. Use of teat dips while milking cows

The MM group uses teat dips often while milking cows. Only few farmers with milking machines rarely use teat dips. For SM group they use teat dips with a lower frequency compared to those who have milking machines. The WM group seldom use teat dips while milking their cows. The MM group adheres more to hygiene in use of teat dips compared to the SM and WM groups.

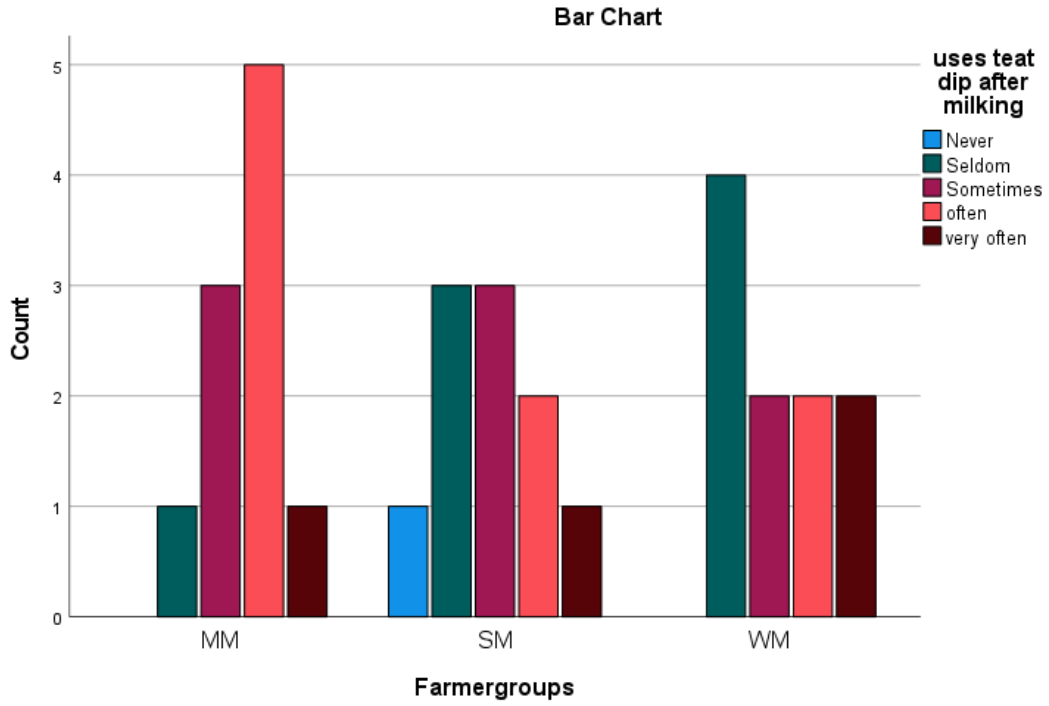


Figure 12: Farmers who used teat dip during milking sessions. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.4.3. Use of colored milk test while milking cows

Colored milk test (CMT) is rarely used by the three groups MM, SM and WM. Both the MM and SM group have a high number of farmers who never use CMT. The WM group had a higher number who often used CMT than their counterparts the MM and SM group. With hygiene measures adhered to CMT may not be of importance while milking

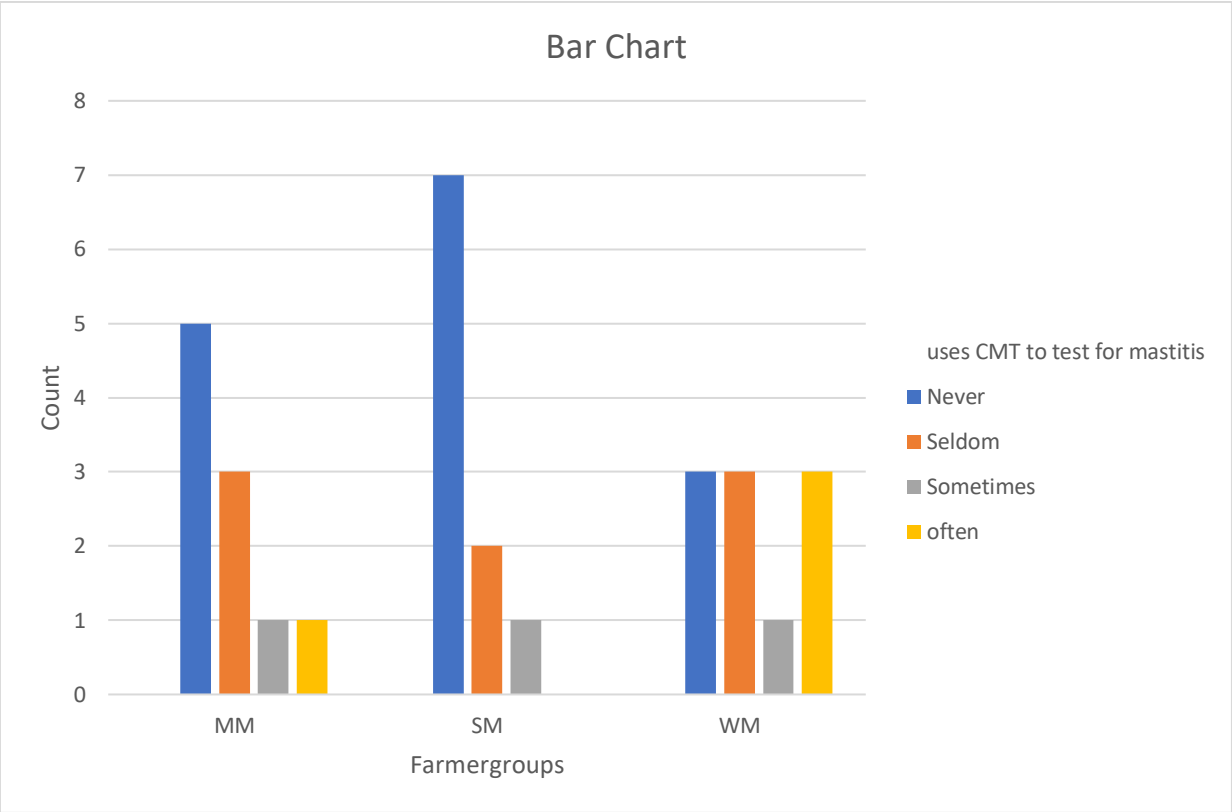


Figure 13: Farmer groups who utilized CMT. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.4.4. Use of strip cup

Most of the farmers MM, SM and WM groups never check or seldomly checked the colour or appearance of milk using a strip cup. However, the WM group were keen and checked milk appearance. Farmers in group WM and SM who had no strip cup checked the appearance of the milk using the palm of their hand

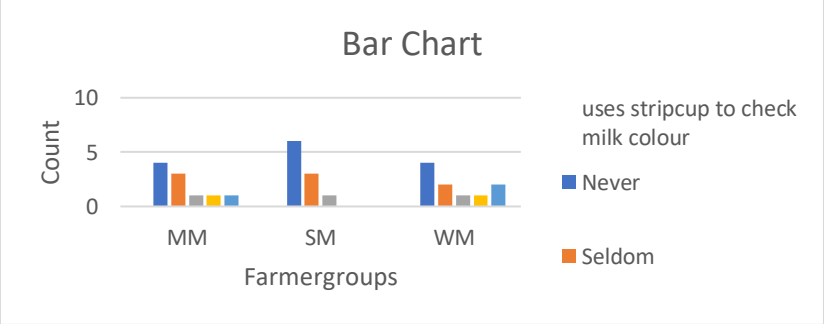


Figure 14: Farmers who used a strip cup to check milk abnormalities. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.4.5. Use of towels for cleaning the udder

The group MM seldomly or at times used two (2) towels one to clean the udder and the other to dry. Most farmers in MM, SM and WM groups only used one towel to clean and dry the udder. Farmer groups MM, SM and WM are not keen to use two towels before milking their cows

