INVESTIGATING HYGIENIC PRACTICES AND MICROBIAL SAFETY OF MILK SUPPLIED BY SMALL-HOLDER FARMERS TO PROCESSORS IN BOMET, NAKURU AND NYERI COUNTIES IN KENYA

BY

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DECLARATION

I, **Miriam Wanjiru Mogotu,** do declare that this Thesis is my original work and has not been presented for an award in any other institution.

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DEDICATION

I dedicate this Thesis to my mum who has been the biggest supporter of my dreams and who has sacrificed so much to enable me to realize my goals.

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ABBREVIATIONS

AFC Agricultural Finance Corporation

ASDS Agricultural Sector Development Strategy

ECF East Cost Fever

FAO Food and Agriculture Organization

GDP Gross Domestic Product

KDB Kenya Dairy Board

KNBS Kenya National Bureau of Statistics

NDDP National Dairy Development Project

SDP Small-holder Dairy Project

TVC Total Viable Counts

GENERAL ABSTRACT

Smallholder farmers dominate the Kenyan dairy sector producing 95% of the total milk. However, several concerns have been raised on the quality and safety of milk they produce. This study assessed the hygienic practices and microbial safety of milk supplied by smallholder farmers to processors in Bomet, Nyeri and Nakuru counties in Kenya. Interviews and direct observations were carried out to assess hygiene and handling practices by farmers and a total of 92 milk samples were collected along four collection channels: direct suppliers, traders, cooperatives with coolers and cooperatives without coolers. Microbial analysis was done following standard procedures and data analyzed using GenStat and SPSS. This study revealed that farmers did not employ good hygienic practices in their routine dairy management. They used plastic containers for milking and milk storage (34.2%); did not clean sheds (47.9%) and did not set aside cows that suffered from mastitis (83.6%), factors resulting to poor microbial quality of raw milk along the collection channels. The highest mean total viable counts (8.72 $\log_{10}$ cfu/ml) were recorded in Nakuru while Nyeri had the highest mean *E. coli* counts (4.97 $\log_{10}$ cfu/ml) and Bomet recorded the highest mean counts of 5.13 and 5.78 $\log_{10}$ cfu/ml for *Staphylococcus aureus* and *Listeria monocytogenes* respectively. Based on all above-mentioned parameters, the microbial load in most samples from all three counties exceeded the set Kenyan standards. Farmer trainings, improving road infrastructure use of instant coolers at cooperatives and quality based payment systems are recommended as measures to curb microbial growth.

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CHAPTER ONE:

INTRODUCTION

1.1. Background Information

Kenya's dairy sector has a significant socio-economic role in the national economy. It is a source of livelihood and nutrition for many, generating about 4% of the national GDP and has been ranked among the largest in sub-Saharan Africa (KDB, 2020). Dairy production in Kenya is mainly practised in the highlands and is mostly intensive or semi-intensive farming (Bonilla *et al.*, 2017). The dairy herd in Kenya comprises of an estimated 3.3 million head of pure-bred Fresian-Holstein, Ayshire, Guernsey, Jersey and other crosses which produce over 5 billion litres of milk per year (TEGEMEO INSTITUTE, 2016).

Small scale farmers dominate the dairy industry at the production level (Bonilla *et al.*, 2017) where they produce over 95% of the national milk produced (KDB, 2020). There are more than one million smallholder dairy farmers in Kenya who contribute more than 70% of Gross Marketed Production from the farms (Reynolds, 2015). The small scale dairy farmers practice intensive and semi-intensive farming where they keep herds of cross breeds variedly from one to five cows which are mainly fed using the crops from the farm hence an interdependency between the crops and the livestock (Bonilla *et al.*, 2017). The milk produced by these farmers is consumed both in the urban and rural areas (Alonso *et al.*, 2018).

Milk consumption in Kenya is in the top ranks among developing countries and fresh milk is the most consumed (KDB, 2020). A review of price elasticity showed that price change does not affect milk demand which indicates that milk is a necessity to Kenyans (Reynolds *et al*., 2015). At the production level, consumption of milk at home by the household and the calves accounts for about 45% while the remaining about 55% is marketed through various channels (TEGEMEO INSTITUTE, 2016).

Milk has a relatively short shelf-life and thus requires quick and efficient marketing to ensure optimum results (KDB, 2020). There has been great emphasis on the organization of small-scale milk producers into groups such as self-help groups, cooperatives and companies in order to enhance efficiency in marketing of the raw milk through bulking and cooling with dairy cooperatives dominating the marketing of milk by small-scale farmers (KDB, 2020). Other main buyers of raw milk include: households, hotels and institutions (Wanjala, 2018).

Milk processing capacity in Kenya is also on a steady growth and this increase is linked to a growing demand of milk and dairy products with new milk processors coming up in different counties which source their milk from farmers within the community (KNBS, 2016).

However, as much as there is increased demand, processing and marketing of milk, there still remains a challenge of non-compliance to the minimum set national, regional and international quality and safety standards (Bebe *et al*., 2018).

Milk marketed in the formal and informal sectors in Kenya often do not meet the set microbial standards which poses a health hazard to consumers (Knight-jones *et al.*, 2016). Milk and dairy products are enriched with nutrients making them a good environment for both spoilage and pathogenic micro-organisms to grow (Alonso and Grace, 2018). To help solve this issue, more dairy cooperatives have been established where farmers bulk and cool their milk before it is marketed or transported to processors (Odero-Waitituh, 2017). There has also been an increase of middlemen or traders who bulk milk from several farmers and transport them to the cooperatives or processors to ensure efficiency in transportation (Bonilla *et al.*, 2017). Microbial safety of raw milk in Kenya from small-scale farmers has been a grave concern for decades (Knight-jones *et al.*, 2016; Alonso *et al.*, 2018; Brown *et al.*, 2018). There is therefore need to assess hygiene knowledge and handling practices of milk by farmers considering that milk contamination usually begins at the production level. There is also limited data on the microbial quality of milk along the collection channels despite the need for monitoring from production to consumption (Ndungu *et al.*, 2016).

1.2. Statement of the problem

Small scale farmers dominate the dairy industry at the production level (Bonilla *et al.*, 2017) where they produce over 95% of the national milk produced (KDB, 2020). However, the dairy sector faces immense challenges in meeting raw milk quality standards (Bebe *et al*., 2018). Milk contamination begins at the farm level (Odero-Waitituh, 2017) where farm practices by most small holder farmers often do not meet the Kenyan code of hygienic practices, handling and distribution of milk (KDB, 2020). This ranges from a number of factors including lack of knowledge on good farm practices, poor handling hygiene, poor road network and lack of refrigeration on storage and transportation of milk. The large number of smallholder milk producers results to ineffective inspection and regulation of their daily dairy practices (TEGEMEO INSTITUTE, 2016). Presence of transporters or middlemen further complicates traceability of milk and brings a risk of cross-contamination and microbial overload due to poor milk handling, adulteration of milk and long transportation time without refrigeration (Vara Martínez *et al.*, 2017). At the cooperatives, poor handling of milk by the personnel, improper cleaning of equipment and inefficient cooling using conventional coolers also results to milk contamination.

Bomet, Nakuru and Nyeri counties are considered to be among the major milk producing counties in Kenya (KDB, 2020). The counties have various collection channels including small holder farmers, transporters, and cooperatives. Moreover, the counties have processors, both medium sized dairies and industrial dairies most of which have been in the industry for many years and have a high processing capacity of up to 9,000litres and 800,000 litres per day for the medium sized dairies and industrial dairies respectively.

There is need to assess hygiene knowledge and handling practices of milk by farmers considering that they influence the quality of milk produced. There is also limited data on the microbial quality of milk along the collection channels in these counties, especially on individual micro-organisms despite the need for monitoring from production to consumption.

1.3. Justification

Consumers have the right to safe and good quality milk. Raw milk quality influences the quality of the end product even after processing. The study will provide information on the knowledge of hygiene and handling practices done by farmers. It will further provide data on the safety and quality of milk produced by the farmers and along the collection channels until milk reaches the processors. The results will also inform processors on the quality of milk supplied by farmers enabling them to set up policies to either curb poor quality milk or reward farmers using bonuses for good quality milk. Moreover, the study will identify the sections between the farmer and the processor where safety and quality of milk is compromised so that the necessary measures can be taken to improve quality at the right part of the dairy chain. The study will further provide data which can be used for follow up research and traceability on the quality and safety of milk in these counties.

1.4. Objectives

1.4.1. Main objective

To investigate hygiene practices and microbial safety of milk supplied by small-holder farmers to processors and along the collection channels in Bomet, Nakuru and Nyeri counties in Kenya.

1.4.2. Specific objectives

1. To determine hygiene, knowledge and handling practices of farmers in Bomet, Nakuru and Nyeri counties in Kenya

2. To determine the microbial level of milk (Total Plate Count, *Staphylococcus aureus*, *Escherichia coli* and *Listeria monocytogens*) supplied by small-holder farmers along the collection channels.

CHAPTER TWO:

LITERATURE REVIEW

2.1. Kenya's Agricultural sector

The agriculture sector which comprises of crops, livestock, fisheries, agro-forestry and associated services is significant to Kenya's economy where it contributes 26 per cent of the Gross Domestic Product (GDP) and 27 per cent of GDP indirectly through linkages with the other sectors (KARI, 2012, UNEP, 2015). The sector is the largest employer in Kenya's economy accounting for over 55 per cent of the total employment. Furthermore, approximately 75 per cent of Kenyans derive part of their livelihood and income from agriculture and agriculture related activities (KARI, 2012, USAID, 2019). Farming in the country is largely small-scale, with around 75 per cent of total agricultural output produced on rain-fed farms (UNEP, 2019). Currently there are approximately 4.5 million small-scale farmers in Kenya and this includes: around 3.5 million crop farmers, approximately 600,000 pastoralists and 130,000 fisher folk. When put together, their output totals to at least 63% of the national produce (FAO, 2015). However, the sector has experienced some challenges over the past years mainly due to increase in population and extreme weather changes. This has resulted to the government developing some policies including the Agricultural Sector Development Strategy (ASDS) 2010-2020 and the National Food and Nutrition Security Policy with the aim of boosting the agricultural sector (UNEP, 2019).

2.2. Kenya's Dairy Industry

The main role of the Dairy sub-sector is the contribution it has to improving the lives of the people involved in production along the value chain, and its contribution to the nutrition and general health of the communities mainly in the rural areas (FAO, 2011). There are several players found in the Dairy industry; some of who offer farming inputs and services; partners and facilitators who ensure development of the industry; and those who use the inputs and services (FAO, 2011). According to KDB (2011), livestock production contributes about 10 per cent of total and around 30 per cent of agricultural GDP. Dairy products excluding live animals, contribute 30 per cent of livestock GDP and an estimated 25 per cent of the gross marketed products in terms of livestock (KDB, 2014). It is clearly an important section of the livestock sector and a primary source of income to more than one million small holder farmers (TEGEMEO INSTITUTE, 2016). The dairy herd in Kenya comprises of an estimated 3.3 million head of pure-bred Holstein-Fresian, Ayshire, Guernsey, Jersey and other crosses. They produce over 3 billion litres of milk per year with about 2 billion litres produced by dairy cattle alone (IFAD, 2015). Kenyan milk production is about 3 per cent of the 18 per cent produced globally by sub-Saharan Africa. Cow milk is considered to be the most important agricultural commodity in Kenya when the calculations are done at international prices, obtained from over 3.5 billion milking cattle (Porter, 2007).

2.2.1. Evolution of the Dairy Sector

The dairy industry in Kenya dates back to the colonial times. The release of the Swynnerton Plan in 1954 played a significant role in policy change where native Kenyans were permitted to engage in commercial agriculture (Odero-Waitituh, 2017). Immediately after independence, there was a major land transformation exercise in form of, acquisition, redistribution and subdivision of the then large scale farms that were owned by the white settlers. Moreover, this period resulted to a huge shift in dairy farming, which saw a drastic drop in the number of cattle in the large scale farms, while the smallholder farmers engaging and playing a significant role in the dairy sector (Bonilla *et al.*, 2017). This resulted to a trend that has continued to grow and currently over one million small holder farmers produce an estimate of 90 per cent of the raw milk in Kenya (UNIDO, 2015).

2.3. Milk Production in Kenya

Dairy production in Kenya is mainly practiced in the highlands of what used to be known as Rift Valley, Central and parts of Eastern provinces. In terms of concentration of volumes of milk produced per square kilometre per annum, Western and Nyanza Provinces qualify as important dairy production areas (IFAD, 2015). Dairy production in Kenya is mainly done in three ways: intensive or zero-grazing, semi-intensive or semi-grazing and extensive or open range farming (EADD, 2008). When cattle are confined in a stall where they are fed, given water and milked, that is zero-grazing. Fresian Ayshire or their crosses are the ones that mostly graze in this system (Mugambi *et al*., 2015). Zero-grazing has several advantages which include, recycling of resources and interdependency where the animals are fed on some crops grown in the field while the animals produce manure for the food and cash crops in the farm. Moreover, the cattle can be fed depending with the level of production, being in the same compound, they are easy to manage and it is easier to control pests and diseases (Njarui *et al*., 2016). Where there is land availability and farmers keep crosses of dairy bred cattle, semi intensive farming is practised. It comprises of daytime grazing, night feeding in the stalls and supplementing the cattle during milking (Muia *et al*., 2011). Semi-grazing and extensive require less labour and minimal investment as compared to zero grazing, however, they produce lower yields (TEGEMEO INSTITUTE, 2016).

Kenya is still not self -sufficient in milk production as seen in 2017 where the country produced an estimated 5 billion litres of milk against a consumption of 6 billion litres (KDB, 2020). The government of Kenya through the National Dairy Development Project (NDDP) under the Ministry of Agriculture, Livestock and Fisheries promoted intensive, stall feeding units where farmers were emboldened to construct a stall-feeding unit, grow Napier grass (*Pennisetum purpureum*) and draw up a farm budget. Furthermore, they were encouraged and motivated to go to the Agricultural Finance Co-operatives (AFC) to ask for loans to purchase pre or in-calf dairy heifers that were cross bred. Moreover, they organized regular visits from well-trained dairy extension officers who assist farmers in management of their cattle and farms (Odero-Waitituh, 2017). This resulted to increase in milk production as shown in Figure 1, to 4575 kgs per cow per year from 2000 kgs per cow per year in the high potential areas a decade later (Bonilla *et al.*, 2017). However, there is still room for more milk production when good management is done and ensuring improved, well-planned feeding practices, considering that the cattle in Kenya have a much higher genetic potential than the current production of milk (KDB, 2014).

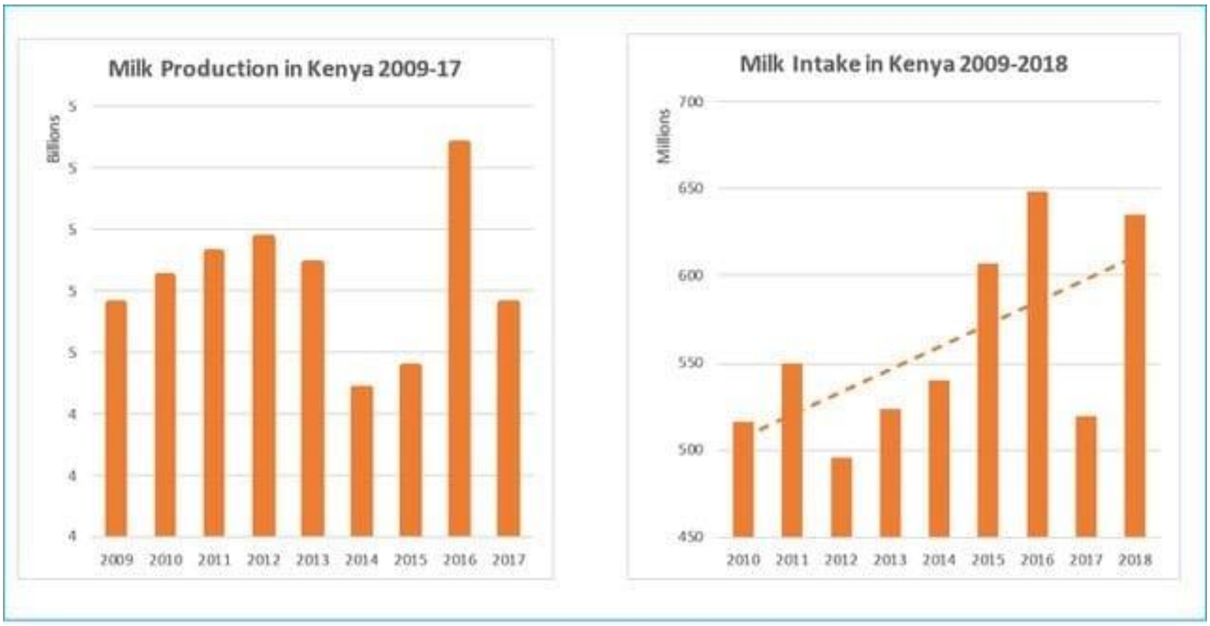


Figure 1: **Total Milk production and Milk Intake in Kenya from 2009-2017.**

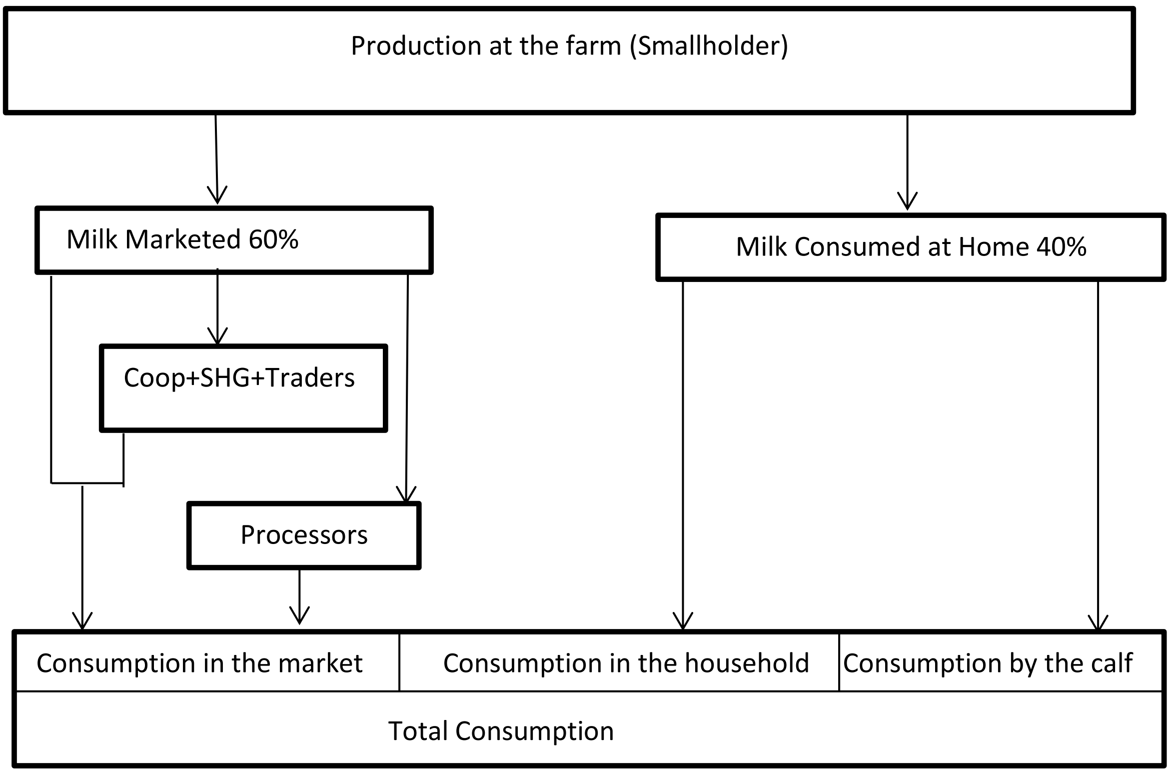
Source: KDB, 2019

2.4. Smallholder Milk Production in Kenya

Small scale farmers dominate the dairy industry mainly at the production level (FAO, 2011). Current milk production assessment done by the Kenya Dairy Board shows that small scale producers account for over 95 per cent of the milk with the large scale dairy producers accounting for the remaining 5 per cent of the national milk production (KDB, 2014). According to a previous study done by Smallholder Dairy Project (SDP, 2005), there are more than one million smallholder dairy farmers in Kenya who contribute more than 70 per cent of Gross Marketed Production from the farms. This trend shows that small scale dairy producers are increasingly dominating the dairy sector (KDB, 2014). A study by FAO (Muriuki, 2003) showed that smallholder dairy production is mainly carried out in farms with small spaces and they usually have herds of cross breeds variedly from one cow to three cows which are mainly fed using the crops from the farm hence an interdependency between the crops and the livestock. It further showed that farmers who practice dairy farming obtain not only milk but also manure and the cattle act as a capital asset to them. In the Kenyan highlands where population density is high, the small scale dairy farmers practice more intensive farming usually zero-grazing where the cattle are fed in stalls using fodder and crop residues from the farm and concentrates are used to supplement them (Njarui *et al*., 2011). It was noted that the rapid switch to small scale dairy production in these Kenyan highlands is due to decrease in sizes of the farm, preference of the dairy breed and an increased dependency on the concentrates and forage that can be purchased rather than grown (Muriuki, 2003). Despite the fact that a large proportion of the cattle in the small holder dairy farming being of good genetic make-up, there are quite a number of challenges that drag behind this sector (USAID/GoK, 2009). A number of the constraints include: inefficient level of feeding as a result of roughages that are of low quality and quantity (Njarui *et al*., 2011). A study by Muia *et al* (2011) found that the wanting conditions of roads in most of the places where small scale dairy farming is practiced influenced the delay of delivery of milk to the market resulting mostly to losses and a high cost of bringing in the inputs. Diseases including East Coast Fever (ECF), Rift Valley Fever and anthrax that affect the cattle are among the constraints faced by the farmers (Omunyin et al., 2014).

