KNOWLEDGE, HANDLING PRACTICES OF CONSUMERS, AND MICROBIOLOGICAL SAFETY OF PROCESSED MILK PRODUCTS SOLD IN NAIROBI COUNTY

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DECLARATION

This dissertation proposal is my original work and has not been submitted for award of a degree in any other university.

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This dissertation has been submitted with our approval as university supervisors

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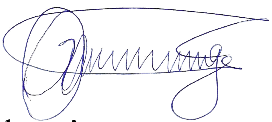
Signature:  03/12/2023

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DEDICATION

I dedicate this project to my family; Leroy, Ryan, Mitch, Elliana, and Clyde for their moral support and especially to my spouse Fred for his encouragement and financial support that has made it possible for me to complete this project.

I would also like to dedicate this project to all people in the food processing industry who have a passion for food safety and always work towards the realization and provision of safe foods to consumers.

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LIST OF ABBREVIATIONS AND ACRONYMS

WHO: World Health Organization

FAO: Food and Agriculture Organization

FDA: Food and Drug Administration

FSSC: Food Safety Systems Certification

KEBS: Kenya Bureau of Standards

KDB: Kenya Dairy Board.

CDC: Centre for Disease Control

UNICEF: United Nations International Children's Emergency Fund

LEB: Listeria enrichment Broth

GMP: Good manufacturing practices

CAC/GL: Codex Food Safety Guidelines.

ISO: International Organization for Standardization

HACCP: Hazard Analysis Critical Control Point

CFU: Colony-Forming Unit

GDP: Gross Domestic Product

ILRI: International Livestock Research Institute

KNBS: Kenya National Bureau of Statistics

OPERATIONAL DEFINITION OF TERMS

Dairy plant: Premises where any milk is received or handled for processing before distribution.

Formal milk market: Markets authorized and licensed by Kenya Dairy board to sell milk.

Kiosks: Small shops mostly found with the residential places.

Milk Kiosks (Dispensers): Machines for handling bilk processed milk and apportion it into smaller quantities for sale.

Milk Processing Systems: All procedures and steps involved in converting raw milk in a processed finished product that is ready for consumption.

Pasteurization: Heat-treatment process that destroys pathogenic microorganisms usually above 65°C.

Pathogens: Disease causing Micro-organism.

Processed milk: Milk that has undergone pasteurization process and has been packaged.

Supermarket: Is self-service shop that allows the customers to pick by themselves commodities and sell to them for their consumption as the final customers (Shankar, 2016).

Zoonotic Disease: Refers to infectious disease that can be transmitted from animals to man and vice versa.

ABSTRACT

Milk products are considered a main source of dietary nutritional requirements for all people of all age groups in Kenya, especially the infants, pregnant women, the sick and the immune compromised individuals, with an aim to improving their health. However, poor knowledge and inefficient handling practices may make milk products a source of food borne diseases. Additionally, unpasteurized milk is a potent bacterial growth medium and a significant source of bacterial infections. The current research aimed at assessing the knowledge, handling practices of consumers and microbiological safety of processed milk products sold in Nairobi County, determining consumers' knowledge and handling practices of Milk and milk products, establish the prevalence of *TVC, E. coli, Staphylococcus aureus* and *Listeria monocytogenes* microorganisms' contamination on processed milk and milk products and determining implementation of GMP in milk processing systems by the processors for control of the above microorganisms. In addition, it aims at creating evidence-derived awareness and providing continuous education especially for vulnerable groups regarding the risks associated with pathogens in milk products. Data was collected through structured questionnaires and was administered through face-to-face interviews and then analysed using SPSS. The Fisher's formula was used to get the sample size where 360 consumers were randomly selected. Furthermore, samples of fresh milk, yoghurt cheese and ice creams were collected from supermarkets and prepared for analysis of microorganisms. Purposive sampling technique was used in selecting processors brands of milk products at the point of sale in the 3 different study areas and a total of 36 samples were analyzed. Ten processing facilities were also purposively selected to assess the level of implementation of food safety management systems such as ISO 22000, GMPs, and HACCP. Fresh milk was the most consumed milk product at 94% closely followed by yoghurt (93%) with ice cream and cheese trailing. About 69.9% of the respondents consumed fresh milk on daily basis, while 53.7% consumed yoghurt on weekly basis, 37.3% rarely had yoghurt and just about 27% of the respondents indicated that they had ice cream while majority (65.2%) indicated they rarely consumed ice cream. More than 91% of the respondents boiled milk before use while nearly 90% of the respondents used milk for tea preparation. It was also noted that most of the respondents (59%) owned a fridge and out of these, 15.6% boiled milk to make it last longer while 39.6% used it immediately. Furthermore, chi-square tests showed an association between the education levels of milk consumers and their parametric choice on good quality milk (*P=0.000*). Of the samples collected in Karen, ice cream had the highest contamination level of *TVC* (3.26 $\log_{10}$ CFU ml^{-1}). Ice cream samples from Langata had the highest Total Viable Count contamination levels at 4.35 $\log_{10}$ CFU ml. The overall prevalence of *E. coli* in milk and milk products was 41.6% with a mean count of 0.34 $\log_{10}$ CFU ml^{-1} in Karen, 0.07 $\log_{10}$ CFU ml^{-1} in Kibera and 0.11 $\log_{10}$ CFU ml^{-1} in Langata while *Staphylococcus aureus*

was detected in 33.3% of the milk and milk products. It was also observed that all the milk processors tested for total viable counts (TVC), and *E. coli* while only 50% and 33.3% of the processors tested for *S. aureus* and *L. monocytogenes* respectively. Majority (83.3%) had well-documented cleaning programs and had a system of controlling cross contamination which was enforced through different colour codes (66.7%), memos and notices (16.7%) and through colour coding of processing equipment (16.7%). In conclusion, the majority of respondents had a level of knowledge viewed as sufficient about the milk processing and temperature. Despite the fact that majority of milk processors had implemented good manufacturing practices (GMP) and conformed to good processing practices, regulators need to encourage and emphasize on the routine analysis of the other food pathogens such as the Staphylococcus aureus and Listeria monocytogenes through routine surveillance. There is also need to improve the microbial quality of milk products by employing measures that will establish proper management practices to ensure improved hygiene, good manufacturing practices and food systems that will help to minimize microbial contamination.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND INFORMATION