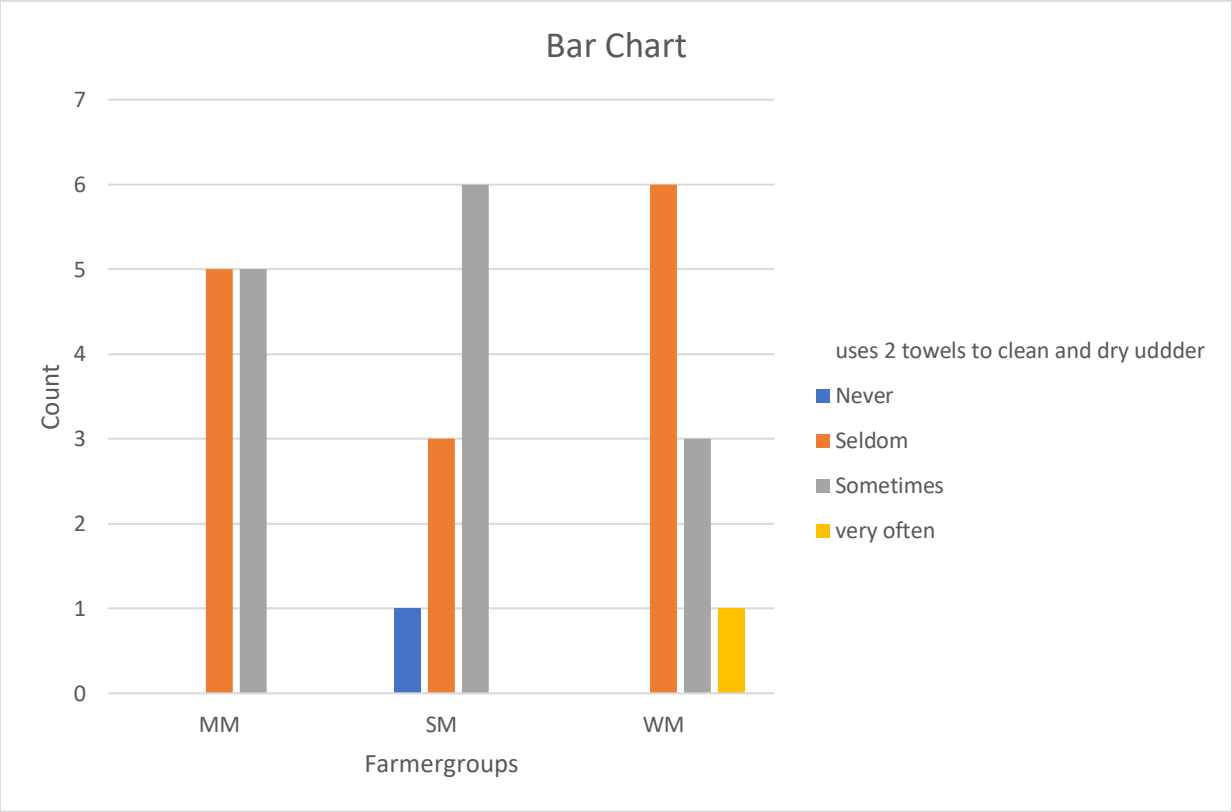


Figure 15: Farmer groups using 2 towels to clean and dry the udder. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.5.6. Condition of milking salve

Almost all farmers in MM, SM and WM rarely sealed and kept the milking salve in cool and dry conditions. In most cases the milking salve was left open and exposed to contaminants. Milking salve could be a point of entry for infections as it was not kept under proper conditions

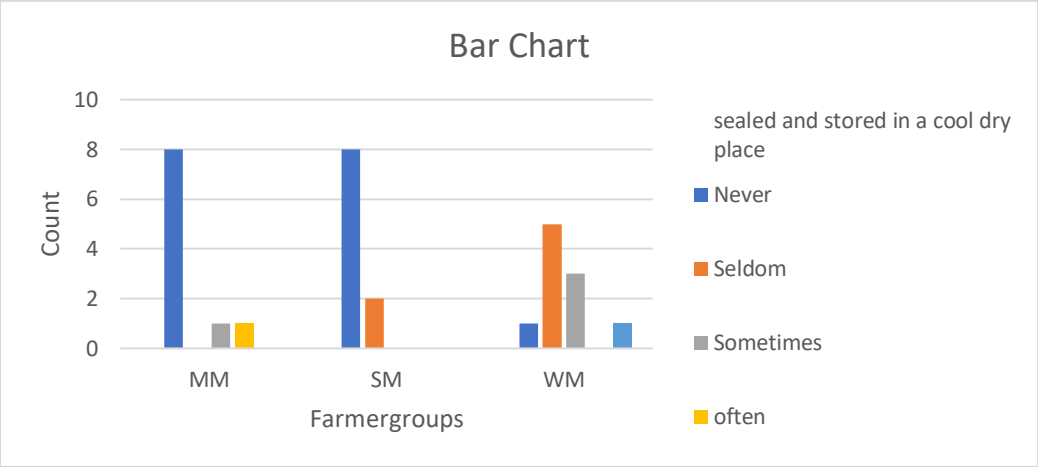


Figure 16: Conditions of the milking salve. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.4.7. Cleanliness of the milking parlour

The milking parlours were often cleaned daily by all farmers in groups MM, SM and WM. Very few farmers in SM and WM did not clean at least twice daily. The milking parlour was kept clean by all farmer groups to ensure milk is handled in hygienic conditions.

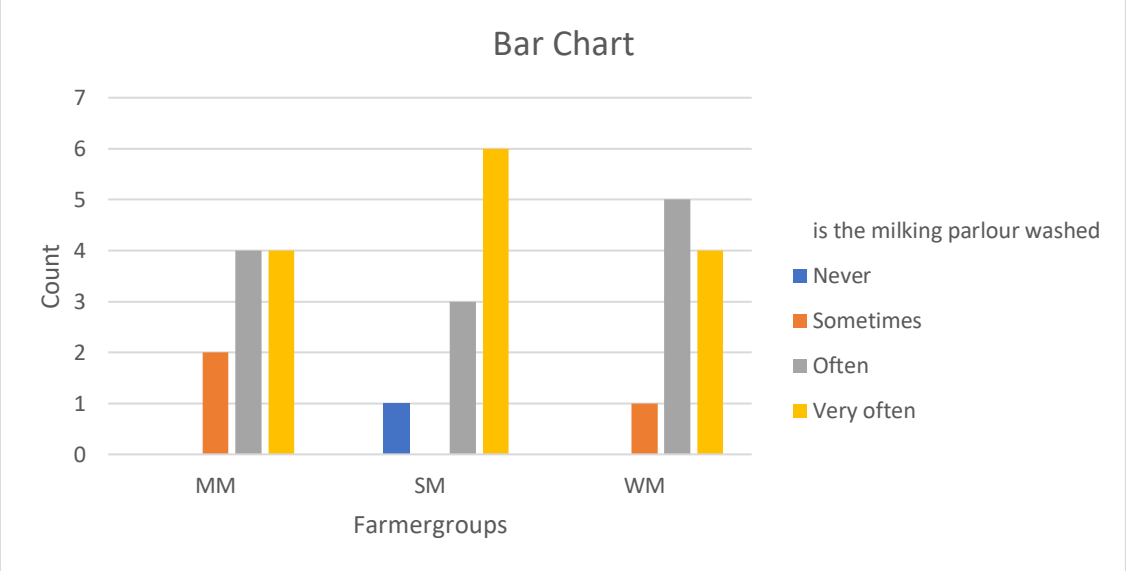


Figure 17: Frequency of cleaning the milking parlour. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.4.8. Stripping teats off milk

Farmer in group WM ensured that they strip off all milk from the cow after milking. This was replicated by the SM group and half of the MM group. However, for the MM group some machine would milk completely thus no need of stripping off. Stripping the teat after milking is necessary to prevent infection in dairy cows.

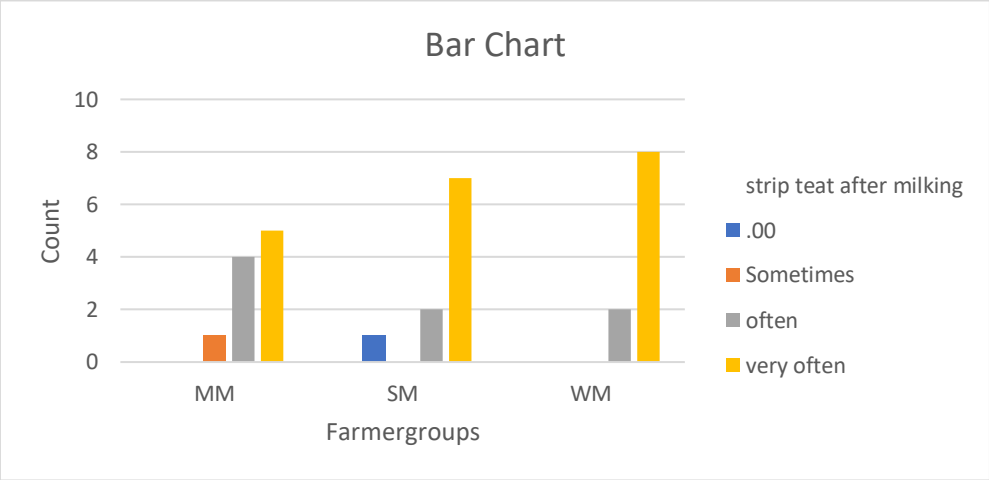


Figure 18: Farmers who stripped teats after milking. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

4.5. Economic benefits derived from using milking machines

From table 5 below above farmer group MM were able to produce more milk per year than their counterparts SM and WM. The MM group has the ability to manage more cows compared to the SM and WM group. The MM group receives a higher income compared to the SM and WM group.