2.5. Milk Consumption and Demand

According to an SDP report (SDP, 2004), Kenya's milk consumption is in the top ranks in the developing countries with an average of 100kg per year per capita. However, this calculation is based on availability. Consumption of milk at home by the household and the calves accounts for about 40 per cent of the milk that is produced by the farmers (FAO, 2011). The remaining 60 per cent is marketed through various channels as shown in **Figure 2:**



SHG= self-help groups

Figure 2: **milk marketing of channels**

Source: Muriuki et al, (2003).

An SDP study found that Kenyan's also consume other dairy products accounting for 18 per cent of their income. This is without forgetting the fact that most of the dairy consumption is fresh milk. Furthermore, a review of price elasticity showed that price change does not affect milk demand indicating that milk is a necessity to Kenyans (SDP, 2004). Moreover, the income of the consumers affects their demand of the dairy products resulting to an influence on the processing, collection and distribution of these products which is mostly done in the urban areas where consumers who have a higher purchasing power are the ones who mostly get these products rather than those in the rural areas (Reynolds et al., 2015).

There have been diverse predictions about the where milk supply in Kenya is headed in the future. Some are optimistic that there will be surplus in production to warrant for exportation while the antagonists see a deficit in the supply of milk (FAO, 2011).

2.6. Marketing and Processing of Milk

2.6.1. Milk Marketing

Milk has a relatively short shelf-life and thus requires quick and efficient marketing to ensure optimum results (KDB, 2014). In 1992, there was liberalization of the dairy industry by the government of Kenya which saw private milk processors springing up and the market forces being controlled by demand and supply and an increase in the uncertainty of milk payment (TechnoServe, 2008). Marketing is the performance of all business activities involved in the flow of goods and services from the producer to the consumer. This shows that there are several key players in the marketing chain each with its own role and interests. The players include: consumers (who are the most important), producers and intermediaries who perform various functions such as transportation, distribution and retailing with the goal pf making the highest profit possible (KDB, 2014). According to a study by (Wanjala, 2018) on the marketing channels of milk in western Kenya, it showed that the four main milk markets or buyers include: households, hotels, institutions and cooperatives. Dairy cooperatives dominate the marketing of milk in Kenya with most of the marketed milk being produced by the small scale farmers.

There has been great emphasis on the organization of small-scale milk producers into groups such as self-help groups, cooperatives and companies in order to enhance efficiency in marketing of the raw milk through bulking and cooling. It is estimated by the KDB that there are approximately 365 such groups who collect, bulk and market the raw milk to milk bars, mini dairies, traders and processors (KDB, 2014).

2.6.2. Milk Processing

Small scale milk producers have found it necessary to organize themselves into dairy cooperatives so as to supply their raw milk to the processors (KDB, 2014). Over the past few years, milk processing in Kenya has been dominated by four major processors: New KCC, Brookside Dairy Limited, Githunguri Dairy Farmers Cooperative and Sameer Dairies. Each of these companies process more than 100,000 litres of milk per day, with some processing more than 400,000 litres per day during the high seasons (KDB, 2014).

According to the KDB, there have been over 40 licensed milk processors since the liberalization of the dairy industry in 1992. However, the current number of active milk processors has dropped to 25 mainly due to mergers, acquisitions and insolvencies. Moreover, the national volume of milk being processed increased by 244 per cent from 152 million litres in 2001 to 523 million litres in 2013 (KDB, 2014).

The output from these Kenyan processors include: white liquid milk both pasteurized and long-life, fermented milk (yoghurt, mala and cheese), flavoured liquid milk, ghee, butter, milk powder and cream, some of the challenges faced by the Kenyan milk processors are competition from the informal sector causing them to operate below their capacity (USAID, 2015), seasonal fluctuations in raw milk supply and high cost of milk production and processing. However, there have been increased investments in the recent past so as to meet the growing demand of milk and milk products (KDB, 2014).

2.6.3. Informal Dairy Channels

The unprocessed milk channels is made up of traders who buy milk from the rural producing households and then transport it while still raw for sale in the urban and peri-urban centres where most consumers are located (KDB, 2014). More than a decade ago, the informal milk outlets were reported to control 80 per cent of the marketed milk (Karanja, 2003). However, this is not the current case and the volumes handled by this channel may be much less as claimed by some of the stakeholders in the industry (KDB, 2014). A study by Kembe et al., (2008), found that there are direct sales that are found in the informal dairy channel including sales to kiosks, nearby households, brokers, hawkers who deliver to consumers and small traders. Kenyan consumers greatly prefer raw milk (FAO, 2011). An SDP brief report provides some reasons why unprocessed milk is preferred. They include: cost effectiveness the milk is cheaper than the processed milk up to 25 to 55 per cent, depending on how much money the consumer has to spend on the milk, it can be sold in various quantities, one does not have to go to the shops or supermarkets to purchase the milk since it is widely accessible and usually within close proximity to where the consumer lives and its taste and high butter fat content is greatly preferred. It is also important to note that a lot of farmers sell their milk in the informal market since there is almost no milk rejection which is mostly experienced in the collection centres (Muriuki, 2011). Furthermore, milk is often the only source of significant revenue to most of these farmers hence they would prefer selling to the informal market where money is given at hand after selling the milk rather than wait for the processors who pay them at the end of the month (Technoserve, 2008). The selling of milk through this unprocessed channel is of major concern due to the perceived health risk especially its microbial load by the time it reaches the consumer (FAO, 2011; Alonso and Delia, 2018).

2.6.4. The Formal Milk Sector

This is the market segment that is licensed by the Kenya Dairy Board. It is made up of operators who include more than 25 processors, 59 mini dairies, 68 cottage industries and 1172 milk bars (KDB, 2014). Licenses are mainly given to: milk bars each dealing with 1000 litres/day, cottage industries dealing with 3000 litres/day, mini dairies handling 5000 litres/day, processors handling 5000 litres/day, producers who treat or process the milk for sale and distributors who buy to resale the milk (FAO, 2011). Processors handle approximately 80 per cent of milk in the formal sector (Technoserve, 2008).

2.6.5. Exports and Imports of Milk and Dairy Products

Kenya was a net exporter of dairy products until the 1970s, from then on, the country has been alternating between exports and imports (FAO, 2011). Currently, Kenya exports substantial amounts of milk and milk products to the region. The main products exported are long-life milk and milk powder. Moreover, dairy imports have declined with time since the country has become more self-sufficient in milk and milk products. However, specialized milk products are imported from New Zealand and the European Union. It is important to note that intra-regional trade in dairy products in the East African Community has continued to increase significantly which benefits the Kenyan dairy industry (KDB, 2014).

2.7. Milk Quality and Safety

The EAC standard defines milk as ‘’the normal secretion that is clean and fresh obtained from the udder of a cow that is healthy, has been well fed and kept, but excluding the colostrum milk usually obtained during the first seven days after calving’’ (EAC, 2018). The technical regulation called Standards for Milk under the Food, Drugs and Chemical

Substances Act says that “milk or whole milk shall be the normal mammary secretion free from colostrum, obtained from the mammary glands of a healthy cow and shall contain no added water or preservatives or any other substances and is composed of not less than 3.25 per cent milk fat and not less than 8.5 per cent non-fat milk solids’’.

Milk quality and safety are the totality of characteristics of the milk and milk products that bear on their ability to satisfy all legal, customer and consumer requirements (UNIDO, 2015). However, milk quality and safety are not synonymous. According to FAO and WHO, quality includes all the milk attributes that influence its value to consumers whereas safety includes all measures intended to protect human health (FAO & WHO, 1995).

A large amount of milk in Kenya is marketed unprocessed and there is limited monitoring of the market by the regulatory bodies hence there is a concern of public health risks with the main concern being diseases such as brucellosis and tuberculosis (FAO, 2011). According to a study done SDP, it was found that the microbial quality of milk sold in the informal market was low with variable levels of zoonosis and brucellosis. It was further noted that most of the consumers who bought milk from the informal market boiled it before consumption and this reduce the chances of infections by bacteria (SDP, 2004).

Kilango *et al*. (2012) insists that while boiling makes the milk safer by eliminating most micro-organisms, there is still the risk of consumer exposure to pathogenic bacteria due to recontamination. There is a misperception that milk sold in the informal sector is of low quality and more of a health hazard than pasteurized milk in the formal sector (Doyle *et al.*, 2015). However, milk in the informal sector is not necessarily unsafe just as milk in the formal sector is not necessarily safe (Alonso *et al.*, 2018). A study by Omore *et al*. (2004) found that in Kenya, packaged milk in supermarkets was no better at meeting the milk quality and safety standards than raw milk sold in kiosks and door-to-door.

2.7.1. Compositional Milk Quality

Milk is a complex biological fluid secreted in the mammary glands of mammals. Its function is to meet the nutritional needs of neonates of the species from which the milk is derived (UNIDO, 2015). The general composition of milk is as shown in Table 1.

Table 1: Typical composition of bovine milk is as shown in the table below (UNIDO, 2015):

Attribute	**Average (%)**	**Range (%)**
Water	87.3	85.5 – 88.7
Fat	3.9	2.4 – 5.5
Protein	3.25	3.2 – 3.5
Carbohydrate (mainly lactose)	4.6	4.5 – 4.9
Ash	0.65	0.6 – 0.7

It is important to note that the exact composition of bovine milk varies with individual animals, the breed, season, diet and phase of lactation. Milk produced in the first days post parturition is called colostrum which is high in protein and immunoglobulin but is not allowed to enter the food supply chain (UNIDO, 2015).

Over the years, farmers have been found to adulterate their milk with water, margarine, hydrogen peroxide and other substances which is considered illegal as it changes the composition of the milk. This is due to the fact that farmers are paid on the basis of the milk volume rather that the quality of milk (Koge *et al.*, 2018).

The most common form adulteration is addition of water to the milk and this is known as 'economic adulteration' (Das, *et al*., 2016). It is mostly done by suppliers so as to increase milk volume. This results in dilution of the milk thus lowering the nutritional value of the milk (Das *et al*., 2016). In addition, there is introduction of bacteria when contaminated water is used causing serious health problems upon consumption of the milk (Azad and Ahmed, 2016). Addition of water further changes the specific gravity of the milk and it losses its natural colour (Das *et al*., 2016). The scientific instrument used to measure the specific gravity of milk is a lactometer which shows if there is any water that has been added to the milk (Das *et al*., 2016).

Mostly, to compensate for the change in the specific gravity, farmer and traders have been found to add starch, salt and sugar so as to increase the solids non- fat content (Azad and Ahmed, 2016). Presence of too much starch in the milk can result to diarrhoea caused by the effects of starch that is not digested in the colon; also, diabetic patients will experience serious complications when there is accumulation of starch in the body (Singuluri & Sukumaran, 2014).

Milk fat is pretty costly hence some farmers or traders will remove the fat from the milk and instead add non-milk fat such as vegetable oil and margarine for additional financial gain (Azad and Ahmed, 2016). To dissolve and emulsify the oil in water resulting to a frothy solution which is considered a good milk attribute, detergents are usually added (Singuluri & Sukumaran, 2014). This can result in gastritis and inflammation of the intestine or lead to other gastro-intestinal complications (Azad and Ahmed, 2016). Legislation and regulations have been put in place to monitor milk adulteration. However, with the informal sector dominating the marketing of milk in Kenya, monitoring becomes a challenge (FAO, 2011).

2.7.2. Microbial Safety of Milk

The milk found marketed in the formal and informal sectors in Kenya often do not meet the set microbial standards which poses a health hazard (Alonso *et al.*, 2018). However, since most consumers tend to subject the milk to heating usually at boiling temperatures, it reduces susceptibility to disease (Lindahl *et al.*, 2018).

Milk and dairy products are enriched with nutrients making them a good environment for micro-organisms to grow. This includes both spoilage and pathogenic micro-organisms (FAO, 2013). Milk that is contaminated with bacteria not only does it spoil very fast but also some bacteria may be potential causes of food-borne diseases in humans when milk is consumed (Gwandu *et al.*, 2018). Bacteria may get into the milk from the primary source where the animal is infected as with the case of mastitis or the more common source of bacterial contamination is through the unhygienic milk production chain (Gwandu *et al.*, 2018).

Milk from the udder of a healthy cow contains a very low microbial count hence the bacteriological quality of the milk upon milking is usually good (Boor *et al.*, 2017). Furthermore, there is an inhibitory system naturally found in the milk which for the first three to four hours after milking at ambient temperature significantly reduces the number of micro-organisms (Jay *et al*., 2005). Contamination of milk can occur from several sources once the milk has been secreted from the udder. This includes: soil, water, beddings, faeces, milking equipment and the workers (FAO, 2013). It is important to note that, a number of factors will influence the prevalence of pathogens in milk. They include: the number of heads of cattle on the farm, the size of the farm, health of the dairy herd, hygiene level on the farm and its surroundings, practices on the management of the farm, geographic location of the farm and the season (Reta *et al*., 2015).

Studies show that up to 90 per cent of all dairy-related diseases are due to these pathogenic bacteria: *Brucella abortus, Escherichia coli, Mycobacterium bovis, Campylobacter jejuni, Salmonella spp, Clostridium botulinum, Listeria monocytogens and Staphylococcus aureus* (Donkor, *et al*., 2010, Fox and Cogan, 2010). *L. monocytogens* is widespread in the environment and lives in plants and soil hence contaminates the milk through the external environment (Oliver *et al*., 2005). It is vital to consider that the bacteria can multiply even in refrigeration temperatures (FAO, 2013) hence it is of significant public health concern since its infection can result to spontaneous abortion in pregnant women or still birth (FAO and WHO, 2004). *Staphylococcus aureus* is heat labile and it does not compete well with other micro-organisms. *S. aureus* contamination usually happens after boiling the milk when there is little competition with other micro-organisms (Doyle *et al.*, 2015).

2.7.3. Milk Quality and Safety Requirements

The dairy industry has recognized that low safety and quality of milk and milk products has negative health and economic consequences and can reduce demand across emerging markets (UNIDO, 2015). In order to produce safe and good quality milk, all actors along the dairy value chain have an important role to play. These actors include: input providers who have to comply with standards such as producing aflatoxin free feeds (Lemma *et al.*, 2018). Farmers who need to source inputs from approved suppliers and improve animal husbandry and hygiene during milking (FAO, 2013). Co-operatives who need to minimize the time they take for collection, install cooling facilities, build laboratory facilities where milk testing could be carried out and train milk graders (Martínez *et al.*, 2017). Processors need to invest in laboratory facilities as well as staff training and offering extension services (Alonso and Grace, 2018). Finally, the regulators who need to enforce quality standards all through the dairy chain (UNIDO, 2015). It is important to note that until recently, small scale traders have been involved in programs that are aimed at upgrading their businesses to formal frameworks. Of significance is the management of safety and quality aspects in milk businesses with training programs being introduced to develop the capacity of the traders and milk handlers on the importance of maintaining the quality and safety of milk and milk products (UNIDO, 2015).

CHAPTER THREE:

ASSESSMENT OF KNOWLEDGE AND HYGIENIC HANDLING PRACTICES OF DAIRY FARMERS IN BOMET, NAKURU AND NYERI COUNTIES IN KENYA

3.1. ABSTRACT

Small holder dairy farmers dominate the dairy sector in Bomet, Nakuru and Nyeri counties in Kenya. Most of them supply milk to processors in the counties however; there have been increasing quality and safety concerns about milk supplied by small holder farmers in Kenya. Milk quality and safety begins at the farm level. This study was therefore conducted to assess knowledge and hygienic handling practices by farmers in these counties. Semi- structured questionnaires were administered to the farmers coupled with direct observation of practices. Data was statistically analysed using SPSS and level of association assessed using Chi Square test. It was observed that most of the farmers did not employ the necessary hygienic practices during milking or in milk handling. For instance, 56% of farmers in Nakuru used plastic buckets and containers for milking and storage of milk, 90% of farmers in Nyeri used a reusable cloth to clean udders, 67% of farmers in Bomet used water without soap to clean hands before milking. Farmers in the counties had moderate knowledge on milk quality where 59% of farmers in Nyeri thought that it was okay to feed spoilt feed to cows and about 84% of farmers in Nakuru could detect mastitis in cows. It was further observed that farmers used untreated insufficient water to clean hands, udders and milking equipment, they did not set aside cows with mastitis and took more than thirty minutes to deliver milk to the processors. Efficient extension services are required to strengthen farmers' awareness on good hygiene practices and proper infrastructure is also recommended to reduce the long delivery time of milk.

3.2. INTRODUCTION

Kenya's dairy sector has a significant socio-economic role in the national economy. It is a source of livelihood and nutrition for many, generating about 4% of the national GDP and has been ranked among the largest in sub-Saharan Africa (KDB, 2020). Dairy production in Kenya is mainly practised in the highlands and is mostly intensive or semi-intensive farming (Bonilla *et al.,* 2017). The dairy herd in Kenya comprises of an estimated 3.3 million head of pure-bred Fresian-Holstein, Ayshire, Guernsey, Jersey and other crosses which produce over 3 billion litres of milk per year (TEGEMEO INSTITUTE, 2016).

As many other countries in Africa, milk production in Kenya is highly dependent on smallholder dairy farmers. There are more than one million small holder dairy farmers in Kenya who dominate the dairy industry accounting for around 95% of the total milk produced (KDB, 2020). The smallholder farmers mainly practice intensive or semi-intensive dairy farming with herds of about 2-5 cows each yielding an average of 5kgs of milk per cow per day. These cows are fed using crops from the farm hence interdependency between the crops and the livestock (Odero-Waitituh, 2017). Despite the fact that a large proportion of cattle in the small holder dairy farming are cross breeds of good genetic make-up, there are several challenges that drag this sector behind including: inefficient level of feeding which affects the quantity of milk produced, diseases like East Coat Fever (ECF) which affect the cattle and poor road networks which results to delay in delivery of milk (Tegemeo Institute, 2016).