In Kenya, milk products are considered as a main source of dietary nutritional requirements for all people of all age groups especially, the infants, the pregnant women, the sick and the immune compromised individual, with an aim to improving their health (UNICEF, 2019). According to data obtained from the Kenya Dairy Board website (KDB, 2020), 5 billion litres of cow's milk is produced annually in Kenya, out of those 600 million litres is processed and formally marketed in various towns, Nairobi accounted for the largest percentage of the formal market in Oct 2020, with consumption of 59,710,445 litres of the total amount produced. The formal milk market is for the milk that has been processed by establishment that have been registered by Kenya Dairy board (KDB). These establishments include Dairies, Milk bars, Companies, retail outlets, Milk Kiosks (Dispensers).

Worldwide, in the dairy processing industry and indeed in food processing industry at large, , Hygiene indicator microorganism has been used as a measure of the suitability of the processing environment, personnel hygiene, effective pasteurization process, Good sanitation processes or proper post processing handling (Metz *et al*., 2019). The most common hygiene indicators microorganisms used for foods and drinking water include the Total Plate Count (TPC), coliforms, *Enterobacteriaceae spp* including *Escherichia coli*, *Staphylococcus aureus*, *Listeria spp* and the yeasts and molds. (Martin *et al*. 2016).

Coliforms are bacteria that are present everywhere, in the soil or plants. They are normally found in the digestive track and excrement of warm-blooded animals including humans. Coliforms are also used as indicator microorganisms and are used to show the hygienic status or handling of any food component. Coliforms are categorized as total coliforms, faecal coliforms and *E. coli.* Other than *E. coli* that are pathogenic, the other two are harmless and may not cause any disease(Eden, 2014).

The bacteria *E. coli* is ordinarily found in the intestines and guts of some animals. Because *E. coli* is always present in faeces, it is largely used as an indicator organism to indicate faecal contamination ineffectiveness of sanitation programs in ready-to-eat foods production and existence of enteric pathogens. *E. coli* contamination may result in food poisoning, respiratory illness, pneumonia and or urinary tract infections. *E. coli* can also produce a toxin called Shiga which damages the lining of your intestine especially *E. coli* O157:H7. E. coli, other that causing the intestinal infection is also a predominant cause of other illnesses including pneumonia, urinary tract infection and most commonly meningitis, especially in neonates with a fatality rate of 15% to 40%.(Ekici & Dümen, 2019).

Presence of *Staphylococcus aureus* in the food is an indication of poor hygiene by food handlers and insufficiently cleaning and sanitation of the equipment. Since Staphylococcus aureus is very rampart where GMPs (good manufacturing practices) is not strictly followed in ready to eat foods handling and processes and most likely occurs as a result of post processing contamination (Leung, 2014). Staphylococcus food poisoning is prevalent in poultry, meat (including ham and corned beef), canned foods, dairy products and bakery products, and is characterized by the sudden onset of nausea, vomiting, diarrhoea, and gastric spasm. Like with other food borne illness, the susceptible groups are normally individuals with compromised immunity including the pregnant women, the elderly and neonates.(Doyle, 2012).

Listeria monocytogenes is a recognized zoonotic pathogen in the dairy industry is an intracellular, facultative, gram-positive rod of the genus *Listeria*. Currently there are several serotypes of *Listeria monocytogenes* totalling thirteen that have been isolated, although only four serotypes are of concern to human namely; 1/2a, 1/2b, 1/2c and 4b which leads to an estimated 95% of human listeriosis which is a mild non-invasive gastrointestinal infection or *Listeriosis* which is an acute invasive gastro intestinal infection with relatively high mortality rate affecting , especially people with compromised immunity including the pregnant women, the elderly and new-borns characterized by various symptoms including; gastroenteritis, fever, diarrhoea, muscle aches, nausea, vomiting and fatigue; which may lead to encephalitis, meningitis, still births and abortion in pregnant women (FAO/WHO, 2004).

Combination of interventions is needed to control *Listeria monocytogenes* and the other hygiene indicator organism's contamination (CAC/GL 61, 2007). There is need to address the entire milk processing systems not just focusing on the effectiveness of the pasteurization as a control, these include, management of sourcing and handling of the milk as a raw material, control of pasteurization, GMPs that control cross contamination, effective cleaning and sanitation procedures, verification methods for cleaning effectiveness, Trainings, Environmental pathogens control program and finally analysis of products prior to dispatch to the market as required by the codex guidelines on hygiene in milk processing (CAC/RCP 57-2004). Observation of the general layout of the facility is also critical because the flow of air is a contributing factor to *Listeria* spread within the facility (FDA, 2017),(Piet *et al*., 2016).

The control and prevention of contamination of food products with indicator microorganism require a complete focus on the good manufacturing practices (GMPs): all food handlers must undergo a food handlers' medical exam at least once every six months, they should practice good hand hygiene ensuring that their hands are cleaned and sanitized before handling any food. Processing environment must be clean and equipment should also be clean and sanitized to avoid cross contamination (Lee *et al*., 2017).