The following statements were obtained from farmers in the survey.

1) Milking machines help ease load of work
2) They decrease turnover of workers
3) They reduce prevalence of mastitis within the herd
4) Milk coming off a milk machine has no contaminants, its clean
5) Workers can be able to attend to other duties for those with milking machines

Table 6: Average milk production and income for farmer groups per year. MM= farmers with milking machines, SM= farmers who had shelved machines, WM= farmers willing to purchase milking machines

	MM	**SM**	**WM**
Milk yield/cow/yr (litres)	4773	4043	4071
Number of cows	24	15	19
Average milk production/yr (litres)	114552	60646.14	77351.92
Average income per year/group (KES)	KES. 5154840	KES. 2729076.30	KES. 3480836.40

Milk price per litre = KES. 45

4.6. Financial Products

Finance officers were interviewed from the following institutions equity bank, K unity microfinance, GDC sacco society and Kabete sacco. Both equity bank and K unity had an agribusiness division which dealt with farmers. There was only one product provided by equity bank known as Kilimo mendeleo loan which ensured farmers could build more houses, add more livestock and equipment. Kunity microfinance had three products namely

1) Agriloan (kilimo secured)
2) Agriloan (Kilimo unsecured)
3) Agriloan (mifugo)

The products were available to dairy farmers.

GDC SACCO limited had three main products available to dairy farmers such as mazao loan, ngombe loan and asset finance. Kabete SACCO had no definite loan tailored to dairy farmers. However, they could access either long-term loans or short-term loans as long they were a member of the SACCO and made monthly remittances.

4.7. Knowledge of financial institutions and milking machine retailers

The financial institutions interviewed had a limited knowledge of milking machines and their effect of quality in milk. All financial institutions were interested in promoting their products to farmers during trade fairs and demonstrations but most of the technical aspects were left to cooperative and government extension agents. Milking machines companies did not have a direct contact with banks thus offered their products through cooperatives. Farmers were only trained on use of milking machines upon purchase but not before. There was a gap between milk machine companies and financial institutions.

4.8. Farmers opinion on use of loans to buy milking machines

Farmer group MM and SM would advise WM not to take a loan to purchase a milking machine. However, the WM group has some farmers who would consider using loan facilities to purchase milking machines. Farmers considering to purchase milking machines would not contemplate on accessing financial loans to buy them.

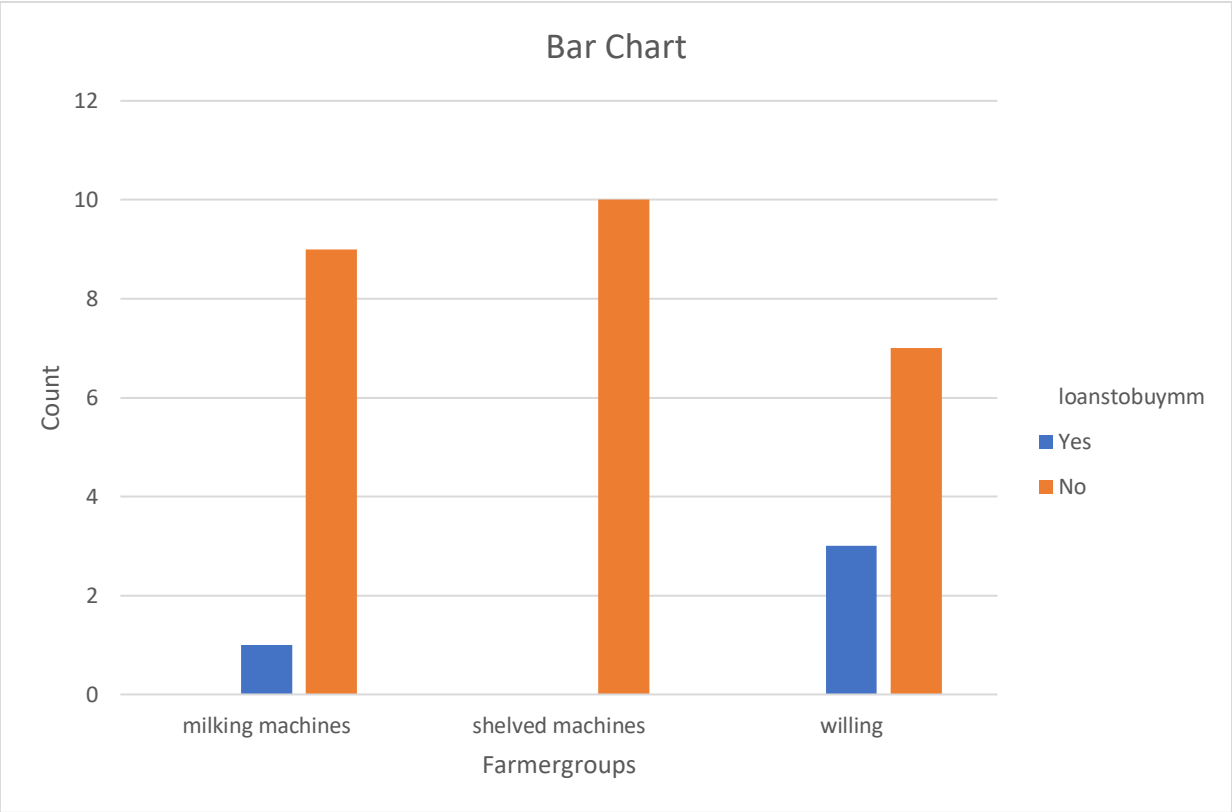


Figure 19: Farmers responses on use of loans to purchase milking machines

4.9 Linkages existing between finance and small holder dairy farmers

Dairy cooperatives both in Githunguri and Kabete sub counties had good working relationships with FIs especially K unity micro finance which was used to make payments of milk deliveries to farmers. the MFI in conjunction with SACCOS were used to access finance as long as they were members of the dairy cooperative society and actively delivered milk. However, for Kabete SACCO any person who was active and made monthly contributions could access credit despite him not being an active dairy member at KDFCS.

Farmers in both cooperatives did not have dairy milk production records thus on their own could hardly access credit from FIs. They were dependent on delivery records to cooperatives for access of credit. Credit offered was deducted from proceeds of milk delivered

5.0. Discussion

5.1. Milk losses

5.1.1. Milk losses due to diseases

The major cause of milk losses among the three (3) farmer groups were diseases mainly mastitis, pneumonia and foot and mouth disease as reported by farmers in both Githunguri and Kabete sub counties. The most common disease leading to high milk losses between and among the groups was mastitis. Muturi (2020) notes that mastitis leads to milk losses as the abnormalities and antibiotic withdrawal period leads milk to be discarded.

The main cause of mastitis among farmers with milking machines and those without were hygiene practices which is in comparison to farmers in Jaipur (Singh and Ramachandran, 2020). While all farmers with milking machines washed them after milking some practices such as using one towel for multiple cows would transmit the disease, and also lack of use of teat dips which may have affected farmers without milking machines more as the majority did not use teat dips. While the udders were clean its possible for farmers to understand that water only cannot remove pathogens from teats thus should always use teat dips (Suarez Martinez *et al.,* 2019). This may have been a reason why mastitis incidences were higher for farmers without milking machines compared to those with machines. Most of the farmers in all groups would only use one towel per cow which could have played a role in milk losses due to mastitis. At times workers found it tiresome to wash towels they would use one towel for around three cows and argue that since they use hot water harmful pathogens would be killed. Without drying the udder water used may drip and get into the milk container causing contamination (Orwa *et al.,* 2017). This in some cases caused transmission of mastitis in the herd especially if one of the cows was infected leading to milk losses.

Milk losses for those with milking machines may also have been due to contaminants in the milking salve. Almost all 26 out of 30 respodents do not completely seal the milking salve leaving it open to harmful microbes that may transmit mastitis.