Milk from smallholder farmers is marketed both in the formal and informal sectors (Brown *et al.,* 2018). However, over the years, there have been major quality and safety concerns about the milk supplied by smallholder farmers (Alonso *et al.*, 2018). Cases of adulteration of milk, high microbial counts, high somatic cell counts, presence of antibiotic residues and contamination of milk with aflatoxin M1 among others, have been increasing at an alarming rate (Ndungu *et al.*, 2016; Alonso *et al.*, 2018; Wanjala, 2018). Health risks have become issues of concern due to the large amount of milk that is marketed unprocessed and due to weak monitoring of the market (Alonso and Grace, 2018).

Milk quality and safety begins at the farm level. Several studies have shown that contamination of milk mostly begins at the production level and increases along the chain (SNV, 2017). Contamination of raw milk may be from the environment and/or infected cows (Kashongwe *et al.*, 2017). Raw milk contamination may also occur as a result of poor farm practices, improper hygiene and handling practices on farm, during transport and at the cooperatives or bulking points (Kamana *et al.*, 2017). Dairy farmers should ensure good farm management activities for the production of clean and hygienic milk considering that the quality of raw milk will influence the quality of dairy products after processing (Murphy *et al.*, 2016). This includes: feeding good quality feeds and clean water to cows, cleaning sheds and disposing off the dung, proper cleaning of udders before milking and setting aside sick cows to avoid infection (Maleko *et al.,* 2018). Furthermore, equipment used for milking, storage and transportation are the main sources of milk contamination with microorganisms (SNV, 2017). Milk cans, buckets and cloths used to clean the udder are frequent sources of milk contamination. It is therefore important that all product-contact surfaces, equipment and utensils are cleaned immediately before and after use (Doyle *et al.*, 2015). The use of plastics is not recommended for milk storage for they are difficult to clean thus harbouring spoilage and pathogenic bacteria (Ndungu *et al.*, 2016). Proper storage of milk in cases where arrival of milk to the cooperatives or processors takes longer than two hours should be considered. Cooling of the milk is necessary in such cases to avoid rapid multiplication of bacteria (SNV, 2017). Milk is highly perishable therefore producers must ensure proper handling during transport and fast transportation to the cooperatives or processors to minimize losses due to spoilage or spillage (KDB, 2020).

Bomet, Nakuru and Nyeri counties are among the highest milk producing areas in Kenya (KDB, 2020). The counties have large numbers of smallholder dairy farmers some of whom supply milk to processors in the counties which eventually reaches consumers throughout the country or is exported. It is therefore important to assess the handling and hygiene practices of milk by these farmers and further assess their knowledge on the handling practices of dairy cows and milk at the farm. The outcome of this study is expected to provide information on knowledge and hygiene practices which will be useful in developing mitigation measures to curb milk quality and safety issues at the farm level.

3.3. MATERIALS AND METHODS

3.3.1. Study Site

The study was carried out in Bomet, Nakuru and Nyeri counties in Kenya. These areas were chosen because according to the Kenya Dairy Board, these are among the highest milk producing counties in Kenya (KDB, 2020). The counties have large numbers of small holder dairy farmers, transporters or middlemen and several licensed cooperatives where bulking of the milk is done. Moreover, the counties have processors both medium sized dairies and industrial dairies, most of whom have been in the industry for many years and have a high processing capacity of up to 9,000 litres and 800,000 litres per day for the medium sized and industrial dairies respectively. These processors source their milk from the small scale farmers in the counties. Furthermore, the counties have several collection channels of how the milk reaches the processors from the farmers which is of main focus in this study.

3.3.1.1. Bomet County

Bomet County lies between latitudes 0^{o} 29' and 1^{o} 03' south and between longitudes 35^{o} 05' and 35^{o} 35' east. It borders four counties: Kericho to the north, Nyamira to the west, Narok to the south and Nakuru to the north-east (Figure 3). It has an estimated population of over

950,000 where 50.3 per cent are women and 49.7 per cent men (KNBS, 2020). Agriculture is the main economic activity of the county with tea farming and dairy production leading in the sector. Dairy farming contributes a large percentage of household incomes with the county recording a total of 397, 000 litres of milk daily. Dairy farmers sell their milk to processors including NKCC, Brookside, and Daima dairies among others (CGOB, 2020).

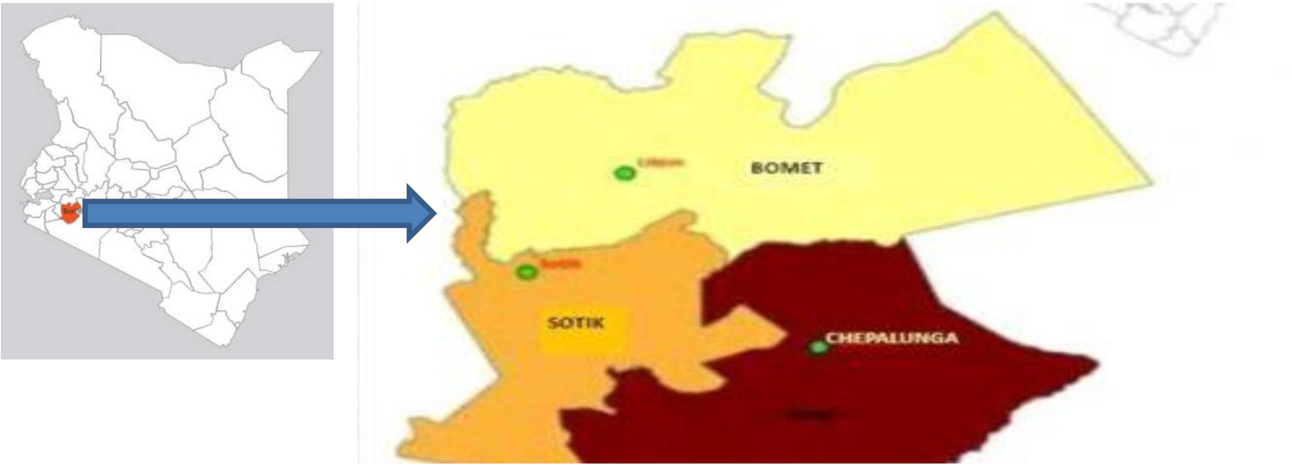


Figure 3: Map of Kenya showing Bomet County. Source: Kenya County Guide, 2018

3.3.1.2. Nakuru County

Nakuru County lies between latitude 0^{o} 18' south and between longitudes 36^{0} 48' east. It borders seven counties: Laikipia to the north east, Kericho to the west, Narok to the south west, Kajiado to the south, Baringo to the north, Nyandarua to the east and Bomet to the west (Figure 4). Nakuru has a population of over 1.5 million where 50.2 per cent are male and 49.8 per cent female (KNBS, 2020). Agriculture is the mainstay of the County with large-scale farming, horticulture and dairy farming dominating the sector. The county has about 381,600 dairy cattle head which produced around 298 million litres of milk in 2019. There are numerous manufacturing industries in the county including milk processing plants and several milk cooling plants (CGON, 2020).

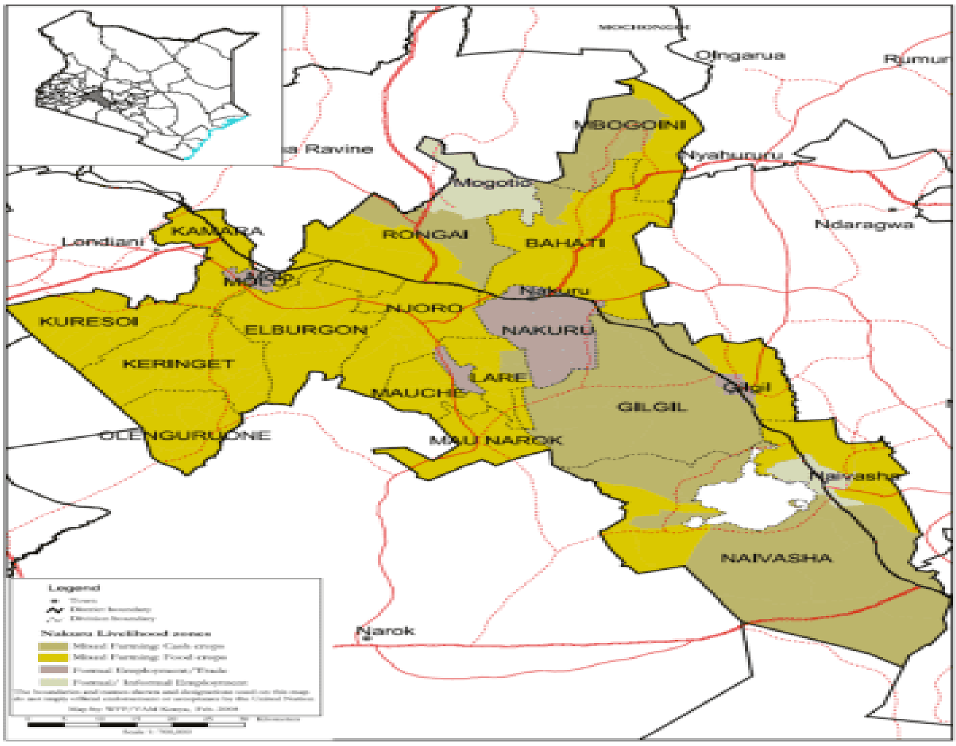


Figure 4: **Map of Kenya showing Nakuru County. Source: Kenya County Guide, 2018**

3.3.1.3. Nyeri County

Nyeri County lies between latitudes 0° 25' 12.47" North and between longitude 36° 56' 51.32" East. It borders five counties: Kirinyaga and Meru to the east, Laikipia to the north, Nyandarua to the west and Murang'a to the south (Figure 5). It has a population of about 693,000 where 51.2 per cent are female and 48.8 per cent male (KNBS, 2020). Agriculture is the main economic activity of the County with tea, coffee and dairy farming dominating the sector. The county has over 169,000 dairy cows with about 80 per cent of the households keeping at least one cow and has 25 milk cooperatives which farmers use to bulk and market their milk (CGONY, 2019).

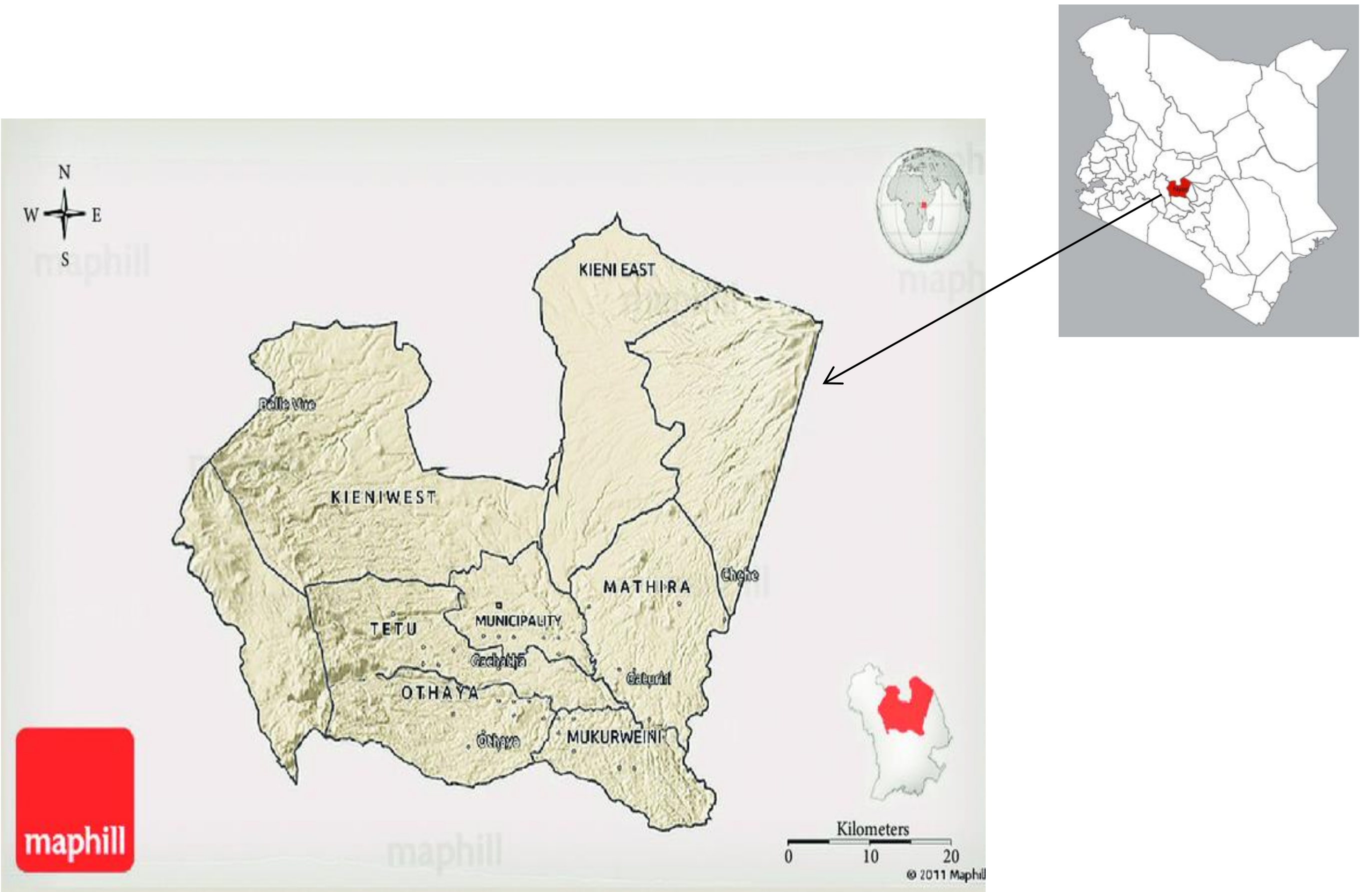


Figure 5: Map showing Nyeri County. Source: Google Maps, 2021

3.3.2. Study Design

Cross-sectional questionnaire-based study was used from July 2019 to December 2019 across the smallholder dairy farms in the study area for the household survey.

3.3.3. Sampling Procedure

Inclusion and exclusion criteria were used in the sampling procedure where in each of the three counties one processor who was the main supplier of formal milk was selected. The target population for household survey were dairy farmers who supplied milk directly to the selected processors in the three counties in 2018. A list of these farmers was obtained from each processor and exhaustive sampling (selecting the population since it was small) was done. There were 27 respondents from Bomet County, 23 from Nakuru and 23 from Nyeri giving a total of 73 respondents.

3.3.4. Interviews of direct suppliers of milk in the counties

A pre-tested semi- structured questionnaire was administered to farmers to assess knowledge on hygiene and practices regarding milk hygiene and handling. In addition, direct observations were carried out at the farms on farm hygiene, cows, milking equipment and personnel (Appendix C5).

3.3.5. Ethical Considerations

Local chiefs in each sub-location where the study was carried out in the counties were consulted before beginning the household survey. Interviews were done only from farmers who consented and farmers were assured of the confidentiality of the data obtained since individual names are not included in the results. Further, only sample data and aggregated values are reported.

3.3.6. Data Analysis

Data was analysed using descriptive statistics where Statistical Package for the Social Sciences (SPSS) version 22 (SPSS Inc., Chicago IL, USA) was used to depict the implementation of the code of hygienic practices. Significant differences in Sociodemographic characteristics, knowledge and hygiene practices in the various counties were tested using one way ANOVA at 95% confidence interval. Associations between sociodemographic characteristics with knowledge and hygiene practices in the various milk sheds were tested using Chi^2.

3.4. RESULTS

3.4.1. Sociodemographic characteristics of the Respondents

The sociodemographic characteristics of the direct suppliers are as represented in Table 2. . There was no significant difference ($p > 0.05$) in gender, age of respondents in all categories, marital status in terms of being married or living with spouse and level of education of respondents at the elementary and middle school level hence the populations were comparable in the three counties. However, there was a significant difference ($p < 0.05$) in type of farming practised in the counties where most of the farmers (92.3%) in Bomet practiced semi-intensive farming while 83.3% and 100% of farmers in Nakuru and Nyeri respectively practised intensive farming.

Table 2: Sociodemographic Characteristics (percent respondents) of direct suppliers in Bomet, Nakuru and Nyeri Counties

Characteristic	**Bomet**	**Nakuru**	**Nyeri**	**Total**
Gender				
Male	61.5	44.4	65.4	57.5
Female	38.5	55.6	34.6	42.5
Age (years)				
18-35	26.9	27.8	11.5	22.1
35-50	42.3	38.9	38.5	39.9
>50	34.6	33.3	50.0	38.0
Education level				
No formal education	3.8	22.2	0.0	8.2
Elementary	30.8	38.9	50.0	39.7
Middle school	50.0	38.9	19.2	37.0
High school	11.5	0.0	30.8	15.1
University	0.0	0.0	0.0	0.0
Marital status				
Married	80.8	77.8	73.1	76.7
Single	19.2	0.0	11.5	12.3
Divorced	0.0	0.0	3.8	1.4
Widow/er	0.0	22.2	11.5	9.6
Farm system				
Intensive	7.7	83.3	100	60.3
Semi-intensive	92.3	16.7	0.0	39.7

3.4.2. Milking methods and Milking Hygiene Practices

Different milking methods and milking hygiene practices were observed as shown in Table 3. There was no significant difference ($p > 0.05$) in the type of milking done by farmers in the counties where most of them used hand or manual milking. The frequency of milking did not vary significantly ($p > 0.05$) in the counties where a large percentage of farmers milked the cows twice a day. There was a significant difference ($p < 0.05$) in the sources of water in the counties where 50.2% and 46.5% of farmers in Bomet and Nakuru respectively sourced water from wells while 80.2% of farmers in Nyeri had tap/ piped water. Washing hands before milking did not vary significantly ($p > 0.05$) in the counties where 67.3%, 82% and 58.2% of farmers in Bomet, Nakuru and Nyeri respectively used water without soap. Cleaning of the udders did not vary significantly ($p > 0.05$) in the counties where most farmers in the counties used warm water to clean the teats while none of the farmers used water with soap to clean the teats. Method of cleaning of the udders varied significantly ($p < 0.05$) in the three counties where almost half (43.5%) of the farmers in Bomet used their hands to clean the udders while most of the farmers in Nakuru and Nyeri used a cleaning cloth to clean the udders. There was no significant difference ($p > 0.05$) in the applying of pre-milking products in the counties where most farmers used lubricants before milking. Fore stripping each quarter before milking did not vary significantly ($p > 0.05$) in the counties where half (50%) of farmers in Bomet and 69.9% of farmers in Nyeri fore stripped each quarter before milking while 62% of farmers in Nakuru did not fore strip each quarter before milking. There was no significant difference ($p > 0.05$) in teat dipping in the counties where most (70.7% and 79%) farmers in Bomet and Nakuru respectively did not practice teat dipping while 50% of farmers in Nyeri practiced teat dipping.