1.2 STATEMENT OF THE PROBLEM

Most consumers in Nairobi perceive processed milk as safe and of good quality; this is according to a study conducted by International Livestock Research Institute in April 2020, on Consumer perception of milk safety in Kenya (Nadhem Mtimet *et al*., 2020). However, the presence of hygiene indicator micro-organisms in a food product may be an indication of inefficient processing method, poor handling and post processing contamination which then raises concerns on the safety of product for consumption (Buchanan & Oni, 2012). That goes to show that regardless of the kind processing a food goes through if at the end of it all it's contaminated with the indicator microorganism the food carries with it the risk that can cause an illness. With the ever-increasing urban population in Nairobi, the risk of food-borne diseases related to milk and milk products' safety and safety practices skyrockets with an increase in milk consumption frequencies. Lack of knowledge among consumers on the causative agents of these compromises pose a further public health challenge. Some studies have been done previously on hygiene indicator microorganisms' contamination, however mostly have been have been on poultry or meat and what have been done on milk products did not link the contamination to the processing systems making it hard to get most relevant information.

1.3 JUSTIFICATION OF THE RESEARCH

The Kenya government through the Dairy Industry Act cap 336 prohibits the sale of raw milk to the consumers (CAP 336, 2012) and the KEBS standards of all milk and milk products gives the *Escherichia coli, Staphylococcus aureus* and *Listeria monocytogenes* levels as absent in 25g of the sample or simply nil. It would be paramount to verify that approved manufacturers are able and capable of ensuring no contamination with hygiene indicator microorganisms in the end product considering the severity of listeriosis even though it's rare. The study will focus on the following Milk and Milk products consumed in Kenya, which include; Fresh milk, Ice cream and Cheese.

Although some research has been done on *Listeria* Contamination in milk, they have not linked the findings of the research to the processing systems of the processors on these milk products, which we know is a main factor to the Listeria contamination, one of such studies was a study done in Nairobi in 2019 on Isolation of listeria species in Milk and meat products. This study will help to improved consumers level of awareness on risks associated with hygiene indicator microorganisms contamination to allow them make informed choices of products to consumers or to avoid. The Kenya Dairy Board (KDB), Public Health and Kenya Bureau of Standard (KEBS) being the key Regulatory bodies in the milk production will be able to use this information to come up with guidelines and to intensify surveillance and protect the end consumers.

1.4 AIM OF THE RESEARCH

The research aims at creating evidence-based awareness and providing continuous education especially for vulnerable groups regarding the risks associated with pathogens in Milk Products.

1.5 PURPOSE OF THE RESEARCH

The Purpose of the study is to generate data that would influence the regulatory bodies to make hygiene indicator microorganisms testing critical for all processed milk and milk products offered for sale.

1.6 OBJECTIVES OF THE RESEARCH

1.6.1 General Objective

To assess knowledge, handling practices of consumers and microbiological safety of processed milk products sold in Nairobi County.

1.6.2 Specific Objectives

i. To determine consumers' knowledge and handling practices of Milk and milk products.

ii. To establish the prevalence of TVC, *E. coli*, *Staphylococcus aureus* and Listeria monocytogenes microorganisms' contamination on processed milk and milk products.

iii. To determine implementation of GMP in milk processing systems by the processors for control of TVC, *E. coli*, *Staphylococcus aureus* and *Listeria monocytogenes* microorganisms' contamination.

1.7 RESEARCH QUESTIONS

i. Are consumers aware of the risk of *Microorganisms in processed milk?*

ii. Is E. coli, Staphylococcus aureus and Listeria monocytogenes absent in all processed products sold in Nairobi County?

iii. Have all milk products processors implemented effective milk processing systems GMPs necessary to control *TVC, E. coli*, *Staphylococcus aureus* and *Listeria monocytogenes* microorganism's contamination?

CHAPTER TWO: LITERATURE REVIEW

2.1 HISTORY AND GENERAL OVERVIEW OF MILK PRODUCTION IN KENYA

While the agricultural sector contributes about 24 percent of the Kenyan GDP, the dairy sector contributes about 12 percent of the agricultural GDP in Kenya (Zavala Nacul & Revoredo-Giha, 2022). Therefore, the sector is significant in the agricultural sector, thus attracting a lot of research efforts from researchers both from East Africa and other regions. In this line, many peer-reviewed research studies have been published regarding dairy farming in Kenya, especially on the issue of milk hygiene in the different counties in Kenya. The segment at hand aims to review some of the information given in these research studies regarding the topic at hand and give an overview of how these research studies were essential in building a foundation for the current research. Additionally, the gaps in these peer-reviewed studies are identified, and the context of how these gaps will be bridged is given.

2.2 GENERAL CONTEXT OF MILK HYGIENE IN THE KENYAN DAIRY INDUSTRY

According to Kagera *et al*., (2019), the dairy farming sector in Kenya is generally associated with lower hygiene practices due to low adherence to the standards of milk quality by many farmers. From milk production to the point where this commodity reaches the final consumer, the hygiene problem is prevalent in the dairy sector. Small-scale farmers feed their animals with feeds containing different contaminants such as aflatoxins. These substances then find their way into the milk produced by the animals. Additionally, the milk processes and the containers used are not adequately hygienic (Nyakobi *et al*., 2021). In addition to the unhygienic measures during production, fresh milk is frequently distributed to the general public unpasteurized, either directly from the producers, through unofficial marketplaces, or dairy farmer cooperatives. Resources are exceedingly few, and the degree of cleanliness and productivity in smallholder farming is subpar (Holi *et al*., 2021).