Figure 20: Storage conditions of milking salve in most farms

5.1.2. Milk loss as a result of contamination

Contamination of milk was observed among affected farmers who had shelved milking machines and those who were willing to purchase machines. Hygiene of the milking parlour is an important factor for production of quality milk as observed by (Gurmessa, 2015). Losses were as a result of hair, fecal dirt stuck in the cow fur and flies. Whenever the shed was not properly cleaned well cows would have fecal matter stuck in their fur fall in milk hence contamination (Singh and Ramachandaran, 2020). However, all farmers ensured they washed the parlour 2 to 3 times per day but those who hand milked had to deal with this contaminants leading to milk losses. Farmers with milking machines did not suffer from this kind of losses as the process is enclosed.

5.1.3. Milk loss due to spillage

Due to the narrow opening in some milking containers spillage could be observed for those hand-milking as noted by Orwa et al (2017). Milk spillage was also caused by cattle especially if distractions occurred while being milked thus it would kick the milking can causing a considerable loss (Tostivint *et al.,* 2017). When putting milk to a bulking container spillage occurred. Most spillage occurred during transportation to the collection centre, especially during the rainy season where personnel would trip spilling nearly all the contents causing a considerable loss, especially in Kabete sub-county.

5.2 Information about milking machines

Farmer groups learned information on milking machine technologies from other farmers or agricultural magazines and newspapers and agricultural shows and trade fairs. Most farmers who had shelved their machines and those willing to purchase and also some with milking machines had their choices influenced by counterparts experiences. The experiences of those farmers/relatives with machines shared to them led them to purchase or put into plans (Martinez-Garcia et al., 2016).

Farmers with milking machines got information had obtained information from farmer magazines and newspapers both hard and soft copies. They would read about farmer experiences of milking machines in developed countries thus purchased them for their own use thus becoming adoptors of milk machine technologies (Straete, 2004). Trade fairs and agricultural shows proved to be a source of information. However, knowledge obtained was more likely to be from marketers of milking machines.

5.2.1. Knowledge and perceptions of milking machines among farmers

A group had beliefs that milking machines milk blood from cows. This was mostly experienced when owners of milking machines ignored hygiene measures thus due to infections of the udder, blood spots were spotted in milk. Getahun *et al* (2008) reports that not taking hygiene measure could cause a high prevalence of mastitis within the herd, thus traces of blood in milk. This may also be the reason why the SM group experienced high mastitis incidences, and believed machines played a big role in the infections. However, this was not the case as Mein (2012) points out that most new infections are caused by other factors not milking machines.

Farmer groups believed that cows milked using milking machines had a well-developed udder and teat formation. This was relatively true as confirmed by Atigui *et al* (2021) that machine milked animals had well developed teats and udder with a large variability in size and shape. Farmers also believed that milking machines caused teat erosions which is in contrast with Mein *et al* (2003) who reports milking machines do not cause teat erosions.

Farmers reported that initial cost of purchasing milking machines was high which is in comparison to what Ombuna (2018) reported. It was also noted that farmers at times lacked spare parts and had to import them which was costly thus the shelving of milk machines. Ombuna (2018) reports that Kenya imports milk machines mainly from Europe, Turkey and China. However, machines from Turkey and China prove to be less operable thus the majority of machines shelved are from these two countries. It was noted that farmers believed milking machines brought into the Kenyan market are archaic in nature. This was as a result of not incorporating basic technologies such as digitization, while their counterparts in developed nations have them incorporated. From interviews with the research officer and director of KDFCS, extension officers and the SM group reported that milking machine technologies offered in 1970s has not changed from what is being offered currently.

5.3 Parameters for milk hygiene and safety

Farmers from all groups practiced hygiene and safety measures to ensure milk quality. However, some parameters such as washing hands with soap and water before milking, washing and drying the teats before milking and storage of milk salve in a sealed container, in a cool dry place and were not enforced which led to milk losses observed. Before milking a cow it is important to clean and dry the udder as it reduces the bacterial count (Millogo, 2010). However, it was noted that farmers only used one towel to clean and dry the udder and in some extremes, one towel would be shared among many cows. This was a risk as cows with mastitis infection would easily spread it to the milking herd.

Due to the unavailability of hand washing sinks some workers could not wash their hands before milking. Some washed their hands while milking the first cow, but did not repeat the same for new cows despite the fact they were handling ropes to restrain cows which may be harboring infectious agents that would lead to mastitis as also reported by (Muturi, 2010). some of the workers did not use soap while washing their hands and many did not dry their hands before milking the cows which is in comparison to findings of (Nyokabi et al., 2020)

The use of teat dips has not been fully embraced by all farmers where a proportion rarely or seldomly use them. Teat dips are important as they reduce bacterial count before milking and also protect the teat canal from infectious agent as its left open after milking (Millogo, 2010). Ombuna (2018) reported that many farmer do not use teat dip as observed in this study leading to either contamination of milk or udder infections.

The use of CMT was rare among farmers on all groups. This was used by extension officers and veterinary officers as it was only used to confirm mastitis. It was also noted that many farmers did not see the need of purchasing a strip cup thus they used the palm of their hand to confirm milk abnormalities which was also reported in among dairy farmers in Tanzania (Kivaria et al., 2004).

5.4. Economic benefits of using milking machines

There was an increased milk production by farmers who used milking machines compared to those who did not. Farmers using milking machines had a duration below 7 minutes compared to those who did not have milking machines thus improved production (Ombuna, 2018). Time taken during milking is an important factor as it optimizes milk production throughout the lactation period. Due to the short duration of time taken while milking other activities in the farm can be undertaken in the farm. Milk losses as a result of contamination by dirt, flies or fecal and spillage were not present.

Farmers with milking machines had lower milk losses due to diseases with more emphasis on mastitis. This was as a result of low compliance to hygienic practices farmers without milking machines as suggested by shitandi (2004). This also could be a result of high turnover of workers in farms without milking machines. The prevalence of mastitis increased once they hired new workers due to under milking and failure to comply to hygiene practices. There was a low turnover of workers for farms with milking machines thus the lower prevalence of mastitis

5.5. Financial products for milk machines

They were no specific financial products for farmers to buy milking machines in both Githunguri and Kabete sub counties which is in comparison to what Asfaw *et al* (2010) reported in the horticulture sector in Kenya. However, banks, microfinance institutions (MFIs) offered some products to purchase farm assets which would consider milking machines but were short term in nature. Companies selling milk machines did not have agreement with financial institutions (FIs) for farmers to access credit to purchase milk machines. They were mainly dependent on cooperatives to market their products and did not offer them on hire purchase terms to farmers. Cooperatives would negotiate on the farmers behalf where companies selling milking machines were paid all money by the bank while the farmer paid credit to the financial institution using milk delivered (Kilelu et al., 2011). They were no tailor made products for milking machines since there is a low demand thus no need for both FIs and companies to offer one.

5.6. Knowledge of financial institutions on milking machines

The people in charge of financing the agriculture sector in FIs had little background in livestock farming and worked together with cooperatives and government extension officers. Financial officers had limited knowledge about milking machines and how they can improve milk quality among livestock farmers in comparison to what was reported in Uganda by Nuwagaba (2012). However, FIs would send their financial officers to farmer open days, demonstration and agricultural trade fairs to learn while promoting their products.

Milking machine companies did not have a direct relationship with FIs which was the same case in hungary for agricultural machines as reported by Varga and Sipicizki (2015). They were dependent on dairy cooperatives and individual customers to purchase milking machines. They would promote them during agricultural shows, trade-fairs and demonstrations. Milking machines in many FIs were categorized together with assets such as vehicles thus attracted higher interest rates than the rest of agricultural products.

5.7. Perception of farmers on accessing loans to buy milking machines

Farmer would rather not access loans to purchase milking machines. They would rather use the loans to buy cows and increase milk production then consider purchasing milking machines. Others would rather use other sources such as savings to buy milking machines. This is because farmers believe the initial cost of milking machines does not yield a return on investment.

While the government of Kenya (GoK) encourages development of the dairy sector by access to credit facilities, access to credit is very low. Many farmers prefer to access loans for other purposes such as school fees, building houses or purchasing land rather than buying milking machines. Others relied on non-agricultural income to purchase machines (Odhong et al., 2019).

5.8. Reflection

The research started on a positive trajectory as I got an opportunity to cover my topic under the FORQLAB project. I had to conceptualize a research topic and after formulate research questions and a conceptual framework. My supervisor advised me to always think of how I do analyze a research question before considering it which was an important hint. The most difficult part for me was designing a conceptual framework. However, through consultations with my supervisor and literature review I was able to design one that guided my research.