Table 3a: Milking methods and Milking Hygiene Practices (percent respondents) of farmers in Bomet, Nakuru and Nyeri counties

County Practice	Bomet	Nakuru	Nyeri	Total
Type of milking				
Hand/ manual	99	100	97.3	98.6
Machine	1	0	2.7	1.4
Milking frequency				
Once a day	9.7	1.6	0	8.5
Twice a day	90.3	98.4	100	91.5
Thrice a day	0	0	0	0.0
Source of water				
Tap/ pipe	10.7	21.4	80.2	37.2
Well	50.2	46.5	11.3	36.0
River	39.1	32.1	8.5	26.8
Hand washing before milking				
Simply water	67.3	82	58.2	70.2
Water and soap	32.7	18	41.8	29.8

Table 3b: Milking methods and Milking Hygiene Practices (percent respondents) of farmers in Bomet, Nakuru and Nyeri counties

County **Practice**	**Bomet**	**Nakuru**	**Nyeri**	**Total**
Washing udder				
Cold water	20.7	4	2.2	9.1
Warm water	79.3	96	97.8	90.9
Cold water with soap	0	0	0	0.0
Warm water with soap	0	0	0	0.0
Use of cleaning cloth				
Individual cloth	0	0	0	0.0
Common cloth	56.5	100	89.7	82.4
No cloth used	43.5	0	10.3	17.6
Teat dipping				
Yes	29.3	21	50	33.3
No	70.7	79	50	66.7
Use of pre-milking product				
Yes	82	88	100	89.7
No	18	12	0	10.3
Fore strip each quarter before milking				
Yes	50	38	69.9	52.3
No	50	62	30.1	47.7

3.4.4. Milking Equipment and Milk Handling Practices

Figure 6 shows handling practices of milk and milking equipment as observed from farmers in the three milk sheds. There was a significant difference ($p < 0.05$) in type of milking can used by the farmers in the three counties where most of them used plastic containers for milking, storage and transportation of milk with Nakuru recording the highest number (55.6%). There was no significant difference ($p > 0.05$) in refrigeration of milk by farmers after milking; more than 95% of farmers in the three milk sheds did not refrigerate their milk during storage at home or during transportation to the processor. Time of delivery had no significant difference ($p > 0.05$) where more than 50% of farmers in all the milk sheds reported that it took more than thirty minutes for the milk to reach the cooler with some reporting even up to five hours. Cleaning of the sheds varied significantly ($p < 0.05$) where around 20%, 65% and 88% of farmers in Bomet, Nakuru and Nyeri respectively reported that they occasionally cleaned the sheds and disposed of the dung. There was a significant difference ($p < 0.05$) in the use of reusable cleaning cloths to clean udders where more than 50% of farmers in Bomet and Nyeri and all the farmers (100%) in Nakuru used a reusable cleaning cloth. There were cases of mastitis reported by farmers in the past one year and there was a significant difference ($p < 0.05$) in setting aside cows with mastitis in the counties with 100% of farmers in Nakuru and Nyeri reporting that they did not set aside cows that suffered from mastitis.

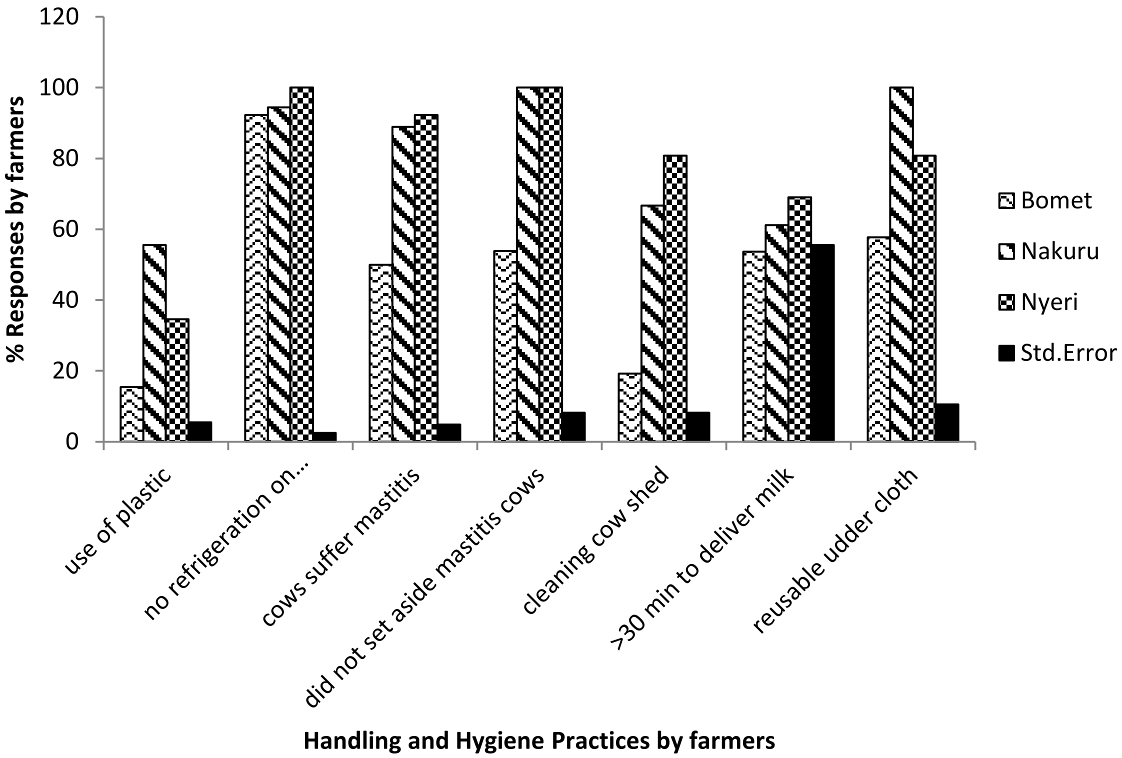


Figure 6: Milking Equipment and Milk Handling Practices by farmers in Bomet, Nakuru and Nyeri counties.

Various cleaning practices were observed as shown in Table 4. There was a significant difference ($p > 0.05$) in cleaning of containers in the three counties where 80% of farmers in Bomet always cleaned the milking containers and all of them used water and soap to clean. All the farmers in Nakuru always cleaned the milking containers with 68% using water and soap but none used water with disinfectant. All the farmers in Nyeri always cleaned the milking containers however; most of them (41.4%) used only water to clean the containers while 20.7% used water with disinfectants.

Table 4: Cleaning Practices by Farmers (percent respondents) in the Various Milk sheds

County	**Bomet**	**Nakuru**	**Nyeri**	**Total**
Hygienic practice				
Frequency of cleaning				
Milking containers				
Always	80.7	100	100	93.2
Most often	19.2	0.0	0.0	6.8
Cleaning udder				
Hand	42.3	0.0	9.2	17.8
Cleaning cloth	57.7	100	80.8	82.2
Cleaning containers				
Simply water	0	32	41.4	25.5
Water and soap	100	68	37.9	54.0
Water and Disinfectant	0	0	20.7	20.5

3.4.5. Knowledge on Hygiene and Handling Practices

It was found that farmers have a moderate level of proper knowledge on hygiene and handling practices as shown in Table 5. There was no significant difference ($p > 0.05$) on dangers of feeding spoilt feed to cows in the counties. Notably more than half (58.6%) of farmers in Nyeri said that it was okay to feed spoilt feed to cows which would be an issue of concern on milk quality. There was no significant difference ($p > 0.05$) in hygienic milking and delivering milk promptly as ways of ensuring milk did not spoil in the three counties. There was also no significant difference ($p > 0.05$) in knowledge of mastitis. Most farmers in the counties knew the disease and could detect it in cows. There was a significant difference

($p < 0.05$) in adulteration and density as causes of milk rejection in the three counties. Most farmers (34.6%) in Bomet thought that milk adulteration would lead to rejection on delivery while 44.5% and 41.3% in Nakuru and Nyeri respectively thought that addition of water to alter the density would lead to milk rejection on delivery.

Table 5: Knowledge on hygiene and handling practices by farmers (percent respondents) in the studied counties

County	**Bomet**	**Nakuru**	**Nyeri**	**Total**
Knowledge on hygiene				
Is it okay to feed spoilt feed to cows				
Yes	30.4	32.0	58.6	38.4
No	69.6	68.0	41.4	61.6
How do you ensure that milk does not get spoiled during storage				
Boiling	15.4	14.6	19.2	15.1
Cover container	7.6	19.7	42.3	23.3
Deliver promptly	34.6	5.9	15.4	19.2
Hygienic milking	3.8	17.6	3.8	8.2
Store in a cool place	15.4	5.9	3.8	8.2
Do Nothing	23.1	36.3	15.4	26.0
What are the causes of milk rejection on delivery				
Acidity	3.8	5.6	3.8	4.1
Organoleptic (smell, temperature, visible foreign particles)	17.3	5.6	3.8	9.6
Low density (water addition)	15.4	44.5	41.3	30.1
Adulteration (using other substances except water)	34.6	12.5	23.2	23.3
Others	11.5	11.5	12.5	17.8
Don’t know	17.3	9.2	15.4	15.1

Can you detect mastitis in cows				
Yes	95.7	84.0	86.2	89.0
No	4.3	16.0	13.8	11.0

3.4.6. Association between sociodemographic characteristics and hygiene practices in the counties

In Bomet, there was significant association (X^2 = 16.759, $p < 0.05$) between the level of education of the respondents and the type of milking can they used as shown in Table 6. Most of the illiterate respondents and those who went to elementary school used plastic containers more while those who attained middle school and high school education used aluminium cans more.

Table 6: Association between Sociodemographic characteristics and hygiene practices in the counties

Parameters	**County**	**X^2**	**p-value**
Level of Education and Type of Milking can used	Bomet	16.759	p=0.028
Type of Farming and Frequency of Cleaning Shed	Bomet	17.944	p=0.021
Gender and Cleaning of Containers	Nyeri	2.410	p=0.038
Level of Education and Knowledge on Causes of Milk Rejection	Nakuru	26.809	p=0.043

X^2 – Chi Square value

Additionally, in Bomet there was significant association (X^2 = 17.944, $p < 0.05$) between the type of farming practised by respondents and cleaning of the sheds. Those who practised intensive farming cleaned the sheds often compared to those who practised semi-intensive farming who rarely cleaned the sheds.

In Nyeri, there was significant association ($X^2 = 2.41$, $p < 0.05$) between the gender of the respondents and cleaning of milking containers where male respondents mostly used simply water to clean while female respondents used water and soap or disinfectants to clean containers.

There was significant association ($X^2 = 26.809$, $p < 0.05$) between the level of education of the respondents in Nakuru and their knowledge on causes of milk rejection on delivery. Respondents who were illiterate cited that they did not know the causes of rejection while those who had attained elementary, middle and high school education cited various causes including acidity and density.

3.5. DISCUSSION

Dairy farming in the counties were male dominated with the exception of Nakuru County where there were more (55.6%) female dairy farmers. This could be due to the higher number (22.2%) of widows in the county compared to 0% and 11.5% in Bomet and Nyeri respectively. The significant association ($p < 0.05$) between gender of the respondents and cleaning of milking containers in Nyeri shows that female respondents were more conscious on proper cleaning of the containers unlike their male counterparts.

There was significant association ($p < 0.05$) between the level of education of the respondents and the type of milking can they used in Bomet. Similarly, there was significant association ($p < 0.05$) between the level of education of the respondents and their knowledge on causes of milk rejection on delivery in Nakuru. This indicates that more intervention is required in regards to training of the farmers and offering them extension services to improve their knowledge on good hygiene practices.

Most (92.3%) farmers in Bomet practised semi-intensive dairy farming where cows were allowed to graze in the fields during the day and housed in stalls at night. This could be due to larger sizes of land in the area compared to the small land sizes in Nakuru and Nyeri where population is higher causing farmers to practice intensive dairy farming. Farmers in Bomet further housed their animals in open kraals and this was also due to the semi-intensive farming system done in the area unlike in Nyeri and Nakuru where cows were housed in stables with roofs for farmers practiced intensive dairy farming.

Farmers in the three counties mainly milked their cows manually or by hand owing to the fact that they were small scale farmers who kept around 2-5 cows. Milking was mainly done twice a day in the counties where the morning milk was delivered to the processor while the evening milk was consumed at home, sold to neighbours and the surplus mixed with the morning milk from the following day and delivered to the processors. This disagrees with a study by (Knight-jones *et al.*, 2016) who observed that farmers in Western Zambia milked their cows only once per day and usually at midday. This could be due to the differences in breeds of the cows where in Zambia farmers mainly kept indigenous breeds which produce less milk compared to the exotic breeds in this study.

Water plays an important role in a dairy farm (Reta and Addis, 2015). It is given to cows for drinking, used to clean hands, udder and milking equipment. Farmers in Bomet and Nakuru mainly sourced water from wells and from rivers especially in the dry season. Most (80.2%) farmers in Nyeri had access to tap water which they used to feed the cows and for cleaning purposes. It was observed that much of the water from the wells and rivers was untreated before use which could be a major source of contamination (Boor *et al.*, 2017).

Hand washing before milking and cleaning of milking equipment was insufficiently done in the counties. Use of cold water without soap to wash hands and cold water with soap to clean milking equipment was rampant in the counties practices which do not guarantee efficient cleaning. Furthermore, most (>70%) farmers used warm water to clean the udders before milking however none (0%) used water with soap to clean the udders. All these practices could be attributed to the rush done during milking as observed at the farms. Farmers had other chores and farm work to do hence milking was a rushed affair causing them to miss or ignore the important cleaning steps before milking. This agrees with a study by (Kebede and Megerrsa, 2017) in Ethiopia who observed that 40% of the farmers used cold water with soap to clean milking equipment which they thought efficient. It was further observed that most farmers used insufficient water to clean their hands, udders and milking equipment in the three counties. This could be due to shortage of water especially during the dry season where farmers had to walk long distances to fetch water. Ndungu *et al.*, (2016) observed in an earlier study that farmers in Nakuru and Nyandarua counties in Kenya practised insufficient cleaning of hands and equipment during milking which was mainly attributed to water shortage. Improper cleaning, use of water without heat treatment and absence of disinfectants fastens the growth of heat resistant micro-organisms leading to high microbial counts in milk (Doyle, 2015).

None (0%) of the farmers in the counties had an individual cloth for cleaning the udders. It was observed that farmers used the same cloth to clean milk equipment, wipe hands before milking and clean udders of different cows before milking. It was also noted that most farmers rarely changed the cloth in a year. This disagrees with a study by (Kebede and Megerrsa, 2017) in Ethiopia where 74% of farmers in Addis used individual towels to clean udders and wipe hands and equipment. This could be due to higher level of awareness of farmers in the study who employed modern milking practices. Cleaning cloths can be a source of milk contamination especially when they are not properly cleaned or changed often and could contribute to transfer of mastitis between cows (Orregård, 2013; Wanjala *et al.,* 2018) .

Most farmers used pre-milking products which ranged from those that act as disinfectants, those that provide barrier effect or lubricants and those that act as both disinfectants and lubricants. However, it was observed that farmers rarely practiced teat dipping to disinfect the udders a practice which prevents mastitis infection in cows (SNV, 2017). This could be attributed to the fact that teat dips are an added expense for these small scale farmers or they lacked awareness on the importance of teat dipping.

Farmers in Bomet and Nakuru and Nyeri rarely practised fore -stripping of each quarter before milking. This is also explained by the fact that farmers rushed the milking process due to other chores around the house and farm thus skipping important steps that influence milk quality. This agrees with (Kebede and Megerrsa, 2017) who did a study in Ethiopia and observed that 58% of farmers did not do fore-stripping of the udders before milking mostly because they ignored the step. Fore stripping each quarter before milking is important for observation of mastitis a common disease in dairy cows. Mastitis milk has high somatic cell count and is associated with other spoilage and pathogenic microorganisms hence unfit for consumption or processing (Kashongwe *et al.*, 2017).

Use of plastic buckets for milking and plastic containers for storage and transportation of milk in the counties was rampant owing to their availability and convenience. Lack of basic training on the importance of using aluminium cans and lack of funds to purchase aluminium cans which cost more than plastic containers could have contributed to increased use of plastic containers. This agrees with a study done by (Ndungu *et al.*, 2016) who observed that 90% and 49% of farmers in Nakuru and Nyandarua counties respectively used plastic containers for transportation of milk. Plastic containers are difficult to clean especially around the handles which are difficult to reach thus contributing to milk contamination (Knight-jones *et al.,* 2016). Aluminium cans have been found to be more appropriate for storage and transportation of milk for they are easy to clean and do not adhere to dirt (Orregård, 2013).

The level of awareness about mastitis by farmers was good in the three counties. Farmers could identify mastitis in cows and some reported cases of mastitis in the past year. However, most of them did not set aside the affected cows. Setting aside cows with mastitis involves discarding milk from the infected cows which most farmers view as losses. Mastitis infection in cows contributes to high microbial counts in milk especially *Staphylococcus aureus* (Orregård, 2013). Farmers are encouraged to practice hygienic milking practices and set aside cows with mastitis to avoid infection transfer between cows (FAO, 2015).

Farmers in Bomet rarely cleaned the sheds compared to farmers in Nyeri and Nakuru. This could be due to the semi-intensive farming practiced in Bomet where cows spent the day grazing thus reducing the amount of dung in the sheds unlike in Nakuru and Nyeri where cows were housed day and night. Mud and dung from the shed stick to the udders which if not properly cleaned before milking, become a source of milk contamination (Gemechu *et al*., 2015).

Farmers held their milk at the farm without refrigeration after milking to attend to other chores. Lack of electricity in some of the places or lack of funds to purchase refrigerators could be reasons why most farmers in the three counties did not refrigerate their milk. Moreover, most farmers spent more than thirty minutes to deliver milk to the processors with poor infrastructure and long distances to the processors contributing to the long time it took to deliver the milk. The cost of hiring transporters was high resulting to farmers opting to deliver the milk themselves. This long transportation time without cooling encourages rapid multiplication of bacteria before milk reaches the processor especially in warm tropical weather (Wallace, 2015). This agrees with a study done by (Ndungu *et al.*, 2016) who observed that more than 70% of farmers in Nakuru and Nyandarua counties spent more than thirty minutes to deliver milk to the cooperatives or the processor due to long holding time and poor infrastructure especially during the wet seasons.

Farmers' awareness on feeding spoilt feed to cows was low in the counties. Small scale farmers mainly use crops from their fields to feed cows where mostly the spoilt discarded feeds are given to the cows (Odero-Waitituh, 2017). Most farmers cited that delivering milk promptly, hygienic milking and covering containers were some of the ways of ensuring the milk did not spoil on storage. Farmers were further aware about the causes of milk rejection on delivery mostly because they had been informed by the processors or they might have experienced rejection of their milk.

3.6. CONCLUSION

Based on the findings of this study, farmers in the three milk sheds did not employ good hygienic practices in dairy management. Milking was done without taking into consideration measures to ensure quality where farmers used plastic buckets for milking and storage of milk; they rarely cleaned the sheds and cleaned udders with a reusable cloth. Measures to prevent mastitis in cows like teat dipping were not observed and in cases where mastitis occurred, farmers did not set aside infected cows. The long holding and delivery time without cooling further compromises milk quality before it reaches the processors. Consistent training on good farm management and hygienic handling practices is necessary. Proper infrastructure will also enable farmers to deliver milk promptly thus lowering chances of contamination.

CHAPTER FOUR:

MICROBIAL QUALITY OF MILK SUPPLIED BY SMALL-HOLDER FARMERS TO PROCESSORS IN SELECTED COUNTIES IN KENYA

4.1. ABSTRACT

Microbial contamination of milk reduces its nutritional quality and poses a health risk to consumers due to presence and growth of spoilage and pathogenic microorganisms. Microbial contamination of milk is therefore an important factor in determining the safety and quality of milk and dairy products. This study focused on several microbial parameters which are hygiene indicator microorganisms. Total viable counts, *E. coli* and *S. aureus* are used as hygienic parameters for milk production, milking and milk handling conditions. *L. monocytogenes* was added due to its presence in the environment and its ability to survive low temperatures. A total of 92 samples were collected from the three milk sheds along collection channels: direct suppliers, transporters and cooperatives. Microbial analysis was carried out following standard procedures and data analysed using GenStat. Highest mean Total viable counts were from direct suppliers and first bulk milk samples at the cooperatives recording up to 8.54 and 9.44 $\log_{10}$ cfu/ ml respectively. Highest mean *S. aureus* counts were from cooperatives ranging between 5.29 and 6.3 $\log_{10}$ cfu/ ml. *E. coli* counts were highest at cooperatives too with mean counts of up to 7.17 log cfu/ ml. *L. monocytogenes* highest counts were from after cooler and after transport milk samples from cooperatives where the mean counts ranged between 0 and 8.02 log cfu/ ml. The results showed that milk quality from the farmers was poor thus; constant training of farmers and cooperative personnel on hygienic practices and handling of milk is required coupled with proper road network and installation of instant coolers at the cooperatives to further reduce multiplication of bacteria.