Though hygienic practices are not observed in the latter, milk remains an essential part of the Kenyan diet (Zavala & Revoredo-Giha, 2022). A handful of research has thus been done regarding the issue of milk hygiene from the consumer's perspective. According to research by, Kagera, & Grace (2018), most milk consumers in Nairobi consume fresh, unpasteurized, and UHT milk. A majority of the Kenyan consumers do not consume raw milk; according to Zavala & Revoredo-Giha (2022), 95 percent of the milk consumers in Nairobi boil the milk before consuming this commodity. However, there are a number of contaminants that do not get eliminated by boiling. The issue of aflatoxin in milk is still a significant problem in the dairy sector in Kenya. The substance is an essential problem in the processed food products sold in the country.

2.3 HYGIENE INDICATOR MICROORGANISMS: HISTORY, FAMILY, SPECIES, PATHOGENESIS, AND BACKGROUND

In addition to the issue of toxic substances in milk and milk products, approximately 19 percent of the food loss from households and food stores is associated with dairy products. A major part of the loss (spoilage) is attributed to the food's poor sanitation and post-naturalization contamination, either at the consumer level or processing level (Hoffmann *et al*., 2022). Globally, industries have used bacterial groups such as coliforms, total plate count (TPC), coliforms, and Escherichia coli; Staphylococcus aureus has been used as sanitation indicators in dairy products.

German pediatrician Theodor Escherich first recognized *Escherichia coli* in 1885 under the name *Bacterium coli* commune (Holsinger *et al*. 1997). The primary facultative anaerobe in the intestine and a vital component of the intestinal flora that preserves the host's health, *E. coli* is widely dispersed in the intestines of humans and warm-blooded animals (Croxen & Finlay, 2010). *E. coli* belongs to the *Enterobacteriaceae* family, which also includes many other species and well-known diseases like *Salmonella*, *Shigella*, and *Yersinia*. Although the majority of E. Coli strains are not considered pathogens, they can opportunistically infect immunocompromised hosts as opportunistic infections. Additionally, ingestion of some pathogenic strains of E. coli can cause gastrointestinal illness in otherwise healthy individuals. (Holsinger *et al*.,1997). in people who are otherwise healthy

Pantoja *et al*., (2011) elucidate that Shardinger proposed using *E. coli* as a fecal contamination indicator in 1892. Which was based on the idea that *E. coli* is prevalent in human and animal waste and uncommon in other environments. *E. coli* was additionally simpler to isolate than recognized gastrointestinal pathogens since it was simple to identify by its capacity to ferment glucose (later changed to lactose). Therefore, it was understood that the presence of *E. coli* in food or water was an indication of recent fecal contamination and the presence of other potentially dangerous infections.

It was difficult to use *E. coli* as an indirect predictor of health risk, despite the validity of the theory, since other enteric bacteria, such as *Citrobacter*, *Klebsiella*, and *Enterobacter*, can ferment lactose as well and are phenotypically similar to *E. coli*, thus hard to separate (Croxen & Finlay, 2010). As per Brenner *et al*., (1996), coliform was created to designate this class of intestinal bacteria. Coliform refers to a collection of Gram-negative, facultatively anaerobic, rod-shaped bacteria that digest lactose to create acid and gas in less than 48 hours at 35°C. It is not a taxonomic classification. Coliforms were simple to identify, but their link to fecal contamination seemed dubious as certain coliforms are normally present in environmental samples. As a result, fecal coliforms were first used as a contamination indication. Fecal coliforms are a subset of total coliforms that grow and ferment lactose at high incubation temperatures; they are also known as thermo tolerant coliforms. The term "fecal coliform" was initially coined based on the research of Eijkman. With the exception of water, shellfish, and harvest water studies, which utilize 44.5°C, fecal coliform assays are carried out at

45.5°C for food testing. The majority of the fecal coliforms are *E. coli*; however, other enterics like *Klebsiella* may also ferment lactose at these temperatures and are thus included in the fecal coliform category. The working definition of fecal coliforms now includes *Klebsiella spp*., which lessens the association of this group with fecal contamination. As a result, *E. coli* has come back into use as an indication, which has been made possible in part by the development of better techniques for quickly identifying *E. coli.*

Even though they are used for different purposes, all three categories are being used as indicators. Coliforms are used as a broad indicator of hygiene in the context of food processing or as a particular indicator of the hygienic quality of water. However, fecal coliforms remain to be the preferred signal for shellfish and the oceans where shellfish are gathered. *E. coli* is utilized to indicate recent fecal contamination or unsanitary processing. Lactose fermentation is the basis for majority of enumeration methods used to identify *E. coli,* total coliforms, or fecal coliforms (Selover *et al*., 2021).

On the other hand, *Staphylococcus aureus* has long been acknowledged as one of the most significant germs that harm people. It is the most frequent factor in soft tissue and skin infections, including cellulitis, skin rash, and abscesses (boils) (Orenstein, 2011). Despite the fact that the majority of staph infections aren't dangerous, *S. aureus* does cause some serious infections, including bloodstream infections and pneumonia, as well as infections of the bone and joints. A genus of gram-positive, spherical bacteria called *Staphylococcus* often causes food poisoning, respiratory illnesses, surgical and skin infections, and skin and skin infections. *Staphylococci* were initially identified in pus from a surgical abscess in a knee joint in 1880 by Scottish surgeon Sir Alexander Ogston, who said that "the lumps looked like bunches of grapes." German doctor Friedrich Julius Rosenbach identified several bacteria in 1884 based on the color of their colonies, including *S. aureus* and *S. Albus,* which was later called *S. epidermidis* due to its prevalence on human skin (Taylor & Unakal, 2021).