My methodology involved the use of three techniques that is observation, a survey and interviews. While formulating the survey I had to consider the accuracy of answers I do receive, be careful with wording effect and avoid bias. During field research, observations which were conducted after the survey helped me to get attention to detail for all parameters that were being checked on. For the key interviews some interviewees rejected both audio and visual recordings but agreed on me taking notes. One of my key interviewees declined thus I had to look for an alternative with the same products.

Data analysis was carried out using SPSS version 27 of which video tutorials were useful while learning how to analyze data. The process of transcribing data was a bit difficult as it involved listening, reading and rereading scripts which took most of my time. The research trajectory has helped me develop values of patience especially when you have to rework on logics and torelance and also accepting critical analysis of my work thus fostering critical thinking.

6.0. Conclusion

The study was conducted to examine access of milk machines to improve on milk quality and reduce milk losses in Githunguri and Kabete sub counties. The study was guided by two research questions:

1. Which sensitization measures can be used to enhance adoption of milking machines for farmers with small herds but high milk production?
2. What is the role of financial institutions in ensuring farmers access to credit to invest in bucket milking machines?

The research sub questions were formulated to address the main research questions. They included milk losses, knowledge of farmers on milking machines, hygiene parameters to ensure milk quality and hygiene, economic benefits of milking machines, financial products offered by FIs, knowledge of FIs regarding milk machine technologies, opinion of FIs in obtaining milking machines and linkage between small holder dairy farmers and FIs.

It can be concluded that farmers need to adopt to the use of milking machines since there is an increase in the volume of milk. Farmers with milking machines suffer less milk losses compared to those without machines. For quality milk to be produced farmers have to ensure hygiene measures have to be strictly adhered too. Investment of quality machines is key to optimizing dairy production. European and Indian machines with availability of spare parts should be given preference.

While there are linkages between the farmer and FIs through the cooperative to access credit, milk machine companies have not taken advantage by creating partnerships to offer their products. This can be done by coming up with a business model which would promote milk machines. It can be concluded that farmers would rather not take credit to purchase milking machines. They would rather focus on increasing milk production and purchase machines from those proceeds or through savings.

In conclusion, for farmers to improve on milk quality there is need for adoption of milking machine technologies. Although, the initial cost of investment is higher FIs can come up products suitable for smallholder dairy farmers to access financial services .

8.0 Recommendations and interventions

To enhance adoption of milk machines, members of GDFCS and KDFCS have to understand its impact on milk quality. Therefore, its recommended that:

1. Extension officers both in government and cooperatives work together to train masses on the benefits of milk machines and how it improves milk quality and reduces milk rejection.
2. FIs, milk machine companies and cooperatives should set up credit groups of farmers willing to access quality milking machines whereby access to credit would be easier than individual farmers.

8.1. Interventions to promote access to milking machines

8.1.1. Promotion of milking machines

Due to perceptions of farmers it was noted in this study that farmers have beliefs that milking machines may increase the prevalence of mastitis. This may be some of the reasons why farmers may harbor feeling that they do not need milk machines. However, with benefits such as ease of labour, optimal milk production, quality and hygienic milk as a proposition may see the increase in uptake of milking machines

8.1.2. Training and extension

There is need for farmers to adopt to education for them to adopt to milk machine technologies and also adhere to hygiene standards during milking. Training should not be limited to farmers but extension, marketing and financial officers need capacity building to increase their knowledge. Training of farmers will enable them to acquire skills which will motivate them to adopt milking machine technologies.

8.1.3. Developing a business model

Milk machine companies need to develop a business model in which they can access the market hence improving the adoption of their technologies. They should leverage on increased milk quality and reduced losses.

8.1.4. Setting up demo farms

The use of demonstration farms will enable both farmers and extension officers to acquire practical knowledge hence the ability to operationalize milking machines. This will also be used to showcase hygiene procedures and how records are developed and kept to monitor the productivity and health of the herd.

8.1.5. Promoting access to credit

The adoption of technologies such as milking machines requires finance. Smallholder dairy farmers are vulnerable on this front as they lack security to access credit. This affects them on accessing dairy equipments that would enable them improve on milk quality. Due to the high cost of milking machines access to credit may delay adoption to milk machine technologies.

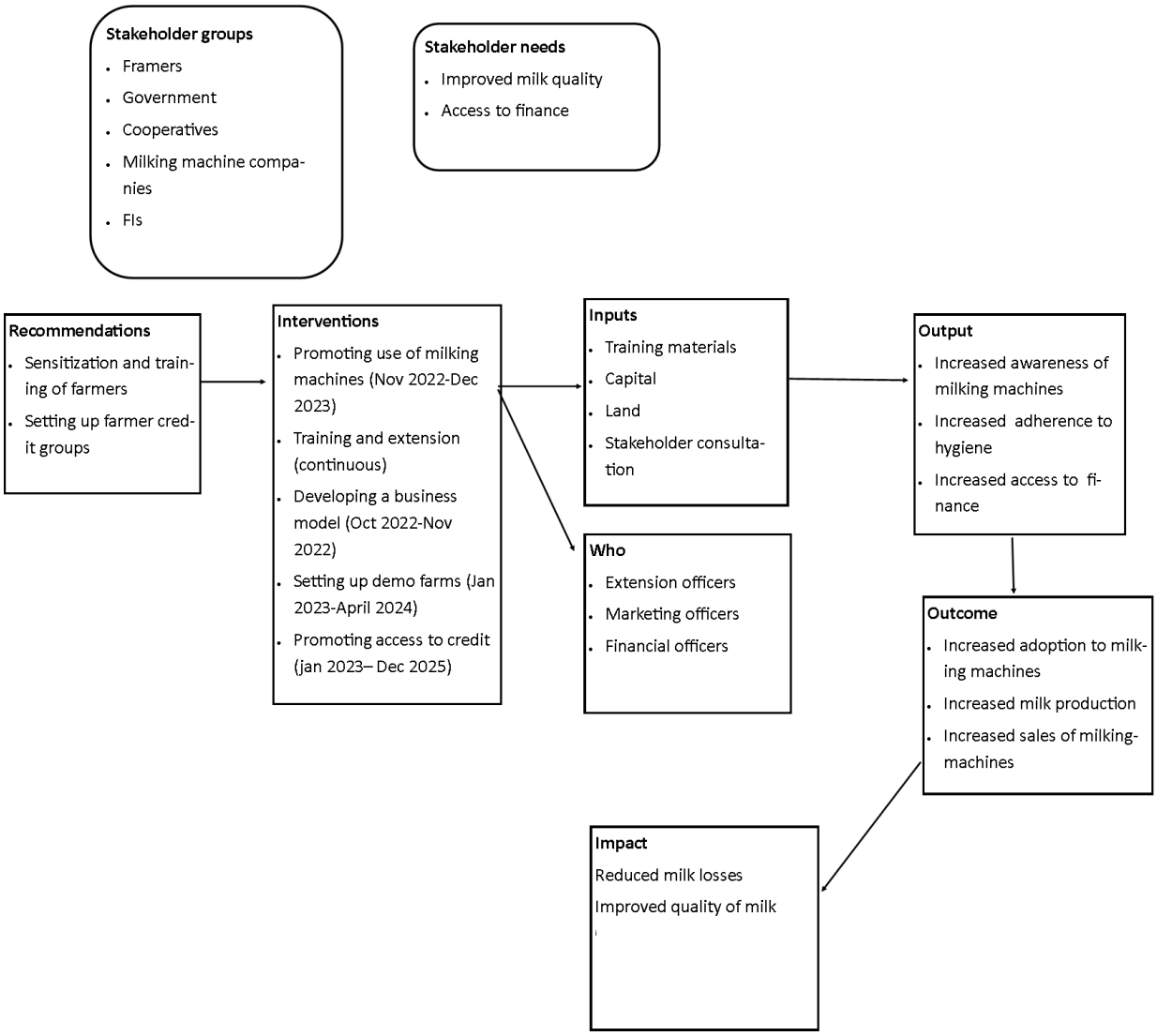


Figure 21: Recommendations and interventions based on theory of change

8.2. Business model canvas for milking machine companies

<table>
<tr>
<td rowspan="2">Key partners

• Dairy cooperatives
• Dairy farmers
• Government
• Financial institutions
• Universities and Research institutions
• NGOs</td>
<td>Key activities
• marketing of milking machines
• Product development
• Extension services and technical support</td>
<td rowspan="2">Value proposition
• Develop a milk management system
• Service and technical support for 1 year
• 1 year Warranty of machines</td>
<td>Customer relationships
• Develop a quality brand
• Provide free training to farmers on use of machines</td>
<td rowspan="2">Customer segments
• Individual customers
• Dairy cooperatives</td>
</tr>
<tr>
<td>Key resources
• Office space
• Skilled staff
• Manufacturing knowledge</td>
<td>Channels
• Retail shop
• Delivery to farmer</td>
</tr>
<tr>
<td colspan="3">Cost structure
Variable costs and fixed costs
• Labour
• Electricity and gas
• Depreciation costs
• Wages</td>
<td colspan="2">Revenue streams
• sale of milking machines
• Sales of dairy equipment</td>
</tr>
</table>