4.2. INTRODUCTION

Kenya's dairy sector has a significant socio-economic role in the national economy. It is a source of livelihood and nutrition for many, generating about 4% of national GDP and has been ranked among the largest in sub-Saharan Africa (KDB, 2020). Small scale farmers dominate the dairy industry at production level (Bonilla *et al.*, 2018) where they produce over 95% of national milk produced (KDB, 2020). Dairy production in Kenya is mainly practiced in the highlands and is mostly intensive or semi-intensive farming (Bonilla *et al.*, 2018). Dairy herd in Kenya comprises of an estimated 3.3 million head of pure-bred Fresian-Holstein, Ayshire, Guernsey, Jersey and other crosses which produce over 3 billion liters of milk per year (TEGEMEO INSTITUTE, 2016).

Milk produced by small-scale dairy farmers is consumed both in urban and rural areas and is a necessity for most Kenyans (Alonso *et al.*, 2018). Milk has a relatively short shelf-life thus requires quick and efficient marketing to ensure optimum results (KDB, 2020). There has been great emphasis on organization of small-scale milk producers into groups such as self-help groups, cooperatives and companies in order to enhance efficiency in marketing of the raw milk with dairy cooperatives dominating the marketing of milk (KDB, 2020). Milk processing capacity in Kenya is also on a steady growth owing to the growing demand of milk and dairy products with new milk processors coming up in different counties who source milk from farmers within the community (KNBS, 2020).

As much as there is increased demand, processing and marketing of milk, there still remains a challenge of non-compliance to national, regional and international quality and safety standards (Bebe et al., 2018). This is mainly due to lack of efficient monitoring and proper enforcement structures in the country.

Milk marketed in the formal and informal sectors in Kenya often does not meet the set microbial standards, posing a health hazard (Knight-jones *et al.*, 2016). Milk and dairy products are rich in nutrients making them a good environment for growth of both spoilage and pathogenic micro-organisms (Alonso and Grace, 2018).

To reduce milk spoilage, more dairy cooperatives have been established where farmers bulk and cool their milk before it is marketed or transported to processors (Odero-Waitituh, 2017). There has also been an increase in the number of middlemen or traders who bulk milk from several farmers and transport it to the cooperatives or processors. While some have helped in ensuring efficiency of milk transportation most have brought more complication in traceability of milk (Bonilla *et al.*, 2018).

There is need to assess hygiene knowledge and handling practices of milk by farmers considering that milk contamination usually begins at production level and given that microbial safety of raw milk in Kenya from small-scale farmers has been a grave concern for decades (Knight-jones *et al.*, 2016; Alonso *et al.*, 2018; Brown *et al.*, 2018). Understanding the various socio-demographic characteristics of the respondents will provide additional knowledge on how they influence hygiene knowledge and handling practices of milk by farmers. Presence of middle-men or traders further complicates traceability of milk and brings a risk of cross-contamination and microbial overload due to poor milk handling by transporters, adulteration of milk and in some cases long transportation time without refrigeration (Vara Martínez *et al.*, 2017). There is also limited data on microbial quality of milk along collection channels despite the need for monitoring from production to consumption (Ndungu *et al.*, 2016).

The micro-organisms in this study were selected in order to obtain a clear picture on the status of milk safety supplied by small-holder farmers to processors in the selected counties.

High TVC values is an indication of raw milk that is not suitable for consumption which also indicates increased risk of presence of pathogenic microorganisms (Knight-jones *et al.*, 2016). *S. aureus* is a common source of food poisoning and it mostly enters the milk during handling by humans who are carriers of *S. aureus* hence it is an indicator of poor personal hygiene of the individuals handling milking and milk equipment (Tegegne and Tesfaye, 2017). Presence of *E. coli* indicates presence of other coliforms and is an indicator of feacal contamination thus poses great safety and public health concerns (Wallace, 2008). *L. monocytogenes* is commonly introduced into the milk from poorly preserved silage and the environment and it also has the ability to survive in low temperatures (Ulusoy and Chirkena, 2019).

4.3. MATERIALS AND METHODS

4.3.1. Study Site

The study was carried out in Bomet, Nakuru and Nyeri counties in Kenya. This is as described in section 3.3.1.

4.3.2. Study Design

The study adopted a cross-sectional design with laboratory analysis for milk microbial quality.

4.3.3. Sample Size

In each county one processor who was the main supplier of formal milk was selected. Samples for microbial quality were obtained from farmers who supplied milk directly to these processors (direct suppliers), traders and cooperatives who delivered milk to the processors. Exhaustive sampling was done for direct suppliers where 26 samples were from Bomet, 18 from Nakuru and 26 from Nyeri. Exhaustive sampling was also done for traders and cooperatives who supplied milk to the three processors. Three (3) samples from transporters in Nakuru were obtained. A total of 7 cooperatives were sampled: 2 in Bomet, 2 in Nakuru and 3 in Nyeri. Three (3) samples were obtained from each cooperative with coolers and 2 samples were obtained from each cooperative without coolers. A total of 92 samples were obtained: 32 from Bomet, 27 from Nakuru and 33 from Nyeri as shown in Table 7.

Table 7: Sampling distribution in the three milk sheds

County **No. of samples**	**Bomet**	**Nakuru**	**Nyeri**	**Total**
Direct Suppliers	26	18	26	70
Coop with cooler	6	6	3	15
Coop without cooler	0	0	4	4
Traders	0	3	0	3
Total	**32**	**27**	**33**	**92**

4.3.4. Sampling of Milk for Microbial Analysis

A total of 92 raw milk samples were collected from the three counties: 32 from Bomet, 33 from Nyeri and 27 from Nakuru. Milk samples were collected along four major channels:

a) farmers who supplied milk directly to processors (Direct Suppliers),
b) traders who bulked milk from several farmers and transported it to cooperatives,
c) Cooperatives which delivered bulked milk from farmers to processors using their own means of transportation
d) Cooperatives from which processors collected bulked milk using their own transportation tankers.

However, not all four channels were common in the three milk sheds as shown in Table 8. Bomet had direct suppliers, a cooperative (Coop 1) which delivered bulked milk using its own transportation means and a cooperative (Coop 2) from which the processor collected the bulked milk using its own tanker. Nakuru had direct suppliers, traders and cooperatives

(Coop 3 and 4) from which the processor collected the bulked milk using its own tanker. Nyeri had direct suppliers, a cooperative (Coop 5) which delivered bulked milk using its own transportation means and cooperatives (Coop 6 and 7) from which the processor collected the bulked milk using its own tanker.

Table 8: Type of channel in each milk shed

Type of channel **County**	**Direct suppliers**	**Traders**	**Coop delivers with own means**	**Processor collects**
Bomet	Present	None	Coop 1	Coop 2
Nakuru	Present	Present	None	Coop 3 and 4
Nyeri	Present	None	Coop 5	Coop 6 and 7

Raw milk samples from direct suppliers and traders were obtained at the platform before the milk was bulked. Each can or container from every farmer and transporter was stirred or shaken thoroughly before obtaining a 50 ml milk sample.

There were two types of cooperatives: those with coolers (Coop 1, 2, 3, 4 and 7) and those without (Coop 5 and 6). At the cooperatives with coolers, samples were obtained after bulking milk from several farmers before it was pumped to the cooler; this was labelled as First Bulk, after the cooler before the milk was pumped to the tanker; this was labelled as After Cooler and from the tanker after the milk was transported to the processor before it was off-loaded; this was labelled as After Transport. At the cooperatives which had no coolers, raw milk samples were collected after bulking the milk from several farmers – First Bulk and after transportation of the bulked milk to the processor – After Transport.

First bulk raw milk samples of 50ml were aseptically obtained after thorough stirring of the milk in the bulking tank, another 50 ml was aseptically obtained after thorough stirring of the milk in the cooler for the after cooler samples and finally, 50 ml samples were aseptically obtained after thorough stirring of the milk in the transportation tankers for the after transport samples.

Milk samples were tightly closed, labelled and immediately kept in a cool box. They were then transported to the University of Nairobi, Department of Food Science Nutrition and Technology laboratory where they were stored at 4 degrees Celsius and analysed within 24 hours.

4.3.5. Ethical Considerations

Processors and cooperatives personnel were consulted and involved in the planning process before collection of samples. Milk samples were obtained only from farmers who consented and farmers, cooperatives, transporters and processors were assured of the confidentiality of the data obtained.

4.3.6. Microbial Analyses

4.3.6.1. Sample Preparation

Serial dilutions were prepared according to ISO 6887-1 procedure (ISO, 1999). To obtain 15% Buffered peptone water (BPW), 15g of BPW powder was dissolved in 1litre of distilled water according to the manufacturer's instructions (OXOID® Ltd., Basingstoke, Hampshire, England) and sterilised in the autoclave. Samples were removed from cold storage and allowed for 30 minutes to attain room temperature. They were then thoroughly shaken and using a sterile pipette, 1ml of the sample was transferred into a sterile falcon tube containing 9 ml of BPW (10^{-1} dilution), which was followed by serial dilutions as shown in Figure 7. The procedure was repeated up to 10^{-7} dilution and in the last dilution 1ml of inoculum was discarded. The dilutions were mixed thoroughly before they were used to enumerate: TVC, *E. coli*, *S*, *aureus* and *L. monocytogenes*.

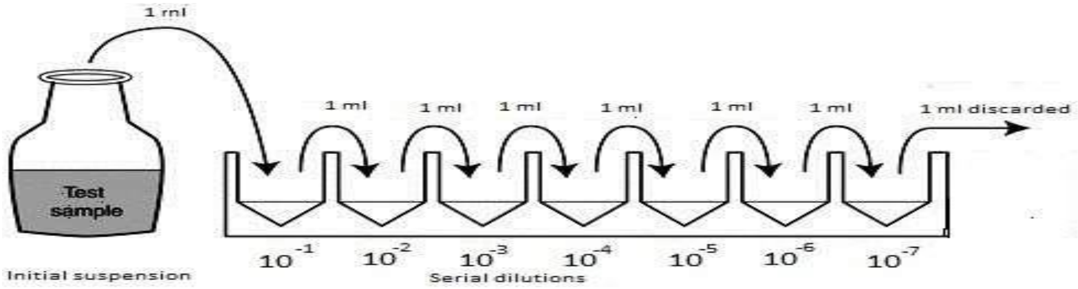


Figure 7: **Procedure adopted for serial dilution of samples**

4.3.6.2. Enumeration of Total Viable Counts

Total Viable Counts were enumerated as per ISO 4833 (ISO, 2001). Dilutions of 10^{-5} to 10^{-7} of homogenate samples were poured into sterile petri dishes in duplicate and sterile Standard Plate Count Agar was added. Plates were covered, gentle sufficient shaking was done and after drying they were inverted and incubated at 37 ^{0}C for 24 hours. A colony counter was used to count plates with colonies ranging from 30 to 300 which were expressed as colony forming units per ml of the sample (CFU/ml).

4.3.6.3. Enumeration of *Staphylococcus aureus*

Staphylococcus aureus was enumerated as per ISO 6888-1:1999 (ISO, 1999). Dilutions of 10^{-2} to 10^{-4} of homogenate samples were pipetted on the surface of previously dried Baird-Parker agar plates in duplicates and spread with a sterile bent glass rod. Plates were incubated at 37^{0}C for 24 hours. Enumeration was done using a colony counter where the colony forming units were expressed per ml of the sample (CFU/ml). The colonies were identified based on colour which was black and shiny, with narrow white margins, surrounded by clear zones extending into the opaque medium.

4.3.6.4. Enumeration of *Escherichia coli*

Escherichia coli were enumerated as per ISO 16649-2:2001 (ISO, 2001). Dilutions of 10^{-2} to 10^{-4} of homogenate samples were pipetted on to sterile plates in duplicates, sterile HiCrome agar was added and gentle sufficient shaking was done. After drying, plates were inverted and incubated at 37^{0}C for 24 hours. Enumeration was then done using a colony counter where colony forming units were expressed per ml of sample (CFU/ml) for colonies which had bluish green colour.

4.3.6.5. Enumeration of *Listeria monocytogens*

Listeria monocytogens was enumerated as per ISO 10560 (ISO, 2001). Dilutions of 10^{-2} to 10^{-4} of homogenate samples were pipetted onto the surface of dried Listeria chromogenic agar in duplicate and spread with a sterile bent glass rod. Plates were inverted and incubated at 37^{0}C for 24 hours. Enumeration was done using a colony counter for colony forming units on colonies which had blue to blue- green colour and expressed per ml of sample (CFU/ml).

4.3.7. Data analysis

Laboratory data was analysed using GenStat version 15 where mean differences were separated by the least significant difference procedure using Tukey's formula.

4.4. RESULTS

4.4.1. Microbial quality of milk as affected by Collection Channels

4.4.1.1. Microbial Quality of Milk from Bomet Milk shed

In the cooperatives channel, After Cooler milk samples from Coop 2 recorded the highest TVC (8.1 log cfu/ml) while After Cooler samples from Coop 1 had the lowest counts (6.8 log cfu/ml) as shown in Figure 8. There was however, no significant difference ($p > 0.05$) among the samples along the channel. The level of TVC from all the milk sheds exceeded the 6.3 log cfu/ ml set standards (EAC, 2018).

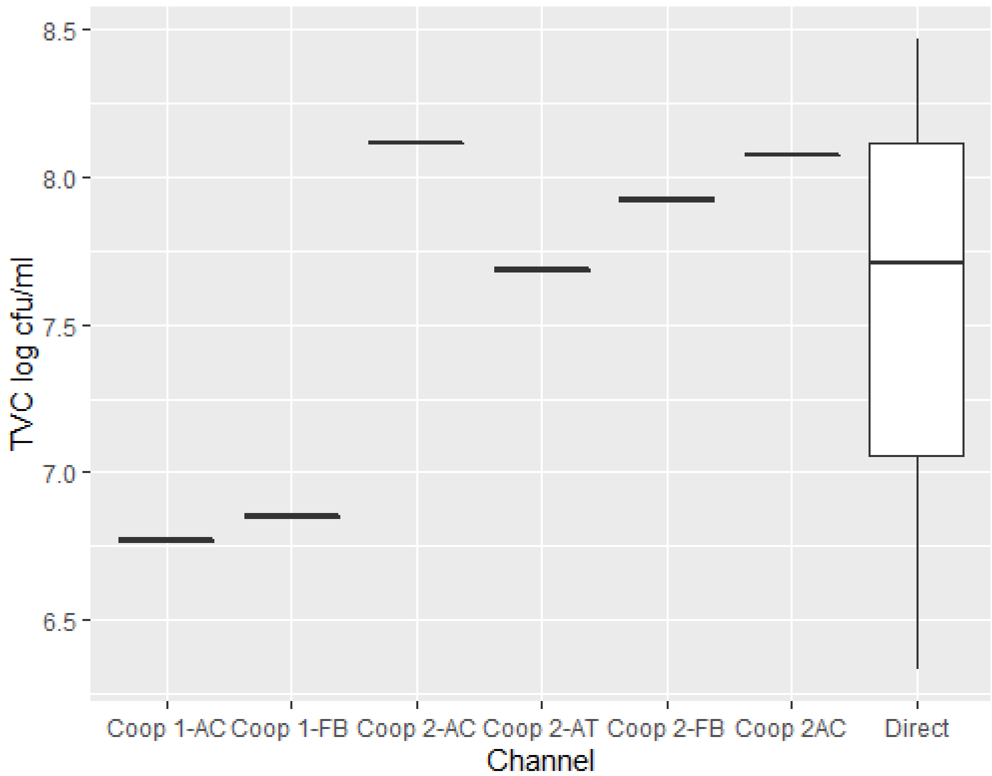


Figure 8: Distribution of Total Viable Counts in Milk, Bomet County

TVC	Total Viable Counts
Coop 1 –AC	Cooperative 1 After Cooler
Coop 1-FB	Cooperative 1 First Bulk
Coop 2-AT	Cooperative 2 After Transport
Coop 1 –AC	Cooperative 1 After Cooler
Coop 1-FB	Cooperative 1 First Bulk
Direct	Direct suppliers

Milk samples from direct suppliers in Bomet County had the highest *S. aureus* counts (5.3 log cfu/ml) while First Bulk milk sample from Coop 1 had the lowest counts (3.5 log cfu/ ml) as shown in Figure 9. There was a significant difference ($p < 0.05$) of the counts in milk samples supplied directly by farmers and those from Coop 1. However; there was no significant difference ($p > 0.05$) in milk samples supplied directly by farmers and those from

Coop 2. Apart from milk from First Bulk and After Cooler samples of Coop 1 which met the set standards of 4.7 log cfu/ ml (EAC, 2018), the rest exceeded the standards.

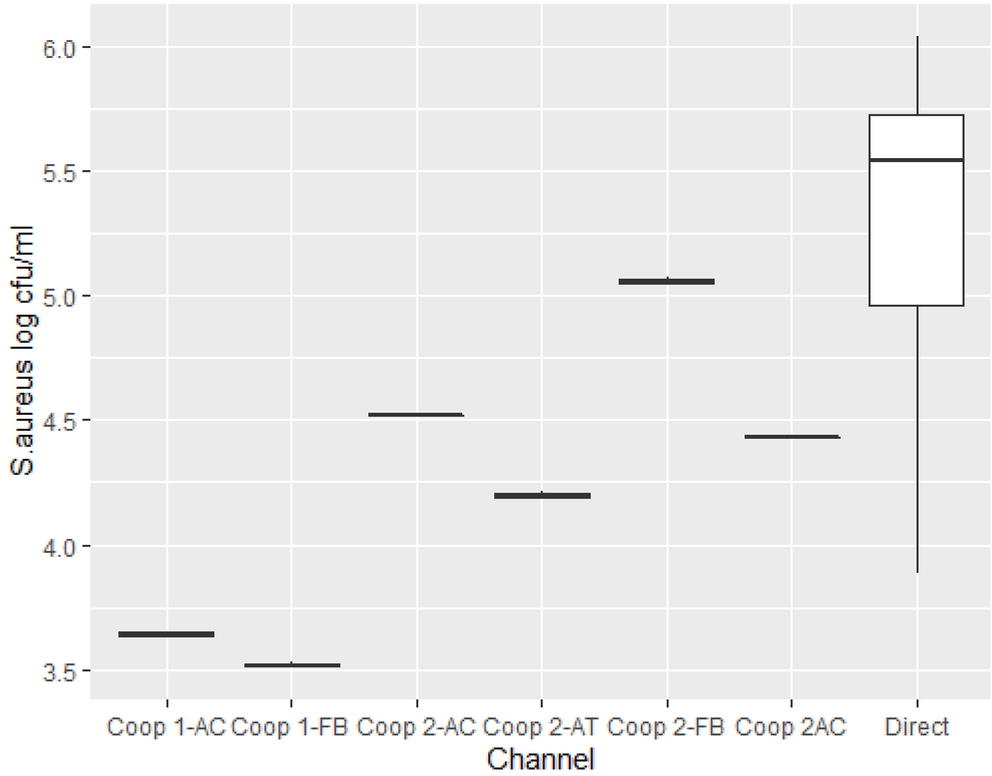


Figure 9: Distribution of *S. aureus* counts in Milk, Bomet County

S. aureus	*Staphylococcus aureus*
Coop 1 –AC	Cooperative 1 After Cooler
Coop 1-FB	Cooperative 1 First Bulk
Coop 2-AT	Cooperative 2 After Transport
Coop 1 –AC	Cooperative 1 After Cooler
Coop 1-FB	Cooperative 1 First Bulk
Direct	Direct suppliers

E. coli counts from the Bomet County samples varied significantly depending on the collection channel as shown in Figure 10 with milk from After Cooler samples of Coop 2 recording the highest counts (5.1 log cfu/ml) while After Cooler samples from Coop 1 had the lowest counts (0 log cfu/ml). There was no significant difference ($p > 0.05$) between First

Bulk and After Cooler milk samples from Coop 1 at $p < 0.05$. All samples along the channel met the set standards of 4 log cfu/ ml (EAC, 2018) with the exception of After Cooler samples of Coop 2.