The last step is the total plate count, which is the count of mesophyll organisms that develop in aerobic circumstances at temperatures between 20 and 45 °C. This count, which takes into account both pathogens and non-pathogens, is used to gauge how sanitary the food being prepared is. The majority of factory tests are conducted using this method. The concept behind colony forming units, or CFUs, is that a single, visually invisible bacterium will develop into a cluster or colony when coming into contact with the necessary nutrition, temperature, and space, at which point it will become visible. Another common counting technique is a statistical technique known as the MPN approach. Here, counting is based on colonies that may develop in a succession of three, five, or even ten tubes of liquid media with varying concentrations (Arifan *et al*., 2019).

2.3.1 *Listeria monocytogenes*

At the beginning of the 20th century a Gram-positive rod-shaped bacterium was first isolated from tissues of infected patients. Hulphers isolated a similar bacterium in 1919 from rabbit liver and named *Bacillus hepatis*. The name monocytogenes was first used in 1926, by Murray and his team after isolating a new bacillus in rabbits and guinea pigs.(Ediron *et al*., 2014). To honor Lord Joseph Lister, the bacterial was renamed *Listerella hepatolytica* by Pirie in 1927. Two years later in 1929, the bacterium was isolated in humans for the first time. In 1940, it was given the name that it's still know by currently; *Listeria monocytogenes* (Ediron *et al*., 2014).

Recognized as a human pathogen for over 70 years, *Listeria monocytogenes* has been identified as a critical food-borne disease-causing bacteria, though rare in occurrence, it has a high mortality rate (Piet *et al*., 2016). *Listeria monocytogenes* is known to be resistant to many environmental due to its unique characteristics that allows it to thrive at refrigeration temperatures, PHs and with an ability to form biofilms that make eradicating it a challenge especially in the food processing facilities (Colagiorgi *et al*., 2017). *Listeria Monocytogenes* causes human listeriosis which is a mild non-invasive gastrointestinal illness or can cause Listeriosis symptoms include: Gastroenteritis Fever Diarrhoea, Muscle pain, Nausea, Vomiting Fatigue. Severe forms of listeriosis may cause encephalitis, Meningitis, Stillbirth and Abortion Pregnant women (FAO/WHO, 2004).

2.3.1.1 *Listeria monocytogene* species

Listeria is a genus of Gram-positive, non-spore-forming, catalase-positive rod-shaped bacteria that were previously classified as members of the *Corynebacteriaceae* family. *Listeria monocytogenes, Listeria innocua*, *Listeria seeligeri*, *Listeria welshimeri*, *Listeria grayii,* and *Listeria ivanovii* are the six species that make up the phylogeny (Wiedmann, 2002). These species appear as small rods with a diameter of 0.4 to 0.5 and a length of 1-2 µm. When examined under a microscope, they are sometimes seen to be grouped in short chains. These species also develop flagella at normal temperature, exhibit a tumbling motion in broth, and exhibit a swarming motility on semi-soft agar at 30°C. Ubiquitous in nature *Listeria spp* are commonly isolated in soil (Weis *et al.,* 1975), in water (Watkins *et al.*, 1981), in sewage and manure (Colburn *et al.*, 1990), in vegetation (Weis *et al.* 1975), in animal feed (Wiedmann *et al.*, 1996), and also in farm environments (Nightingale *et al.* 2004). The species possess unique physiological characteristics that allow their growth to occur at low (refrigeration) temperature (Orsi *et al.*, 2011).

Compared to the other species of the genus Listeria, *Listeria monocytogenes* is the causative agent of listeriosis (Vitas and Garcia-Jalón, 2004). This species is a food-borne pathogen that is gram positive and facultative intracellular that affects humans, notably in those with weakened immune systems, such as the elderly, pregnant women, and new-borns. (Kang *et al*, 2013; Thomas *et al.,* 2015).

Because the species is widely distributed in the environment, the bacterium can easily spread and cause infection. Razavilar and Genigeorgis, (1998) reported that this species can survive and proliferate under low temperatures, varying pH, high concentrations of salt or bile, oxidative stress, carbon starvation, and other unfavourable environments making it a critical risk in foods. There are thirteen distinct serotypes of *Listeria monocytogenes* strains now known, although serotypes 1/2a, 1/2b, 1/2c, and 4b account for nearly all human listeriosis cases. (Salcedo *et al.* 2003).

2.3.1.2 *Listeria monocytogenes* species transmission

Consumption of food that has been contaminated, such as unpasteurized milk or contaminated ready-to-eat foods is one of the ways it enters the body (Linnan *et al.*, 1988). Other routes include transfer of the organism from mother to foetus in utero, directly to the foetus at birth, or through direct contact with microorganisms can cause skin lesions (McLauchlin, 1990). Food contamination with *Listeria monocytogenes* may be as a result of inappropriate preparation, poor washing, and inadequate cooking temperatures, storing food in incorrect refrigeration temperatures and cross contamination of cooked and uncooked foods (Montville and Matthews, 2005). It's challenging to control due to the pathogen's ability to survive and proliferate in a variety of habitats and hosts, as well as its multiple modes of transmission.

2.3.1.3 Listeriosis disease

Listeriosis disease caused by *Listeria monocytogenes*, with fatality rates up to 20-30%, it's one of the most significant zoonotic diseases (Kasalica *et al.,* 2011). According to WHO, *Listeriosis* is ranked as a significant and acute food-borne diseases, (WHO, 2003). *Listeriosis* is a serious emerging diseases threatening human health as a result of consuming contaminated animal foods. (Van de Venter, 1999). Some of the factors that contribute to high cases and outbreak rates in developing countries include poverty, lack of education, poor hygiene, poor environmental hygiene, and inadequate infrastructure. The significant change eating habits brought about by the modern lifestyles, with a high demand for ready to eat meals especially in developed countries, and an increase in consumption of take away foods (Lopez-Valladares *et al.,* 2018) which raises the likelihood of pathogen contamination (Ndieyira *et al.,* 2017). This disease causes wide ranges symptoms including; gastroenteritis, fever, diarrhoea, muscle aches, nausea, vomiting and fatigue; however, severe forms may result in encephalitis, meningitis and abortion in pregnant women (FAO/WHO, 2004).