Figure 22: Canvass business model for milk machine companies

8.0. References

Alonso, S., Muunda, E., Ahlberg, S., Blackmore, E. and Grace, D., 2018. Beyond food safety: Socio-economic effects of training informal dairy vendors in Kenya. *Global food security*, *18*, pp.86-92. https://doi.org/10.1016/j.gfs.2018.08.006 (Accessed 7 June 2022)

Amenu, K., Wieland, B., Szonyi, B. and Grace, D., 2019. Milk handling practices and consumption behavior among Borana pastoralists in southern Ethiopia. *Journal of Health, Population and Nutrition*, *38*(1), pp.1-12. https://doi.org/10.1186/s41043-019-0163-7 (Accessed on 9 June 2022)

Atasever, S., Erdem, H. and Demiryurek, K., 2012. Association of some milking parameters with milk quality of smallholder dairy farms in Samsun region, Turkey. *Journal of Environmental Biology*, 33(1), p.123. URL://pubmed.ncbi.nlm.nih.gov/23033654/ (Accessed 6 June 2022)

Atigui, M., Brahmi, M., Hammadi, I., Marnet, P.G. and Hammadi, M., 2021. Machine Milkability of Dromedary Camels: Correlation between Udder Morphology and Milk Flow Traits. *Animals*, *11*(7), p.2014.**https://doi.org/10.3390/ani11072014** (Accessed on 6 Sep 2022)

Asfaw, S., Mithöfer, D. and Waibel, H., 2010. What impact are EU supermarket standards having on developing countries' export of high-value horticultural products? Evidence from Kenya. *Journal of International Food & Agribusiness Marketing*, *22*(3-4), pp.252-276. https://doi-org.hvhl.idm.oclc.org/10.1080/08974431003641398 (Accessed on 08 Sep 2022)

County Government of Kiambu. 2018. Kiambu County Integrated Development Plan 2018-2022. Nairobi Republic of Kenya. (Accessed 25 May 2022)

Drost, S. and van Wijk, J., 2011. The Milk and Milk Products Value Chain in Ethiopia. (Accessed 25 May 2022)

Food and agricultural organization (2020). FAOSTAT, online database available at http//:faostat.fao.org 2 (accessed on 2 may 2022)

FORQLAB, Project proposal practical knowledge for food and green. Thematic issues, submission round 2022

Gerosa, S. and Skoet, J., 2012. Milk availability: trends in production and demand and medium-term outlook. 10.22004/ag.econ.289000 (Accessed on 2 June 2022)

Getahun, K., Kelay, B., Bekana, M. and Lobago, F., 2008. Bovine mastitis and antibiotic resistance patterns in Selalle smallholder dairy farms, central Ethiopia. *Tropical Animal Health and Production*, *40*(4), pp.261-268. https://doi-org.hvhl.idm.oclc.org/10.1007/s11250-007-9090-5 (Accessed on 2 Sep 2022)

Gurmessa, T., 2015. Microbiological quality and impact of hygienic practices on raw cow's milk obtained from pastoralists and market. The case of Yabello District, Borana zone, Ethiopia. *Global Journal of Food Science and Technology*, *3*, pp.153-158. Available from: http://www.globalscienceresearchjournals.org/. (accessed on 1 Sep 2022)

Green, J., Willis, K., Hughes, E., Small, R., Welch, N., Gibbs, L., & Daly, J. (2007). Generating best evidence from qualitative research: The role of data analysis. Australian & New Zealand Journal of Public Health, 31(6), 545–550. https://doi.org/ 10.1111/j.1753-6405.2007.00141. (Accessed on 1 Sep 2022)

IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp (accessed on 25 May 2022)

Kang'ethe, E.K., Grace, D., Roesel, K. and Mutua, F., 2020. Food safety landscape analysis: The dairy value chain in Kenya. (Accessed on 25 May 2022)

Kiambu County Government. (2013). Kiambu County Strategic Plan 2013-2017. Kenya

Kilelu, C.W., Klerkx, L., Leeuwis, C. and Hall, A., 2011. Beyond knowledge brokering: an exploratory study on innovation intermediaries in an evolving smallholder agricultural system in Kenya. *Knowledge Management for Development Journal*, *7*(1), pp.84-108. https://doi.org/10.1080/19474199.2011.593859. (Accessed on 9 Sep 2022)

Kivaria, F.M., Noordhuizen, J.P.T.M. and Kapaga, A.M., 2004. Risk indicators associated with subclinical mastitis in smallholder dairy cows in Tanzania. *Tropical Animal Health and Production*, *36*(6), pp.581-592. https://doi-org.hvhl.idm.oclc.org/10.1023/B:TROP.0000040935.87175.bb (Accessed on 8 Sep 2022).

Lewis, R.B. and Maas, S.M., 2007. QDA Miner 2.0: Mixed-model qualitative data analysis software. *Field methods*, *19*(1), pp.87-108. (Accessed on 9 June 2022)

Lore, T.A., Omore, A.O. and Staal, S.J., 2005. Types, levels and causes of post-harvest milk and dairy losses in sub-Saharan Africa and the Near East: Phase two synthesis report. https://hdl.handle.net/10568/3741 (Accessed on 9 June 2022)

Manyi-Loh, C., Mamphweli, S., Meyer, E. and Okoh, A., 2018. Antibiotic use in agriculture and its consequential resistance in environmental sources: potential public health implications. *Molecules,* 23(4), p.795. doi:10.3390/molecules23040795. (Accessed on 26 May 2022)

Martinez-Garcia, C.G., Dorward, P. and Rehman, T., 2016. Factors influencing adoption of crop and forage related and animal husbandry technologies by small-scale dairy farmers in Central Mexico. *Experimental Agriculture*, *52*(1), pp.87-109. DOI: https://doi.org/10.1017/S001447971400057X (Accessed on 2 Sep 2022)

Mburu, S., Njuki, J. and Kariuki, J., 2012. Intra-household access to livestock information and financial services in Kenya. *Livestock Research for Rural Development*, *24*(2), p.2012. http://www.lrrd.org/lrrd24/2/mbur24038.htm (Accessed on 8 Sep 2022)

Mein, G.A., 2012. The role of the milking machine in mastitis control. *Veterinary Clinics: Food Animal Practice*, *28*(2), pp.307-320. DOI:https://doi.org/10.1016/j.cvfa.2012.03.004 (Accessed on 7 Sep 2022)

Mein, G., Williams, D.M. and Reinemann, D.J., 2003, January. Effects of milking on teat-end hyperkeratosis: 1. Mechanical forces applied by the teatcup liner and responses of the teat. In *annual meeting-national mastitis council incorporated* (Vol. 42, pp. 114-123). National Mastitis Council; 1999. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.524.4606&rep=rep1&type=pdf. (Accessed on 2 Sep 2022)

Millogo, V., 2010. Milk production of hand-milked dairy cattle in Burkina Faso (Vol. 2010, No. 2010: 4). (Doctoral thesis) http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-3034 (Accessed on 7 sep 2022)

Murendo, C. and Mutsonziwa, K., 2017. Financial literacy and savings decisions by adult financial consumers in Zimbabwe. *International journal of consumer studies*, *41*(1), pp.95-103. **https://doi-org.hvhl.idm.oclc.org/10.1111/ijcs.12318**. (Accessed on 1/Aug/2022)

Muturi, E.W., 2020. Effect of mastitis on milk production in dairy cows in Kenya. *Journal of Animal Health*, *2*(1), pp.85-91. https://doi.org/10.47604/jah.1170 (Accessed on 31/Aug/2022)

Nuwagaba, A., 2012. Savings and credit cooperative societies (SACCOS) as a source of financing agriculture. Challenges and lessons learnt. *Journal of Environment and Earth science*, *2*(11), p.11.