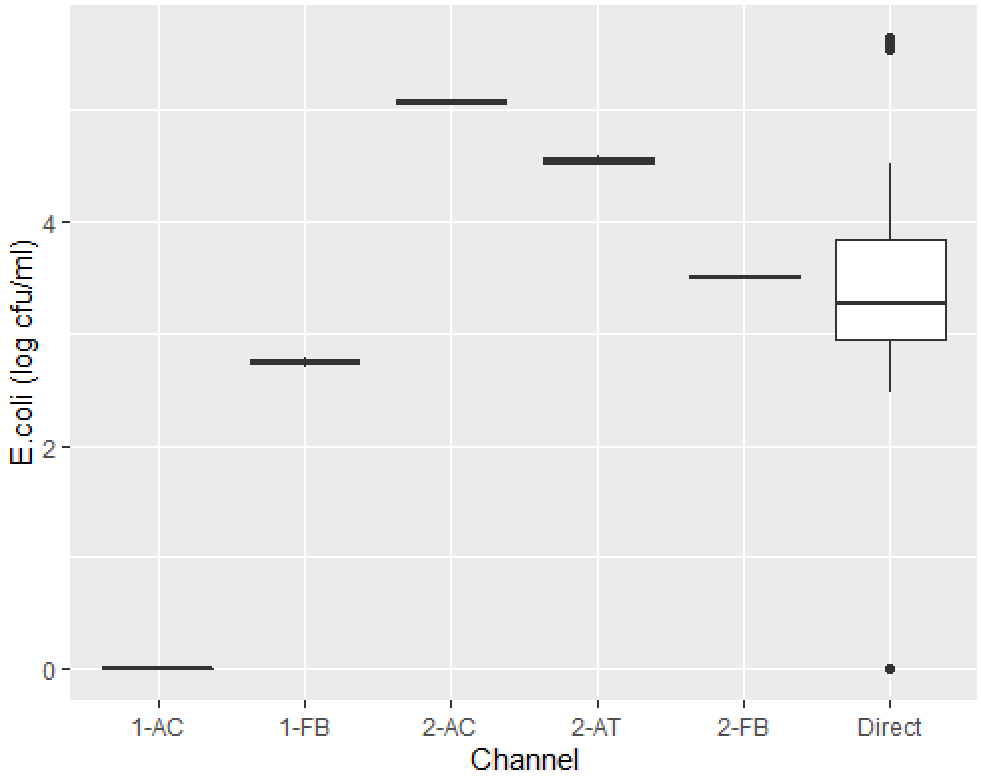


Figure 10: Distribution of *E. coli* in Milk, Bomet County

E. coli	*Escherichia coli*
1 –AC	Cooperative 1 After Cooler
1-FB	Cooperative 1 First Bulk
2-AT	Cooperative 2 After Transport
1 –AC	Cooperative 1 After Cooler
1-FB	Cooperative 1 First Bulk
Direct	Direct suppliers

There were no significant ($p > 0.05$) variations in *L. monocytogenes* counts along the collection channels. Milk samples from direct suppliers had the lowest counts (5.6 log cfu/ml) while samples from After Cooler samples from Coop 1 had the highest counts (6.9

log cfu/ml) as shown in Figure 11. It was noted that from the two cooperatives, After Cooler and After Transport milk samples had higher counts than First Bulk milk samples.

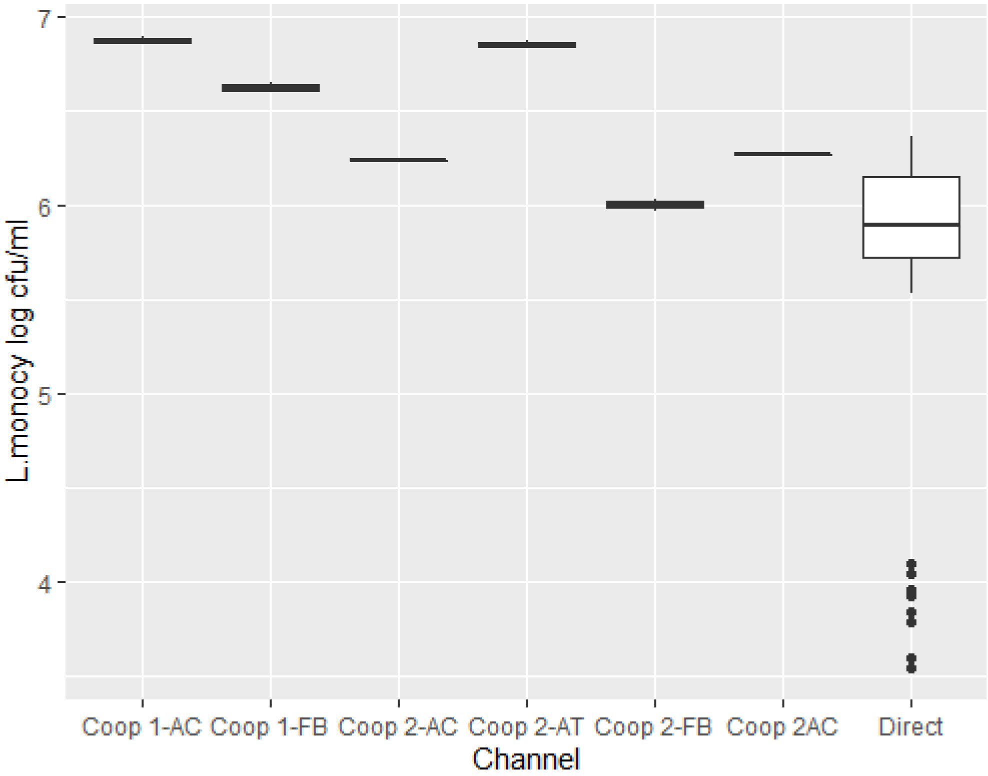


Figure 11: Distribution of *L. monocytogenes* in Milk, Bomet County

L. monocy	*Listeria monocytogenes*
Coop 1 –AC	Cooperative 1 After Cooler
Coop 1-FB	Cooperative 1 First Bulk
Coop 2-AT	Cooperative 2 After Transport
Coop 1 –AC	Cooperative 1 After Cooler
Coop 1-FB	Cooperative 1 First Bulk
Direct	Direct suppliers

4.4.1.2. Microbial Quality of Milk from Nakuru Milk shed

Total viable counts varied significantly ($p < 0.05$) where After Transport samples from Coop 4 had the highest counts (9.5 log cfu/ml) while After Transport samples from Coop 3 had the lowest counts (7.4 log cfu/ml). It was also noted that TVC from cooperative 3 were high in the First Bulk and After Cooler samples but significantly reduced in the After Transport samples. All samples exceeded the set standards of 6.3 log cfu/ ml (EAC, 2018) as shown in Figure 12.

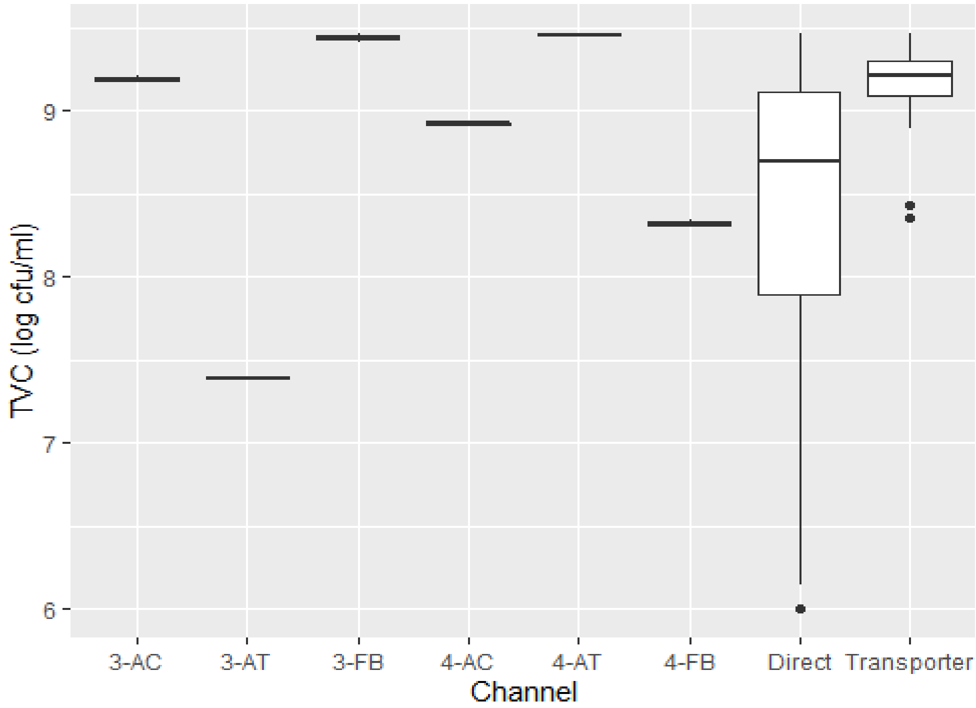


Figure 12: Distribution of TVC in Milk, Nakuru County

TVC	Total Viable Counts
3 –AC	Cooperative 3 After Cooler
2-FB	Cooperative 3 First Bulk
3-AT	Cooperative 3 After Transport
4 –AC	Cooperative 4 After Cooler
4-AT	Cooperative 4 After Transport
4-FB	Cooperative 4 First Bulk
Direct	Direct suppliers

There were no significant ($p > 0.05$) variations in *S. aureus* counts along the collection channels as shown in Figure 13. After Transport milk samples from Coop 4 had the highest counts (6.3 log cfu/ml) together with After Cooler and First Bulk samples from Coop 3 (6.3

log cfu/ml). The After Transport samples from Cooperative 3 had significantly lower counts compared to the First Bulk and After Cooler samples from the same cooperatives. After Transport samples from Coop 3 had the lowest counts (3.7 log cfu/ ml) and the only one that met the set standards of 4.7 log cfu/ ml.

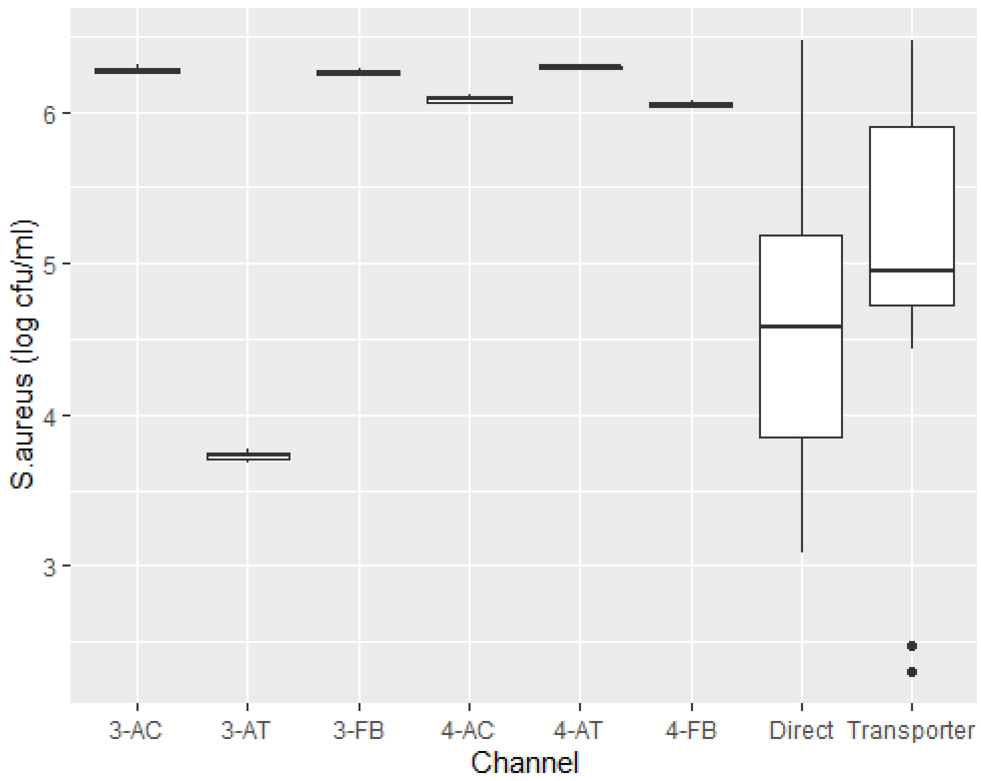


Figure 13: Distribution of *S. aureus* counts in Milk, Nakuru County

3 –AC	Cooperative 3 After Cooler
2-FB	Cooperative 3 First Bulk
3-AT	Cooperative 3 After Transport
4 –AC	Cooperative 4 After Cooler
4-AT	Cooperative 4 After Transport
4-FB	Cooperative 4 First Bulk
Direct	Direct suppliers

There were no significant (p > 0.05) variations in *E. coli* counts along the collection channels as shown in Figure 14. After Cooler milk samples from Coop 3 had the highest counts (6.3 log cfu/ml) while After Transport samples from the same cooperative had the lowest counts (3.4 log cfu/ ml). It was also observed that *E. coli* counts from samples collected from Cooperative 3 After Transport were lower than First Bulk and After Cooler samples from the same cooperative. Milk samples from direct suppliers, traders and Coop 3 After Transport are the only ones that met the set standards of 4 log cfu/ ml.

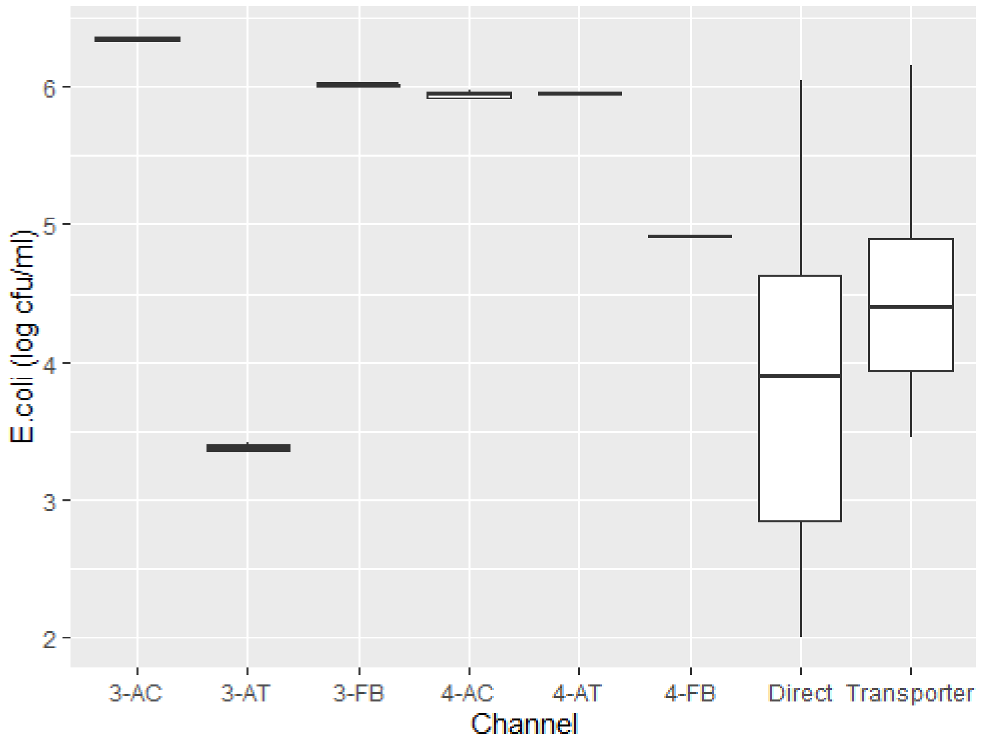


Figure 14: Distribution of *E. coli* counts in Milk, Nakuru County

3 –AC	Cooperative 3 After Cooler
2-FB	Cooperative 3 First Bulk
3-AT	Cooperative 3 After Transport
4 –AC	Cooperative 4 After Cooler
4-AT	Cooperative 4 After Transport
4-FB	Cooperative 4 First Bulk
Direct	Direct suppliers

There was a significant ($p < 0.05$) variation in After Transport samples from Coop 3 with the rest of the samples in *L. monocytogenes* counts along the collection channels. This was an issue of concern considering that samples from the same cooperative had high counts in the First Bulk and After Cooler samples. The First Bulk milk samples from Coop 3 had the highest counts (7.0 log cfu/ml) while After Transport samples from the same cooperative had the lowest counts (0 log cfu/ml) as shown in Figure 15.

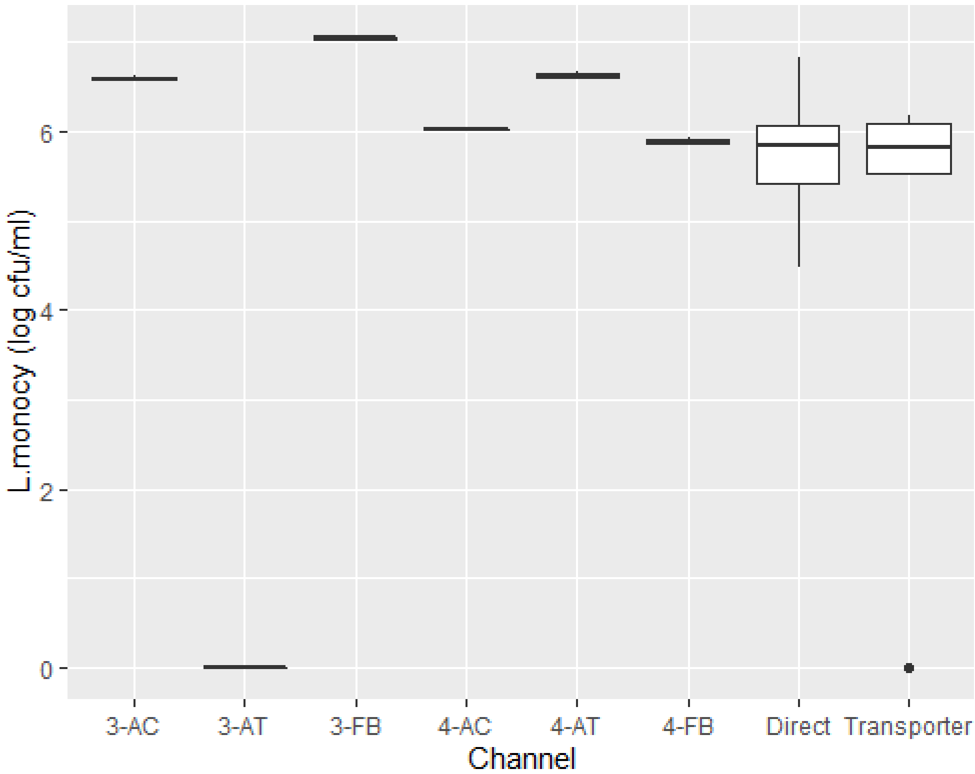


Figure 15: Distribution of *L. monocytogenes* counts in Milk, Nakuru County

3 –AC	Cooperative 3 After Cooler
2-FB	Cooperative 3 First Bulk
3-AT	Cooperative 3 After Transport
4 –AC	Cooperative 4 After Cooler
4-AT	Cooperative 4 After Transport
4-FB	Cooperative 4 First Bulk
Direct	Direct suppliers

4.4.1.3. Microbial Quality of Milk in Nyeri County

There were no significant ($p > 0.05$) variations in TVC along the collection channels. First Bulk Milk samples from Coop 5 had the highest counts (9.4 log cfu/ml) while First Bulk samples from Coop 7 had the lowest counts (8.3 log cfu/ml). Notably, all samples exceeded the set standards of 6.3 log cfu/ ml (EAC, 2018) as shown in Figure 16.