2.3.2 *Listeria monocytogenes* in milk and milk products

Humans contracting *listeriosis* via animal sources has been found to sometime also be an occupational hazard, particularly among farmers, butchers, poultry workers, and veterinary surgeons. *Listeria monocytogenes* contamination of food can occur anywhere along the food value chain, which include farms, food manufacturing premises, selling points, and people's homes (Saunders, 2006).

Listeria spp is a prevalent contaminant in the dairy farms (Castro *et al.,* 2018). Actually, animals' excrement and raw milk have been considered as major sources for *Listeria bacterium* in the dairy environment and the oral-feacal cycle was revealed as a path way for pathogen persistence in the farm (Nightingale *et al.,* 2004).

In several countries, this species has been found in raw milk and dairy products. (Wu *et al.*, 2015). It can grow and survive in raw milk at a variety of temperatures, pH levels, and salt concentrations. (Gahan *et al.*, 1996). The pathogen has been reported in animals such as sheep, goat and cow milk and is considered as a potential source of contamination of raw milk and dairy products, and outbreaks subsequently (Rahimi and Momtaz, 2012). Different rates of the pathogen incidence have been reported (3.4% to 6.0%) in raw milk (Hunt *et al.* 2012). Therefore, fresh raw milk poses a high-risk since it is refrigerated but do not undergo any substantial heat treatment before consumption. According to a study on the prevalence of *Listeria monocytogenes* isolated from milk samples and other dairy products, this organism can also be found in the pasteurization equipment similar to sample of pasteurized milk taken after pasteurization at 72.6°C for 15 s (Navratilova *et al.*, 2004). Defects in technology especially due to inadequate temperature and processing faults may also cause contamination with *Listeria monocytogenes* even after pasteurization. Therefore, its presence in milk is due to either the failure of pasteurization or post-contamination. (Lee *et al.,* 2019**).** Furthermore, according to a study, *L. monocytogenes* is most commonly found in the milk-processing area, including steps, drains, and floors (Kells and Gilmour, 2004).

In addition, Furthermore, a previous investigation from Finland suggested that pasteurized milk-based dairy products could get post contaminated by *Listeria monocytogenes* during the subsequent manufacturing process. (Lyytikainen *et al.,* 2000). The bacteria occur in soft cheeses, butter, yoghurt (Molla *et al.,* 2004).

2.3.3 *Listeria* in the food processing environment

Listeria is a major problem for many food processors because the circumstances in which food is processed and the environment in which it is processed allow it to thrive. For example, this species can grow in a wide variety of temperatures (e.g., 1°C to 45°C), varying pH conditions (e.g., 4.3-9.5), low water activity (>0.90), and high salt concentrations.(Piet *et al*., 2016). Many studies have shown that *Listeria monocytogenes* may colonize, reproduce, and persist in the food processing environment and food processing equipment, which demonstrates the pathogen's environmental survival properties. (Ulusoy & Chirkena, 2019). Overall, Listeria is a remarkably adaptive pathogenic microorganism that can survive freezing, chilling and dehydration on the surface.; however, *Listeria* can be destroyed at pasteurization temperatures above 60 °C for 30 min.(Edition *et al*., 2014).

2.3.4 Pathogenicity of Listeria monocytogenes species

After consumption, the pathogen goes through the intestinal barrier into the blood and lymphatic system and starts to multiply once it reaches the liver and spleen (Andersson *et al.,* 2015). Normally an infection usually begins with the intake of bacteria through contaminated foods that may be resistant to the proteolytic enzymes of the host in the stomach, which is extremely acidic (pH 2.0), contains bile salts, and has non-specific inflammatory assaults. The pathogen's capacity to survive and progress past this stage is dependent on an RNA polymerase (RNAP)-alternative sigma factor protein subunit. (Sleator *et al.,* 2003). Following ingestion, both passively by phagocytosis and aggressively through the activity of listerial surface proteins termed internalins, the pathogen clings to and penetrates host cells. The InlA binds to the surface of the host's epithelial cells with the help of protein E-cadherin. The binding process stimulates the organism's phagocytosis (Kuhn and Goebel, 1999). Listeriae are further engulfed into a single membrane layered vacuole. The listeriae within the vacuoles are destroyed by the phagocytic cells, and they will only survive if they escape the vacuole. Another protein, Listeriolysin, plays a role in the disease's pathophysiology. It’s critical for lysing the vacuolar membrane and thereby enabling the *Listeria monocytogenes* to exit into the cytoplasm (Vazquez-Boland *et al.,* 2001).

In the cytoplasm, the *Listeria monocytogenes* replicates and spreads to new host cells for food. With the aid of Act A, which is a surface protein that causes the polymerization of globular actin molecules to generate polarized actin filaments, the cells will travel to the cell membrane and bulge outwards, generating *listeriopods* (Lopez *et al.,* 1999). The *listeriopods* will subsequently be absorbed by neighbouring cells, allowing *Listeria monocytogenes* to spread while avoiding the host's immune system. The bacteria are then transferred from the colon to the liver and spleen, where neutrophils aided by Küpffer cells kill the majority of them (Doyle, 2005). If the host's T cell–mediated immune response is insufficient, Listeriae will quickly grow in hepatocytes and macrophages and will be transferred via the blood to numerous organs, including the brain and or uterus, where they penetrate the blood–brain barrier and the placental barrier (Doyle, 1987).