Nyokabi, S., Luning, P.A., de Boer, I.J., Korir, L., Muunda, E., Bebe, B.O., Lindahl, J., Bett, B. and Oosting, S.J., 2021. Milk quality and hygiene: Knowledge, attitudes and practices of smallholder dairy farmers in central Kenya. *Food Control*, *130*, p.108303. https://doi.org/10.1016/j.foodcont.2021.108303 (Acessed on 9 May 2022)

Odero-Waitituh, J.A., 2017. Smallholder dairy production in Kenya; a review. *Livestock Research for Rural Development*, *29*(7), p.139. http://www.lrrd.org/lrrd29/7/atiw29139.html (Accessed on 16 May 2022)

Odhong', C., Wilkes, A., van Dijk, S., Vorlaufer, M., Ndonga, S., Sing'ora, B. and Kenyanito, L., 2019. Financing large-scale mitigation by smallholder farmers: what roles for public climate finance?. *Frontiers in Sustainable Food Systems*, *3*, p.3. https://doi.org/10.3389/fsufs.2019.00003 (Accessed on 9 Sep 2022)

Okello, J.J., Gitonga, Z., Mutune, J., Okello, R.M., Afande, M. and Rich, K.M., 2010. Value chain analysis of the Kenyan poultry industry: The case of Kiambu, Kilifi, Vihiga, and Nakuru Districts. DOI:10.13140/2.1.5131.7442 (accessed on 16 May 2022)

Okello, D., Owuor, G., Larochelle, C., Gathungu, E. and Mshenga, P., 2021. Determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya. *Journal of Agriculture and Food Research*, *6*, p.100213. https://doi-org.hvhl.idm.oclc.org/10.1016/j.jafr.2021.100213 (Accessed 29 May 2022)

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M., Staal, S.J., 1999. The Kenya Dairy Sub-sector: A Rapid Appraisal. MoA/KARI/ILRI Smallholder Dairy (R&D) Project Report, Ministry of Agriculture, Kenya. Kenya Agricultural Research Institute and the International Livestock Research Institute, Nairobi, Kenya, 51 pp. https://orcid.org/0000-0001-9213-9891 (Accessed 20 May 2022)

Ombuna, C., 2018. Trends in Hand Milking and Machine Milking in Kenya. *Journal of Engineering and Applied Sciences*, 13: 5655-5660 DOI: 10.36478/jeasci.2018.5655.5660 (accessed on 28 May 2022)

Ongwech, W.L., Gor, C. and Otiende, M.A., 2020. Determinants of Credit Access among Smallholder Dairy Farmers in Kinangop Sub-County, Kenya. **URI:** http://ir.jooust.ac.ke:8080/xmlui/handle/123456789/9321 (Accessed 6 June 2022)

Orwa, J.D., Matofari, J.W. and Muliro, P.S., 2017. Handling practices and microbial contamination sources of raw milk in rural and peri urban small holder farms in Nakuru County, Kenya. *International Journal of Livestock Production*, *8*(1), pp.5-11. DOI: 10.5897/IJLP2016.0318 (Accessed on 2 Sep 2022)

Pambo, K., 2015. Financial technological innovation and access is the key to unlocking African agricultural potential: a case study of dairy in Kenya (No. 1008-2016-80262). (Accessed on 25 May 2022)

Rademaker, C.J., Bebe, B.O., Van Der Lee, J., Kilelu, C. and Tonui, C., 2016. Sustainable growth of the Kenyan dairy sector: a quick scan of robustness, reliability and resilience (No. 979). Wageningen University & Research, Wageningen Livestock Research.

Saenger, C., Qaim, M., Torero, M. and Viceisza, A., 2013. Contract farming and smallholder incentives to produce high quality: experimental evidence from the Vietnamese dairy sector. *Agricultural Economics*, *44*(3), pp.297-308. **https://doi-org.hvhl.idm.oclc.org/10.1111/agec.12012** (Accessed on 2 Aug 2022)

Senerwa, D.M., Sirma, A.J., Mtimet, N., Kang'ethe, E.K., Grace, D. and Lindahl, J.F., 2016. Prevalence of aflatoxin in feeds and cow milk from five counties in Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *16*(3), pp.11004-11021. (Accessed on 25 June 2022)

Singh, A. and Ramachandran, A., 2020. Assessment of hygienic milking practices and prevalence of bovine mastitis in small dairy farms of peri-urban area of Jaipur. *Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive & Social Medicine*, *45*(Suppl 1), p.S21. doi: 10.4103/ijcm.IJCM_363_19 (Accessed on 30 Aug 2022)

Suarez-Martinez, J., Christian, M. and Vance, C., 2019. Mastitis Management: A Training Handbook for Extension Workers.URL: https://hdl.handle.net/1842/37208 (Accessed on 1 Sep 2022)

Shitandi, A. A. (2004). Risk factors and control strategies for antibiotic residues in milk at farm level in Kenya (Vol. 458, No. 458). Doctoral thesis. http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-256 (Accessed on 9 Sep 2022)

Stræte, E., 2004. Innovation and Changing 'Worlds of Production' Case-Studies of Norwegian Dairies. *European Urban and Regional Studies*, *11*(3), pp.227-241. https://doi.org/10.1177%2F0969776404044021 (Accessed on 2 Sep 2022)

Tinsley, E., and Agapitova, N., 2018. Private Sector Solutions to Helping Smallholders Succeed : Social Enterprise Business Models in the Agriculture Sector. *World Bank, Washington, DC. © World Bank.* http://hdl.handle.net/10986/29543 (Accessed on 2 June 2022)

Tostivint, C., de Veron, S., Jan, O., Lanctuit, H., Hutton, Z.V. and Loubière, M., 2017. Measuring food waste in a dairy supply chain in Pakistan. *Journal of Cleaner Production*, *145*, pp.221-231. https://doi.org/10.1016/j.jclepro.2016.12.081 (Accesed 2 Sep 2022)

Varga, J. and Sipiczki, Z., 2015. The financing of the agricultural enterprises in Hungary between 2008 and 2011. *Procedia Economics and Finance*, *30*, pp.923-931. https://doi.org/10.1016/S2212-5671(15)01342-8 (Accessed on 2 Sep 2022)

Wilkes, A., Dijk, S.V. and Odhong, C., 2019. Finance for on-farm investments in dairy production in Kenya. *Wageningen. The Netherlands: CGIAR research program on climate change, agriculture and food security* https://hdl.handle.net/10568/102279 (Accessed on 3 June 2022

9.0. Appendices

Appendices 1: Semi structured questionnaire

1. Experience/education

1) How many years have you been practicing dairy farming?
2) Do you have any form of training in milk handling and safety measures
   □ Yes
   □ No

2. Daily milk production and distribution

1) what is the amount of milk produced per day?
2) What amount of milk is sold to other sources apart from the cooperative?
3) What amount of milk is reserved for home consumption?
4) What amount of milk is reserved for calf intake?
5) What amount of milk is used for other purposes?

Research question 1.

Sub question 1: What are the current milk losses between farmers with milking machines and those without?

1) How much milk do you loose per year due to diseases?
2) How much milk per year is lost due to contamination in a year?
3) What amount of milk is lost due to spillage in a year?
4) What amount of milk is lost due to spoilage in a year?

Sub question 2: What kind of information is available on milking machines to farmers?

1) What misconceptions have you heard about milking machines?
2) Why don't you use a milking machine? (Farmers who have shelved their machines)
3) From which country was the brand of machine used manufactured?

Sub question 3: How can the incorporation of bucket milk machines improve milk hygiene and safety within Kiambu county?

1) do you have any quality control checks?

2) what parameters do you measure?

3) how do you handle variations?

4) Have your milk been rejected?

5) what was the cause of rejection?

6) what measures did you put in place to prevent it from recurring?

7) What did you do with the rejected milk?

8) Do you have traceability measures in place?

9) How often do you clean the milking place?

□ Daily

□ Weekly

□ Monthly

□ Others

Research Question 2

Sub question 1: What are the economic benefits of using milking machines?

1) What are the labor requirements in your farm after acquiring a milking machine?

(From records observe milk production and compare them between groups)

Sub question 3: What is the farmers opinion on using financial institutions in obtaining milking machines?

1) do you have access (or have you had access in the past 6 months) to credit to support your dairy farm

□ Yes
□ No

2) if yes where did you get credit from

□ Banks

□ Microfinance institutions (MFIs)

□ Sacco

□ Dairy cooperative

□ Mobile loans

□ Friends, family or relatives

a) if no would you consider borrowing to invest in a milking machine (those willing to buy milking machines)
   □ Yes
   □ No
b) would you advise farmers willing to buy milking machines to opt for a loan (those who have shelved and own milking machines)

   □ Yes

   □ No

4) if no why? Explain……

5) what is the maximum amount you would borrow ……. kshs (WM only)

6) How would you like to pay for the milking machine?