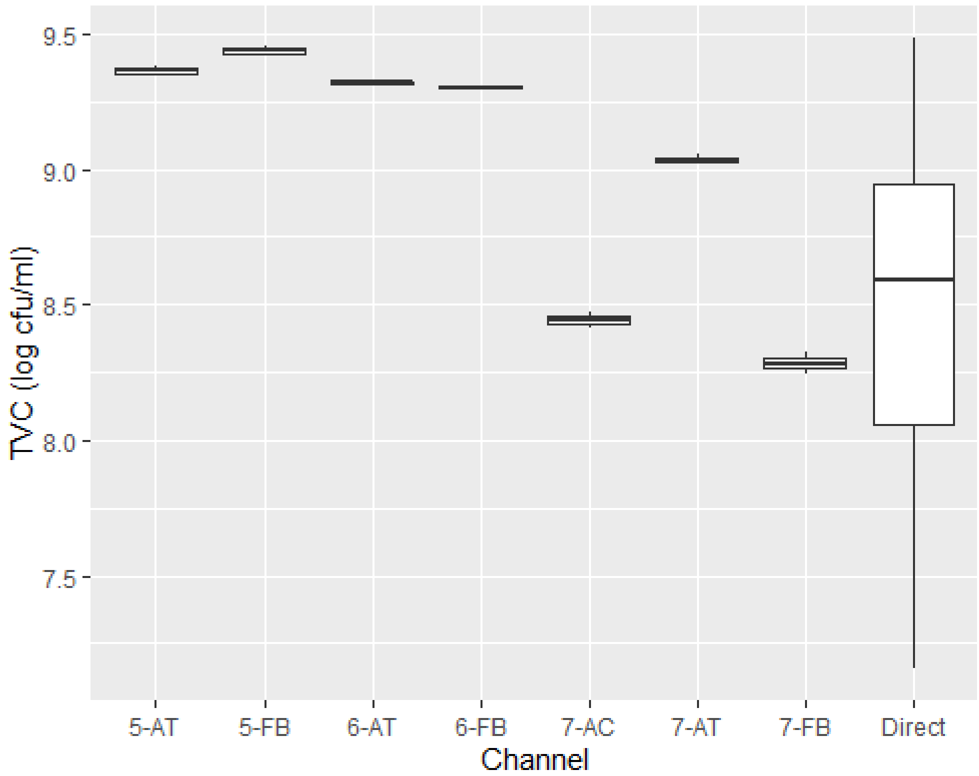


Figure 16: Distribution of TVC in Milk, Nyeri County

5 –AC	Cooperative 5 After Cooler
5-FB	Cooperative 5 First Bulk
6-AT	Cooperative 6 After Transport
6 –FB	Cooperative 6 First Bulk
7-AT	Cooperative 7 After Transport
7-FB	Cooperative 7 First Bulk
7-AC	Cooperative 7 After Cooler
Direct	Direct Suppliers

Milk samples from direct suppliers in Nyeri County varied significantly ($p < 0.05$) with samples from Coop 5. First Bulk samples from Coop 6 had the highest *S. aureus* counts (6.4 log cfu/ml) while samples from direct suppliers had the lowest counts (4.5 log cfu/ml) as shown in Figure 17. Milk samples from direct suppliers, Coop 7 First Bulk and After Cooler are the only ones that had counts below the set standards of 4.7 log cfu/ ml (EAC, 2018) while the rest exceeded the set standards.

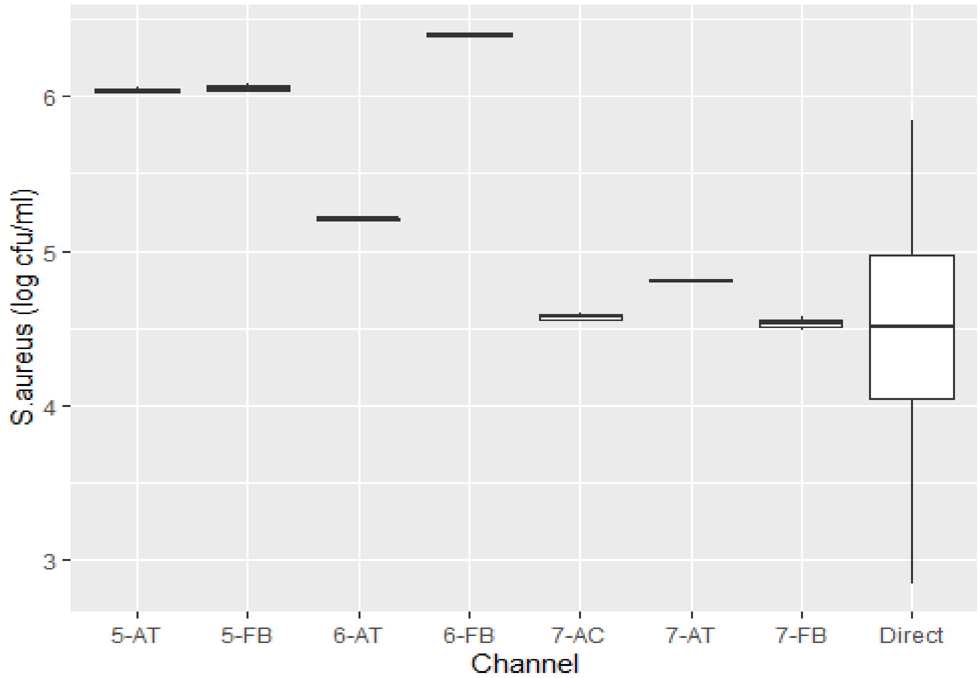


Figure 17: Distribution of *S. aureus* counts in Milk, Nyeri County

5 –AC	Cooperative 5 After Cooler
5-FB	Cooperative 5 First Bulk
6-AT	Cooperative 6 After Transport
6 –FB	Cooperative 6 First Bulk
7-AT	Cooperative 7 After Transport
7-FB	Cooperative 7 First Bulk
7-AC	Cooperative 7 After Cooler
Direct	Direct Suppliers

There were no significant ($p > 0.05$) variations in *E. coli* counts along the collection channels in Nyeri County. After Transport samples from Coop 5 had the highest counts (7.2 log cfu/ml) while After Cooler samples from Coop 7 had the lowest counts (3 log cfu/ml) as shown in Figure 18. Milk samples from direct suppliers, Coop 5 First Bulk and Coop 5 After Transport exceeded the set standards of 4 log cfu/ ml (EAC, 2018) while the rest met the set standards.

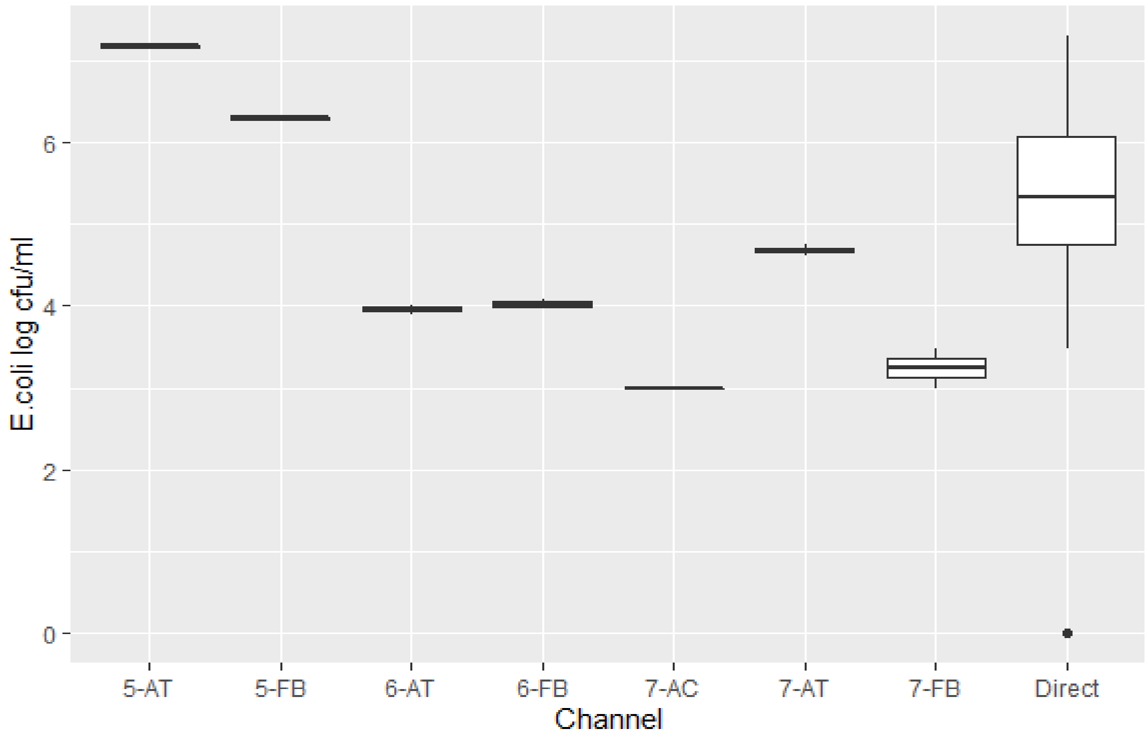


Figure 18: Distribution of *E. coli* counts in Milk, Nyeri County

5 –AC	Cooperative 5 After Cooler
5-FB	Cooperative 5 First Bulk
6-AT	Cooperative 6 After Transport
6 –FB	Cooperative 6 First Bulk
7-AT	Cooperative 7 After Transport
7-FB	Cooperative 7 First Bulk
7-AC	Cooperative 7 After Cooler
Direct	Direct Suppliers

After Cooler milk samples from Coop 7 had the highest counts (8.0 log cfu/ml) followed by After Transport samples from the same cooperative (7.9 log cfu/ml). After Transport samples from Coop 5 had the lowest counts (5.1 log cfu/ml) as shown in Figure 19. However, there were no significant ($p > 0.05$) variations in *L. monocytogenes* counts along the collection channels in the Nyeri milk shed.

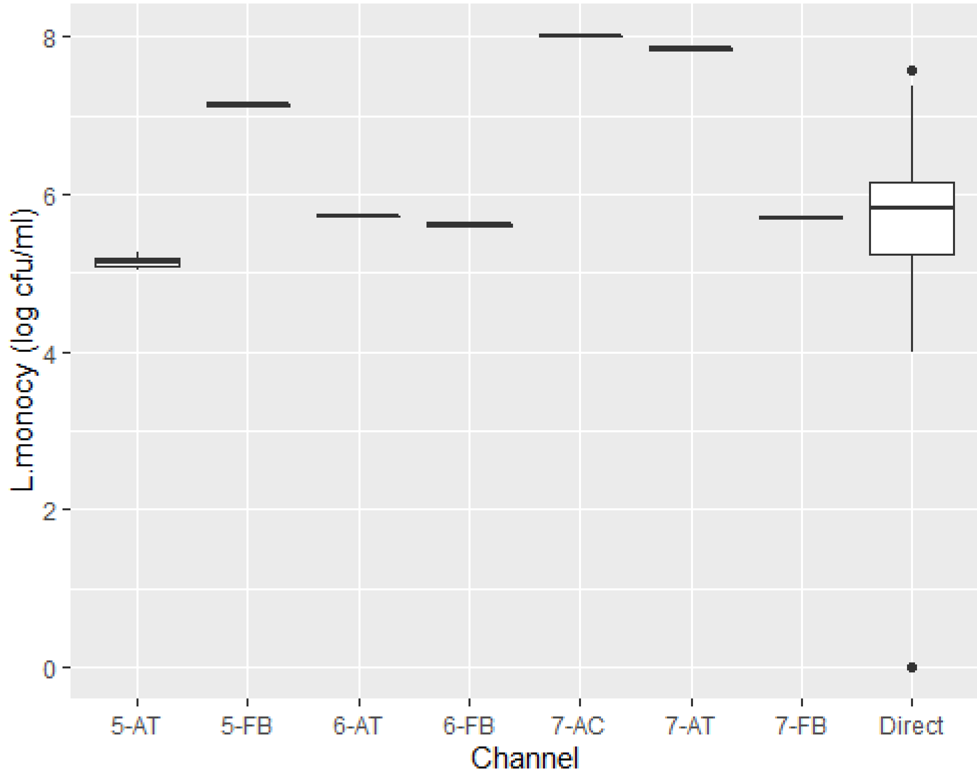


Figure 19: Distribution of *L. monocytogenes* in Milk, Nyeri County

5 –AC	Cooperative 5 After Cooler
5-FB	Cooperative 5 First Bulk
6-AT	Cooperative 6 After Transport
6 –FB	Cooperative 6 First Bulk
7-AT	Cooperative 7 After Transport
7-FB	Cooperative 7 First Bulk
7-AC	Cooperative 7 After Cooler
Direct	Direct Suppliers

4.4.1.4. Milk quality in the various zones

A comparison of microbial mean counts in the three milk sheds was carried out so as to assess the status the status of the quality of raw milk collected in the counties as shown in Table 9.

Table 9: General Microbial quality of milk in the different milk sheds

Microbial attribute **Collection Channel**	**TVC**	***E. coli***	***L.monocytogenes***	***S. aureus***
BOMET	7.588 ± 0.6^{a}	3.253 ± 1.3^{a}	5.783 ± 0.8^{a}	5.132 ± 0.7^{b}
NYERI	8.641 ± 0.6^{b}	4.973 ± 1.7^{b}	5.744 ± 1.3^{a}	4.656 ± 0.8^{a}
NAKURU	8.72 ± 0.8^{b}	4.449 ± 1.2^{b}	5.298 ± 1.9^{a}	5.092 ± 1.2^{b}

Results are mean of duplicate samples ± standard deviation

Means with common letters in superscript in the same column are not significantly different at $p<0.05$

TVC = Total Viable Counts

Nakuru milk shed recorded the highest mean TVC of 8.7 $\log_{10}$ cfu/ml, Nyeri had the highest *E. coli* mean counts of 4.97 $\log_{10}$ cfu/ml and Bomet recorded the highest mean counts of 5.13 and 5.78 $\log_{10}$ cfu/ ml for *S. aureus* and *L. monocytogenes* respectively as shown in Table 9. The Total Viable counts of samples from all the counties exceeded the set standards of 6.3 log cfu/ ml (EAC, 2018). Notably, E. coli counts from Bomet milk shed and S. aureus counts from Nyeri milk shed were the only ones which were within the set standards of 4.0 log cfu/ml and 4.7 log cfu/ml (EAC, 2018) respectively.

4.5. DISCUSSION

4.5.1. Total Viable Counts

TVC results in this study exceeded the set standards of 6.3 $\log_{10}$ cfu/ml or 2 million cfu/ml (EAC, 2018). This could be due to various unhygienic milking and handling practices at the farm. High TVC values is an indication of raw milk that is not suitable for consumption which also indicates increased risk of presence of pathogenic microorganisms (Knight-jones *et al.,* 2016). These food borne pathogens can persist in biofilms resulting to contamination of processed milk products especially in cases where inadequate pasteurization is done (Rola *et al.*, 2016). A common observation in the three counties was that farmers held the milk at the farm after milking without refrigeration to attend to other chores. The long holding time in warm tropical weather results to rapid multiplication of bacteria hence high microbial counts on delivery (Alonso *et al*., 2018). Nakuru County had the highest mean TVC which could have resulted from the rampant use of plastic containers for milking and storage of milk. More than half (55.6%) of farmers in Nakuru used plastic containers compared to 13.4% and 34.6% of farmers in Bomet and Nyeri respectively. Plastic containers adhere to milk residues making them difficult to clean as compared to aluminum containers. This shows an improvement from the situation recorded in a previous study (Ndungu et al., 2016) where 90% and 49% of farmers in Nakuru and Nyandarua counties respectively were found to be using plastic containers for transportation of milk. The improvement could have resulted from various trainings which farmers from Nakuru County received in the last years (Ndambi et al., 2019). Ndungu et al., (2016) further observed high mean TVC: 6.455, 6.276, 6.369 and 7.138 $\log_{10}$ cfu/ml from milk collected from individual cans, collection routes, the milk cooler and tanker respectively in Nakuru County. This study also noted that all (100%) farmers in Nakuru often used a reusable cleaning cloth to wipe hands, equipment and udders of different cows compared to 57.7% and 80.8% of farmers in Bomet and Nyeri respectively (Table 3). This is a poor handling practice due to transfer of bacteria from hands to udder, hands to equipment or between udders of various cows resulting to contamination of milk. Most farmers indicated that they rarely changed these cloths which could be sources of microbial contamination especially when not well cleaned as observed in another study in Nairobi by Wanjala et al., (2018).

High microbial counts were observed in first bulk and after cooler milk samples from Coop 3, though milk from the same cooperative had the lowest microbial counts after it was transported to the processor in a chilling tank. This raises concern and could be due to a number of reasons including addition of hydrogen peroxide which has microcidal properties thus lowering the number of micro-organisms in milk that arrived at the processor (Wallace, 2008). Micro-organisms in milk of high bacteria load could form toxins which are heat resistant and can survive through processing making them present in the end product (Ozer & Yaman 2014; Meunier-Goddik & Sandra 2011).

Cooperatives without coolers had higher microbial counts than those with coolers. Long holding time at these cooperatives with no cooling could encourage rapid microbial growth (Velázquez-ordoñez *et al.*, 2019). An increase in microbial growth observed between first bulk and after cooler samples for cooperatives with coolers could be due to poor cooling efficiency, since it took over 3 hours to cool milk from around 20^{0}C to 4^{0}C. Instant coolers which rapidly cool milk compared to conventional coolers thus reducing multiplication of bacteria are recommended for cooperatives (Ndungu et al., 2016). Also, quality based milk payment systems could be promoted as they would stimulate farmers to improve hygienic practices (Özkan Gülzari *et al*., 2020; Ndambi *et al*., 2019).

4.5.2. *Staphylococcus aureus*

Most of the *Staphylococcus aureus* counts in this study exceeded the set standards where the acceptable limit is 10,000 cfu/ml or 4 log cfu/ml (EAC, 2018). It was observed in the three counties that over 95% of farmers milk manually or by hand which could be a source of *S. aureus* contamination especially when hands are not properly cleaned considering that humans are carriers of the micro-organism (Orregård, 2013). Direct suppliers in Bomet recorded the highest *S. aureus* counts which could be as a result of hand cleaning of the udders as done by 42.3% of farmers in the county compared to 0% and 9.2% of farmers in Bomet and Nyeri respectively (Table 3). It was also observed that these farmers washed their hands simply with cold water before milking which does not guarantee effective cleaning of hands. This agrees with a study done by (Orregård, 2013) in Kiambu county in Kenya where high *S. aureus* counts in 70% of the samples was attributed to hand cleaning of the udders. *S. aureus* is an organism associated with mastitis (Wallace, 2008) which explains the high counts in Nakuru and Nyeri counties where all (100%) farmers did not set aside cows with mastitis resulting to contamination of milk compared to 53.8% of farmers in Bomet.

Cooperatives in Nakuru County recorded the highest *S. aureus* counts. Untidy platforms, inefficient cleaning of the coolers and poor personnel hygiene as observed at the cooperatives could be sources of milk contamination (Wallace, 2008). Cooperative 5 in Nyeri also recorded high *S. aureus* counts. This cooperative received milk from farmers and held it without cooling for a few hours before it was delivered to the processors still without refrigeration, a practice which results to rapid multiplication of bacteria. This study agrees with one done by Wanjala et al., (2017) where mean *S. aureus* counts were 5.83, 6.32 and 5.82 $\log_{10}$ cfu/ml in raw milk collected from Kenyan rural, urban and slum areas respectively all exceeding the set standards. However, results in this study were higher than those found in a study done in Bangladesh where *S. aureus* counts in raw milk samples from farms, chilling centers and traders were 2.90, 2.77 and 2.78 log cfu/ml respectively (Islam *et al.*, 2016).