2.3.5 Prevention and control of *Listeria monocytogenes*

Separate raw milk handling locations and equipment, from pasteurized product handling areas and equipment, as well on-farm processors should implement control measures and procedures that prevent cross-contact of the dairy farm environment with the processing environment for instance different workers, shower and change of clothes/boots, controlled traffic. Also ensure that equipments are adequately cleaned and sanitized and the waste water is properly handled and directed to a well-designed drain. Furthermore, *Listeria monocytogenes* isolates are susceptible to a variety of antibiotics, particularly ampicillin/penicillin, which are the principal antibiotics used to treat listeriosis. (Wieczorek *et al.,* 2012). However, recently there have been reports of resistance of

Listeria monocytogenes strains to single or multiple antibiotics from samples isolated from many other foods and environments (Bertsch *et al.,* 2014). As a result, more study is needed to increase the amount of data available on the prevalence and antibiotic susceptibility of *Listeria monocytogenes* isolated from samples.

2.3.6 Detection and isolation of *Listeria monocytogenes*

The traditional methods for detection and isolation of *Listeria monocytogenes* have been a challenge especially due to the length of time it takes and also detection or isolation of injured *Listeria* cells is not possible, traditionally the bacteria were left to grow in agar plates under chill temperatures of 4 °C until the bacteria colonies grow to a visible size. Because of the time taken for the test to be concluded, more improved test methods were introduced.

2.3.6.1 Enrichment method

Isolation of *Listeria spp* have been done through traditional method whereby a pre-enrichment culture like the LEB (*Listeria spp* enrichment Broth) is used. 25g of the food sample is added to 225mls of the LEB, the sample is then split into 10mls portions and incubated at 30 °C for 24hrs.

2.3.6.2 Selective Enrichment method

After the 24 hours above 0.1ml of the LEB enriched culture is then added to 10ml of modified Fraser broth (MFB) at 20°C and then incubated for a further 2 to 6 hours then results read. Positive, if streaks of MFB are noticed and may appear black or dark brown in colour of a newly made, PALCAM *Listeria* selective agar medium containing special supplements can also be used as an enriched selective media. The ISO 11290-1:2017, which is the standard for detection and enumeration of *Listeria monocytogenes* and of *Listeria spp* in food and feed using the horizontal method can also be used. The methods use the enrichment methods. Acriflavine and Nalidixic acid is used as the primary selective media followed by Fraser broth. Immunoassay (ELISA) is also another method used in detection and isolation of *Listeria spp*, the method is based on *Listeria* antibodies detection, the method is not new and has been used for many years to screen for *Listeria spp*. It's popular because of its simplicity, sensitivity, and accuracy, as well as the fact that testing can be done immediately from enrichment material without the need for time-consuming sample preparation.

2.4 PREVENTION AND CONTROL OF THESE SPECIES

There are a number of ways through which farmers, processors, and final consumers can use to prevent these species. For example, good milking practices, keeping a dry, clean-living environment with the right bedding materials, and immunizing animals are all part of the practices for reducing *E. coli*. All quarters should be fore stripped prior to milking in order to start the milk let-down procedure. On the other hand, the adoption of the tightest hygienic procedures on the farm, particularly during the milking process, as well as milk storage and transit to the dairy sector, is the greatest approach to preventing coliforms from contaminating the milk (Ekici & Dümen, 2019). The problem of

Staphylococcus aureus is better controlled from the side of the final consumer. Avoiding unpasteurized milk, keeping food preparation areas clean and hygienic, and properly washing hands and fingernails prior to preparing, eating, or serving food are all necessary precautions to take in order to avoid contracting food poisoning from this species. Additionally, one avoids preparing food for other people if they have wounds or sores on their hands or wrists, and one should also refrigerate hot meals at temperatures over 60 C and cold foods under (McCabe-Sellers & Beattie, 2004)

2.5 CONCEPTUAL FRAMEWORK

Figure 2.1 shows the interaction between indicator microorganisms in milk products with respect to handling practices, consumer awareness, analysis and processing methodologies.