Appendice 2

Table 3: observation checklist

Farm	**Scoring support scale 1,2,3,4,5**					**comments**
	1	**2**	**3**	**4**	**5**	
1. Environment						
Condition of the milking parlour (clean)						
Floor of the milking parlour						
Drainage						
Milk storage area						
2. Equipment used						
Milking cans						
Milking towels/cow						
Teat dip						
Milking salve						
Hand washing sink						
Strip cup						
Condition of drug storage area						
3. Milking protocol						
Wash hands						
Wash udder						
Uses different towels to dry and wash udder						
Uses teat dip						
Tests milk (CMT), strip cup						
Condition of milking equipment						
3. Records						
Milk records						
Breeding records						
Health records						

Appendice 3

Interview checklist (extension officers cooperatives, government and research scientist) **Research question 1 sub question 1-3 and research question 2 sub question 4**

Table 7: interviewee checklist

list	**questions**	**Response and general observations**
Milk loss	1. What losses are experienced by farmers with milking machines and those without? 2.What are the main causes of milk rejection 3. What quantity of milk is rejected at collection centres?	
Information+farmers opinion	1. which kind of information do farmers have on milking machines? 2. what knowledge do farmers have on maintenance of milking machines? 3. what perceptions do farmers have on milking machines? 4. why are machines considered safe to use compared to hand milking?	
Milk hygiene and safety	1. which hygiene measures do farmers put in place during milking? 2. What information do you have on rejected milk? 3.What are the main causes of unsafe milk products?	

Appendice 4

Interview checklist financial and marketing officers

Table 8: interviewee checklist finance and marketing officers

List	**Questions**	**Response and general observations**
Financial products	1. What type of financial products are available for farmers to invest in? 2. How aware are dairy farmers to financial products? 3. What type of knowledge is shared to farmers regarding products available?	
Role of financial institutions and link to finance	1. What category of farmers are eligible to access loans? 2.What are the main purposes for banks to provide agricultural credit? 3. What awareness have been made to inform dairy farmers on existing loan schemes? 4. Which areas are covered for dairy loan schemes?	
Knowledge of financial institutions	1. Which information do financial institutions have on milking machines? 2. what kind of expertise do financial institutions have in managing dairy farmers credit?	

Appendice 5

Anova for milk production, milk sold, home consumption and calf intake between and within groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
milk production (litres)	Between Groups	195620.000	2	97810.000	4.079	.028
	Within Groups	647500.000	27	23981.481		
	Total	843120.000	29			
milk sold (litres)	Between Groups	167.267	2	83.633	.245	.785
	Within Groups	9224.100	27	341.633		
	Total	9391.367	29			
home consumption (litres)	Between Groups	17.867	2	8.933	2.544	.097
	Within Groups	94.800	27	3.511		
	Total	112.667	29			
calf intake (litres)	Between Groups	24.867	2	12.433	.272	.764
	Within Groups	1232.100	27	45.633		
	Total	1256.967	29			

Table 6: Tukey t test for milk production with multiple comparisons

Appendice 6

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Farmergroups	(J) Farmergroups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
milk production (litres)	milking machines	shelved machines	193.00000*	69.25530	.025	21.2872	364.7128
		willing	134.00000	69.25530	.148	-37.7128	305.7128
	shelved machines	milking machines	-193.00000*	69.25530	.025	-364.7128	-21.2872
		willing	-59.00000	69.25530	.675	-230.7128	112.7128
	willing	milking machines	-134.00000	69.25530	.148	-305.7128	37.7128
		shelved machines	59.00000	69.25530	.675	-112.7128	230.7128
milk sold (litres)	milking machines	shelved machines	-5.70000	8.26599	.772	-26.1949	14.7949
		willing	-3.70000	8.26599	.896	-24.1949	16.7949
	shelved machines	milking machines	5.70000	8.26599	.772	-14.7949	26.1949
		willing	2.00000	8.26599	.968	-18.4949	22.4949
	willing	milking machines	3.70000	8.26599	.896	-16.7949	24.1949
		shelved machines	-2.00000	8.26599	.968	-22.4949	18.4949
home consumption (litres)	milking machines	shelved machines	1.80000	.83799	.099	-.2777	3.8777
		willing	1.40000	.83799	.235	-.6777	3.4777
	shelved machines	milking machines	-1.80000	.83799	.099	-3.8777	.2777
		willing	-.40000	.83799	.883	-2.4777	1.6777
	willing	milking machines	-1.40000	.83799	.235	-3.4777	.6777
		shelved machines	.40000	.83799	.883	-1.6777	2.4777
calf intake (litres)	milking machines	shelved machines	2.10000	3.02104	.768	-5.3904	9.5904
		willing	1.70000	3.02104	.841	-5.7904	9.1904
	shelved machines	milking machines	-2.10000	3.02104	.768	-9.5904	5.3904
		willing	-.40000	3.02104	.990	-7.8904	7.0904
	willing	milking machines	-1.70000	3.02104	.841	-9.1904	5.7904
		shelved machines	.40000	3.02104	.990	-7.0904	7.8904

*. The mean difference is significant at the 0.05 level.

Appendice 7

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
total milk losses (litres)	Between Groups	34615.467	2	17307.733	1.155	.330
	Within Groups	404484.400	27	14980.904		
	Total	439099.867	29			
spillage litres	Between Groups	5509.400	2	2754.700	5.547	.010
	Within Groups	13407.800	27	496.585		
	Total	18917.200	29			
contaminants litres	Between Groups	59.467	2	29.733	16.553	<.001
	Within Groups	48.500	27	1.796		
	Total	107.967	29			
diseases litres	Between Groups	15908.067	2	7954.033	.686	.512
	Within Groups	312888.900	27	11588.478		
	Total	328796.967	29			
spoilage litres	Between Groups	.000	2	.000	.	.
	Within Groups	.000	27	.000		
	Total	.000	29			

Appendice 8

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Farmergroups	(J) Farmergroups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
total milk losses (litres)	milking machines	shelved machines	-82.40000	54.73738	.304	-218.1168	53.3168
		willing	-51.20000	54.73738	.623	-186.9168	84.5168
	shelved machines	milking machines	82.40000	54.73738	.304	-53.3168	218.1168
		willing	31.20000	54.73738	.837	-104.5168	166.9168
	willing	milking machines	51.20000	54.73738	.623	-84.5168	186.9168
		shelved machines	-31.20000	54.73738	.837	-166.9168	104.5168
spillage litres	milking machines	shelved machines	-23.90000	9.96579	.059	-48.6094	.8094
		willing	-31.90000*	9.96579	.009	-56.6094	-7.1906
	shelved machines	milking machines	23.90000	9.96579	.059	-.8094	48.6094
		willing	-8.00000	9.96579	.705	-32.7094	16.7094
	willing	milking machines	31.90000*	9.96579	.009	7.1906	56.6094
		shelved machines	8.00000	9.96579	.705	-16.7094	32.7094
contaminants litres	milking machines	shelved machines	-3.40000*	.59938	<.001	-4.8861	-1.9139
		willing	-2.20000*	.59938	.003	-3.6861	-.7139
	shelved machines	milking machines	3.40000*	.59938	<.001	1.9139	4.8861
		willing	1.20000	.59938	.131	-.2861	2.6861
	willing	milking machines	2.20000*	.59938	.003	.7139	3.6861
		shelved machines	-1.20000	.59938	.131	-2.6861	.2861
diseases litres	milking machines	shelved machines	-55.10000	48.14245	.496	-174.4652	64.2652
		willing	-17.10000	48.14245	.933	-136.4652	102.2652
	shelved machines	milking machines	55.10000	48.14245	.496	-64.2652	174.4652
		willing	38.00000	48.14245	.713	-81.3652	157.3652
	willing	milking machines	17.10000	48.14245	.933	-102.2652	136.4652
		shelved machines	-38.00000	48.14245	.713	-157.3652	81.3652

*. The mean difference is significant at the 0.05 level.

Appendice 8

Milk yield/cow/yr= yield/cow/day*lactation length* 365/calving interval

Milk yield/cow/yr for MM= 17*300*365/395= 4773 l/cow/yr

SM= 14.4*300*365/395= 4043 l/cow/yr

WM=14.5*300*365/395= 4071 l/cow/yr

Total milk yield/ group/yr= milk yield/cow/yr* average herd

MM= 4773*24= 114552 l/yr

SM=4043*15= 60646.15 l/yr

WM= 4071*19= 77351.92 l/yr

Total income/ group

MM=114552*45= KES. 5154840

SM=60646.15*45= KES. 2729076.75

WM= 77351.92*45= KES. 3480836.40