4.5.3. *Escherichia coli*

High *E. coli* counts in raw milk can be attributed to poor farm or herd hygiene (Gemechu et al., 2015). Direct suppliers in Bomet had high *E. coli* counts which could be attributed to the fact that 80.8% of farmers in the area rarely cleaned sheds or disposed dung compared to 19.2% and 33.3% of farmers in Nyeri and Nakuru respectively, resulting to mud and faeces being sources of contamination within addition, hand cleaning of the udders as practiced by 42.3% of farmers in Bomet compared to none (0%) and 9.2% of farmers in Nakuru and Nyeri respectively. This practice does not guarantee efficient cleaning thus compromising milk quality. High *E. coli* counts in Bomet and Nakuru counties could have resulted from contaminated water. It was observed that 50.2% and 46.5% of farmers in Bomet and Nakuru counties respectively, sourced water from wells while 39.1% and 32.1% of farmers from the same counties sourced water from rivers and used the water for cleaning and feeding the cattle without any form of treatment. Farmers in the three counties cited that density or addition of water was a cause of milk rejection on delivery to the processor. Presence of *E. coli* in raw milk samples that were aseptically collected from the three counties can indicate use of contaminated water in cases of milk adulteration as observed by Amenu *et al.,* (2016) in southern Ethiopia. The high *E. coli* counts coincide with a study done by (Alonso *et al.*, 2018), where the median coliform count of raw milk samples consumed in households in Nairobi was 3 million cfu/ml exceeding the set standards of 50,000 cfu/ml (EAC, 2018). In Asia, Koirala (2018) did a study on raw milk samples in Pokhara where total coliform counts of samples at farm level ranged from 0 – $1.2*10^5$ cfu/ml while those from milk collection centers had mean count of $3.4*10^4$ cfu/ml. Presence of *E. coli* indicates presence of other coliforms and is an indicator of feacal contamination thus poses great safety and public health concerns (Wallace, 2008). Raw milk which has high *E.coli* contamination develops off-flavor fast even after processing hence reduced shelf-life of dairy products (Melese Abate Reta and Addis, 2015).

4.5.4. ***Listeria monocytogenes***

It has been noted that *L. monocytogenes* is the only Listeria that has pathogenic effects for healthy humans and when products such as cheese are made from infected raw milk, bacterial growth occurs resulting to a highly contaminated product which causes Listeriosis on consumption (Wallace, 2008). Listeriae are commonly found in the environment (Ulusoy and Chirkena, 2019). Generally, Bomet County recorded the highest *L. monocytogenes* counts likely because more of their animals were allowed to graze which could be a source of contamination compared to those in Nakuru and Nyeri. The most common source of *L. monocytogenes* infections in dairy cows is from poorly preserved silage (Seyoum, *et al*., 2015). Direct suppliers in Nyeri and Nakuru counties recorded high *L. monocytogenes* counts where 58.6% and 32% of farmers in the respective counties cited that it was okay to give spoilt feed to dairy cows, a practice which results to contamination of milk. Cooperatives in the three counties especially those with coolers recorded high *L. monocytogenes* count for the After Cooler and After Transport samples. *L. monocytogenes* has the ability to survive in temperatures as low as 4^0C in already contaminated milk hence the high numbers in the samples. Contamination levels in this study were higher compared to those found in Ethiopia where 18.9% of raw milk samples were found to be contaminated by *L. monocytogenes* at the farm level (Seyoum *et al.*, 2015). This could be due to the fact that farmers in Ethiopia mostly practiced intensive dairy farming thus minimizing contamination of milk.

4.6. CONCLUSION

Microbial analysis from this study showed that microbial quality of raw milk supplied by farmers and along collection channels was of poor quality considering most of the samples exceeded the set standards by regulatory authorities. TVC were highest from direct suppliers and first bulk milk samples at the cooperatives. *S. aureus* highest counts were from direct suppliers and cooperatives without coolers. *E. coli* counts were highest at cooperatives and *L. monocytogenes* highest counts were from after cooler and after transport milk samples from cooperatives. Nakuru milk shed recorded highest mean TVC of 8.72 log_{10} cfu/ ml, Nyeri had highest *E. coli* mean counts of 4.97 log_{10} cfu/ml and Bomet recorded highest mean counts of 5.13 and 5.78 log_{10} cfu/ ml for *S. aureus* and *L. monocytogenes* respectively. Proper road network and installation of instant coolers at the cooperatives will further reduce multiplication of bacteria.

CHAPTER FIVE:

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. DISCUSSION

Microbial contamination of milk mainly begins at the farm level. As seen from this study, use of untreated water, poor hygienic practices during milking and milk handling are factors which influence microbial quality of milk (SNV, 2017).

The high TVC along the collection channels in the various milk sheds could be due to some factors as observed from hygiene and handling practices by farmers. Faeces, mud, soil and slurry become sources of udder contamination as observed in Bomet where farmers practised semi-intensive farming and housed their animals in open kraals hence they rarely cleaned the sheds (Velázquez-ordoñez *et al.*, 2019). The use of a common towel to clean hands, equipment and udders of different cows could be a source of contamination especially if the towel is not well cleaned or changed often (Adkins *et al.*, 2018; Gwandu *et al.*, 2018). Use of plastic buckets and containers was rampant in the counties. They are difficult to clean unlike aluminium cans for they adhere to milk residues making them to be a major source of microbial contamination of milk (Orregård, 2013). Unsanitary handling of milk during transportation or bulking at the cooperatives could further lead to high microbial counts in milk (Ndungu *et al.*, 2016). Long holding time at the farm without cooling and long distance of transportation to cooperatives or the processors without chilling could also lead to rapid multiplication of bacteria (Doyle *et al.*, 2015). At the cooperatives, poor efficiency of the coolers where temperature drop from 20^oC - 4^oC took around 3 hours and long holding time in the warm tropical weather at the cooperatives without coolers could result to rapid multiplication of bacteria by the time milk reached the processor (Dahal *et al*., 2010; Ndungu *et al.*, 2016). TVC analysis in milk is important for it reflects both the hygienic quality and handling of raw milk (Velázquez-ordoñez *et al.*, 2019). High TVC values is an indication of raw milk that is not suitable for consumption for it also indicates increased risk of presence of pathogenic microorganisms (Knight-jones *et al.*, 2016). These food borne pathogens can persist in biofilms resulting to contamination of processed milk products especially in cases where inadequate pasteurization is done (Rola *et al.*, 2016).

S. aureus is a common source of food poisoning and it mostly enters the milk during handling by humans who are carriers of *S. aureus* (Tegegne and Tesfaye, 2017). It produces heat resistant toxins which require prolonged boiling to be inactivated (Orregård, 2013). *S.aureus* contamination is mainly due to poor handling practices during milking, storage, transportation or handling at the cooperatives. Over 95% of farmers in the counties did their milking manually or by hand. However, most of them did not wash their hands with water and soap a practice which could be a major source of *S. aureus* contamination (Rola *et al.*, 2016). It was also noted that more than half of the farmers in the counties used their hands to clean teats before milking a practice which does not guarantee efficiency in cleaning of the udders (Adkins *et al.*, 2017). Several farmers reported cases of mastitis in cows and most did not set aside the infected cows. *S.aureus* is a common microorganism associated with mastitis and is present in high quantities in mastitis milk (Olivier B. Kashongwe *et al.*, 2017). Poor handling of the milk during bulking by transporters and at the cooperatives, poor cleaning of the coolers, dirty surfaces or platforms where milk was received and mixing milk that arrived late with the one received early in the morning as in the case of Nakuru county further contribute to high *S. aureus* counts (Doyle *et al.*, 2015). Lack of refrigeration during transportation to the cooperatives and from the cooperatives to the processors could further result to rapid *S.aureus* multiplication in already contaminated milk (Orregård, 2013).

High *E. coli* counts in raw milk can be attributed to poor farm or herd hygiene (Wanjala *et al.,* 2018). Farmers in Bomet practiced semi-intensive dairy farming hence they did not clean the shed and dispose the dung which could lead to *E.coli* contamination especially when udders are not properly cleaned (Gemechu *et al*., 2015; Wallace, 2015). Farmers in Bomet and Nakuru mainly sourced their water from rivers or wells and used it for cleaning without treatment. Use of insufficient untreated water to clean hands, udders and equipment could be a source of feacal contamination (Doyle *et al.*, 2015). Most farmers in the counties did not disinfect the teats with teat dip a practice which helps prevent *E. coli* contamination of milk (Kamana *et al.,* 2017). Furthermore, presence of *E. coli* in raw milk samples that were aseptically collected could indicate use of contaminated water in cases of milk adulteration (Das *et al.*, 2016). Presence of *E. coli* indicates presence of other coliforms which is an indicator of feacal contamination thus poses great safety and public health concerns (Wallace, 2015). Raw milk which has high *E.coli* contamination develops off-flavour fast even after processing hence reduced shelf-life of dairy products (Reta and Addis, 2015).

L. monocytogenes is commonly introduced into the milk from poorly preserved silage and the environment. Open grazing as seen in Bomet or feeding of spoilt feed which some farmers agreed to could be major sources of *L. monocytogenes* contamination (Ulusoy and Chirkena, 2019). *L. monocytogenes* has the ability to grow in temperatures as low as 4^{0}C which could explain observations made in the three milk sheds where the after cooler and after transport milk samples had higher counts of *L. monocytogenes* compared to the first bulk milk samples (Tahoun *et al.*, 2017). *L. monocytogenes* is the only listeria that has pathogenic effects for healthy humans and when products such as cheese are made from infected raw milk, bacterial growth occurs resulting to a highly contaminated product which causes Listeriosis on consumption (Boor *et al.*, 2017).

5.2. CONCLUSION

Based on the findings of this study, farmers in the three milk sheds did not employ good hygienic practices in dairy management. Microbial analysis from this study further showed that the microbial quality of raw milk supplied by farmers and along the collection channels was of poor quality considering most of the samples exceeded the set standards by regulatory authorities.

5.3. RECOMMENDATIONS

- There is need for consistent training of farmers, transporters and cooperative personnel on good handling practices through partnerships from the processors and the county government.
- Intensive extension services should be provided to farmers through collaboration between the county governments and the processors.
- Trained farmers could also be motivated by incentives such as Quality Based Milk Payment System by the processors.
- The county governments should invest in proper infrastructure in the counties.
- Partnerships through NGOs, county governments and processors will assist in purchase of instant coolers for the cooperatives.

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Appendices

AFRICA-MILK TASK 1.2.

BASELINE FARM SURVEY

QUESTIONNAIRE REFERENCES

1. Household code	
2. Country	
3. Date of survey (DD/MM/YYYY)	___________ / ________________ / ________________
4. Enumerator name	
5. Time: starting interview	
6. Time: ending interview	

SECTION A. HOUSEHOLD AND DEMOGRAPHIC DATA

A.1. Provide the following details about the household head

BE SURE THAT ONLY THE HOUSEHOLD HEAD IS INTERVIEWED:

Full name of the respondent				
First name of the respondent				
County/district of the respondent				
Village of the respondent				
Household GPS coordinates	**Latitude**		**Longitude**	
Ethnic affiliation of the respondent				
Religion of the respondent (codes)				

Level of education of the respondent (codes)		
Marital status of the respondent (codes)		
Religion codes: 1 = Catholic 2 = Muslim 3 = Hindu 4 = Protestant 5 = Traditional African Religion 6 = Atheist 7 = Other(specify)]	Level of education codes: 1 = Illiterate 2 = Elementary school 3 = Middle School 4 = High school 5 = University 6 = Koranic school 7 = Other	Marital status codes: 1 = Married/living together 2 = Single 3 = Divorced 4 = Widow(er)

market; 3=inadequate feeds; 4= Other specify)

C.2. Dairy cows' housing and manure management in 2018

Housing

2.1. Are your **dairy cows penned/housed at night?** [___] =YES [___] =NO (tick)

2.2. If **yes**, provide information on mode of housing during the dry and rainy seasons:

Dry season			**Rainy season**		
Main mode of housing (code)	**Frequency of penning (codes)**	**Breed prioritized (codes)**	**Main mode of housing (codes)**	**Frequency of penning (codes)**	**Breed prioritized (codes)**

Mode of housing codes:		Frequency of penning codes:	Breed prioterised codes:
1= Open kraal 2= Kraal with roof 3= Brick walled 4= Stable with roof + pen	5= Stable with roof / no pen 6= In the house 7= Other: (specify in cell)	1=All the time 2=Night only 3=Occasionally / when need arises (e.g. mating, sick, rain) 4 = Other: (specify)	1 = Endemic (indigenous breeds/local breeds) 2 = Cross-bred 3 = Pure exotic 4 = All 5= Other (specify in cell)

C.3. Dairy cows' feeds and feeding in 2018

3.2. Please estimate the **contribution of free grazing and types** to feed the dairy cows in 2018:

Season	Type of grazing land (code)			Average hours grazed per day
Rainy				
Dry				

Types of grazing land codes *(if more than one, please rank)*:

1 = Community land (open grass land)

2 = State land (roadside grazing, forest land)

3 = Crop land (own)

4 = Crop land (paid for or rented)

5 = Low land (not applicable in Kenya)

6 = Other (Specify)

3.22. Is **water** always available throughout the day **for your dairy cows**? [___] = YES [___] = NO (tick)

3.23. Provide the following details on **watering for dairy cows**:

Water for animals	Dry season	Rainy season
How frequently do you water your cattle? (codes)		
Water source (codes)		
Distance to the watering point (source) (km)		
Is the mentioned water source reliable? 1=Yes 0=No		
Who collects water most regularly? (codes)		
Quality of water (codes		
Do you have to pay? 1=Yes 0=No		
If yes, how much do you pay per liter? (local currency)		
How much water in liters do you use to feed dairy cattle per week?		
And how much do you spend per week? (local currency)		

Frequency of watering codes:	Source codes:	Who collect water? (codes):	Water quality codes:
1 = Once a day	1 = Borehole	1 = Adult males	1 = Excellent
2 = Twice a day	2 = Dam/ storage	2 = Adult females	2 = Good
	3 = Boreholes/Wells	3=Children (confirm that the	3 = Acceptable

3 = Thrice a day 4 = Throughout the day 5 = Other (specify)	4 = River / lake 5 = Natural springs 6 = Stream 7 = Natural occasions/ N/A 8 = Constructed water points/N/A 9 = Rainwater harvesting/stored 10 = household tap water 11 = Other (specify)	children are below 18 years) 4= Workers	4 = Poor 5 = Bad

3.24. What is the **main constraint in watering your dairy cows**? (codes) [ ]

codes:		
1 = Borehole not operational (out of order, fuel shortage) 2 = Water source has dried up	3 = Well too deep / lack of water lifting devices 4 = Not enough labour	5 = Lack of access to water source 6 = Other: (specify) 7= Inadequate money to pay for water 8= Lack of quality water 9= Inadequate storage

C.5. Dairy cow's health and milk hygiene management in 2018

Health management

5.1. What are the **most frequent animal health problems** that have been affecting your dairy cows?:

Animal health problems	Rank most frequent=1 and least =8	Frequency (Codes)	Occurrence in 2018 (1 = yes ; 2 =No ; 3 = don't know)	Number of cows affected	Outcomes (Codes)
1 = Tick borne and other insect borne-diseases (e.g. East Coast fever, Anaplasmosis, Trypanosomosis, Tick burdens)					
2 = Notifiable diseases (e.g. Lumpy skin diseases, Foot &					

Mouth, Black quarter, Anthrax)					
3 = Reproductive health diseases (e.g. Infertility, abortions)					
4 = Routine management-related and controllable diseases (e.g. Calf mortality, Mastitis, Foot problems, Intestinal worms)					
5 = Nutrition diseases and complications (e.g. Milk fever)					
6 = General frequent infections (e.g. Respiratory/ Pneumonia, Diarrhea)					
7 = Poisoning (e.g. Acaricide, snake bite)					
8 = Other (Specify)_________________					
9 = Other (Specify)_________________					

	Frequency codes:	Outcomes codes:
	1 = Frequent 2 = Rare 3 = Never 4 = Don't know	1 = Died 2 = Survived 3 = Slaughtered

Milk hygiene management

5.5. What **type of milking** do you do (most common)? [___] = manual (hand) [___] = mechanic (tick)

5.6. Do you **clean teats before milking**? [___] = YES [___] = NO (tick)

5.7. Do you **wear gloves during milking**? [___] = YES [___] = NO (tick)

5.8. Do you **use pre-milking products**? [___] = YES [___] = NO (tick)

5.9. If **yes**, what is the **nature of the product**? [___] = disinfectant [___] = barrier effect (lubricant) [___] = both

5.10. Do you **use post-milking products**? [___] = YES [___] = NO (tick)

5.11. If **yes,** what is the **nature of the product**? [___] = disinfectant

[___] = barrier effect (lubricant) [___] = both

5.12. **How do you clean the milking equipment** before/after milking? [___] = simply water [___] = soap [___] = disinfectant [___] = other (specify)___________

5.13. Where do you store the milk? [___] = no-specific milk-barrel [___] = metallic milk-barrel

[___] =cooled milk-tank [___] = Jerrican l[___] = mazzi can

5.13b. How many hours does it take for your milk to reach the cooler (farmer to estimate if not sure)/_______/ hours

5.14. How many hours do you store milk at farm before the collection time? /_______/ hours

5.15. Are the **milk containers closed during milk storage**? [___] = YES [___] = NO (tick)

5.16. Is **milk refrigerated during this storage** time? [___] = YES [___] = NO (tick)

5.16b. If no is there any other form of cooling? [___] = YES (specify) [___] = NO (tick)

5.17. Do you recognize cows affected by mastitis? [___] = YES [___] = NO (tick)

5.17 b: How many of your cows suffered from mastitis in 2018

5.17c: How many times did your cows suffer from mastitis in 2018 (enumerator should sum for all cows)

5.18. If **yes,** do you set aside cows affected by mastitis? [___] = YES [___] = NO (tick)

5.18a. If **yes,** how much milk did you lose in 2018 (in litres) due to mastitis from the animals set aside?

5.18 b: How long do you wait before milking per treatment category

Type of treatment	Number of days	How do you decide?	codes
Mastitis			[__1_] = arbitrarily
Antibiotics			[_2] = according to product instructions or veterinary advice
Deworming			
Vaccine			
Other			

5.19. After treating an animal with drugs, **how long** do you wait **before milking it again**?
/____________/ days

5.20. **How is this waiting time decided**? [___] = arbitrarily

[___] = according to product instructions or veterinary advice

5.21 MILK REJECTION at the individual point of collection

Cause of rejection	Number of times rejected in 2018	Quantity rejected (litres)	Where is the rejected milk taken to?
Acidity			
Organoleptic (flavor)			
Density			
Others			

Dairy hygiene practices	Frequency of practice	Codes
Clean the shed and dispose of the dung away from the shed		1=Always, 2 = Most often 3 = Sometimes 4 = Rarely 5 = Never
Wash the milking vessels with clean water and dry them		
Wash the milking vessels immediately after use		
Wash hands with soap and dry the hands with towel		
Wash the udder with clean warm water before milking		
Fore strip each quarter and observe signs of mastitis		
Wipe and dry the udder after washing using clean dry towel		
Apply milking jelly/lubricant after milking		
Disinfect the teats with teat dip		

Sieving milk after milking		
Feeding spoilt feed to milking cows		

D.3. Access to information

3.1. Did you access **information on dairying in 2018**? [___] = YES [___] = NO (tick).

3.2. If **yes**, indicate for each type of information, **source and how you accessed information:**

The type of information **(codes)**	**The two mains sources of information starting with the most important (codes)**		**How did you access information starting with the most important?** **(codes)**	
Feeds				
Concentrate feeding				
Fodder and forage feeding				
Grazing management				
Fodder establishment				
Fodder harvesting & processing				
Fodder conservation				
Feeds ration formulation				
Calf nutrition				
Cattle management				
Cattle housing				
Cattle breeding				
Cattle reproduction				
Health and diseases management				
Manure management				
Milk management & marketing				
Milk prices				
New milk outlets (contracts)				
Milk hygiene management				

Milk quality standard				
Others				
Financial services (loans)				
Livestock training schemes				
Other specify: /_______________/				

Source of information codes:	Method of access to information codes:
1 = Government ministries	1 = /N/A
2 = Farmer/ self-help farmer groups	2 = Extension briefs
3 = Private entrepreneurs/sector	3 = N/A
4 = NGOs, Specify	4 = N/A
5 = Cooperative societies	5 = N/A
6 = A research organization, specify	6 = Media (Radio, Print, TV etc)
7 = A learning institution specify	7 = Field days, demos, barazas etc.
8 = Ongoing projects, Specify	8 = Training workshops, seminars etc
9 = Other (specify)	9 =
	10= Poster/Banners