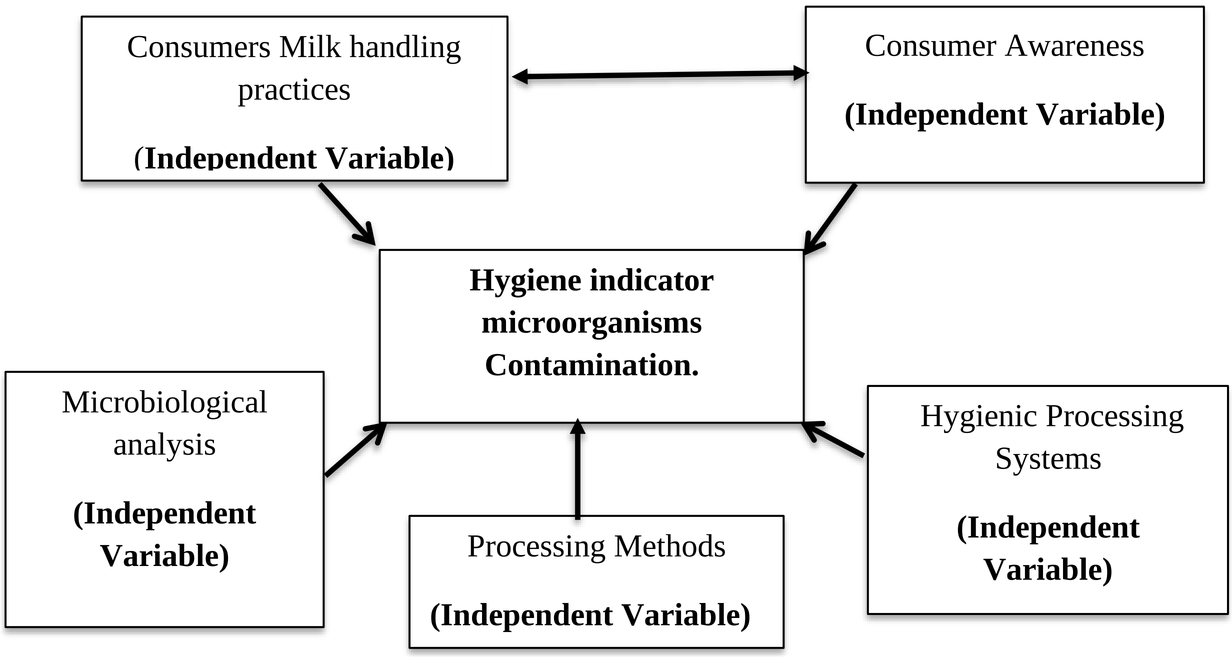

Figure 2. 1: Conceptual Framework

2.6 KNOWLEDGE GAP

Most studies have addressed the issue of milk sanitation and the use of hygiene indicator microorganisms such as coliforms in dairy food safety. However, these studies do not address the issue of knowledge about milk hygiene and practices of handling milk products by consumers in Nairobi County so as to avoid contamination. No study specifically focuses on addressing the issue of the prevalence of hygienic indicator microorganisms in processed milk products sold in Nairobi County. The information is essential in ensuring dairy food safety for the consumers of milk and milk products in Nairobi City County. In this line, the study at hand seeks to bridge this gap by analyzing the knowledge and handling practices of milk product consumers, the safety of milk processing systems, and the prevalence of hygiene indicator microorganisms in processed milk products sold in Nairobi County. There are no records on *Listeria* outbreaks in the country, most of the information obtained mentions gastroenteritis which can be a condition for most of the pathogen’s contamination including salmonellosis or even *E. coli*.

CHAPTER THREE: KNOWLEDGE AND HANDLING PRACTICES OF CONSUMERS OF MILK AND MILK PRODUCTS IN LANGATA AND KIBRA SUB-COUNTIES, NAIROBI

ABSTRACT

Milk is a source of essential nutrients needed by the body. However, poor knowledge and inefficient handling practices may make milk products a source of food-borne diseases. Therefore, this study was carried out to assess the level of knowledge and handling practices among consumers of milk products in Langata and Kibera Sub-counties within Nairobi County. Data was collected through structured questionnaires and was delivered through face-to-face interviews among 360 respondents determined using Fisher's formula and then analyzed using SPSS. Results showed that most of the respondents were females (51%) and were mainly in the age of 29-38 years (47.4%). Most (37%) of the respondents had attained secondary education followed closely by those who had primary (28%) and tertiary education (27.9%). Fresh milk was the most consumed milk product at 94% closely followed by yoghurt (93%) with ice cream and cheese trailing. About 69.9% of the respondents consumed fresh milk on a daily basis, while 53.7% consumed yoghurt on a weekly basis, however, 37.3% rarely had yoghurt and just about 27% of the respondents indicated that they had ice cream while majority (65.2%) indicated they rarely had ice cream. A trend that can be reported for cheese, where nearly all the respondents (96%) rarely consumed cheese. About 77.7% of the respondents did not drink milk immediately after purchase while 54% of them stored purchased milk in fridges for later use. More than 91% of the respondents boiled milk before use while nearly 90% of the respondents used milk for tea preparation. It was also noted that most of the respondents (59%) owned a fridge and out of these, 15.6% boiled milk to make it last longer while 39.6% used it immediately. Boiling and refrigeration were the most preferred methods for maintaining the quality of the milk products. The majority of the respondents (78%) were knowledgeable on the process of milk packaging as a measure of ensuring milk safety. Furthermore, chi-square tests showed an association between the education levels of milk consumers and their parametric choice on good quality milk (*P=0.000*). In conclusion, the level of education for the majority of respondents could be considered sufficient about milk processing and temperature. In addition, many of the respondents indicated that they had a good knowledge of hygiene measures. The public health sectors and related stakeholders have a duty to sensitize and create awareness to the milk consumers on the risks and implications of consumption of milk contaminated with Listeria and other pathogens and ways of protecting the health of these consumers.

3.1 INTRODUCTION

Milk is rich in a variety of nutrients and plays an important role in helping the body meet its calcium, magnesium and selenium requirements, as well as riboflavins, vitamins B12 and pantothenic Acid

(Vitamin B5) requirements. However, milk must be both safe and nutritious. Various factors affect the safety and health of milk intended for human consumption among them risky behaviours including improper handling and consumption (Amenu *et al*., 2019). For milk products to be safe, wholesome and suitable for human consumption, The Kenya government through the Dairy Industry Act cap 336 prohibits the sale of raw milk to consumers (CAP 336, 2012). The milk must be pasteurized prior to conversion into any other milk product. In order to pasteurize milk or milk products, each particle of the milk must be heated to one of the specified pasteurization time/temperature combinations using equipment that has been correctly constructed and is being used. The most popular pasteurization method involves rapidly heating milk to at least 63°C and holding it for a minimum 30 minutes, or at least 72°C for 15 seconds (Lucey, 2015) followed by rapid cooling to 4°C with the aim of destroying all pathogens present in milk.

Though some people may be worried about the nutritional effect of pasteurization on raw milk, it has been proven that pasteurization is a reliable technique for enhancing milk's safety and increasing its shelf life without any significant change to its nutritional value. Milk that has been pasteurized is not inferior nutritionally when compared to raw milk, however its safest and most wholesome when it comes to control of illnesses (Hoque & Mondal, 2019). It's just as well since, most consumers in Nairobi perceive processed milk as safe and of good quality; this is according to a study conducted by International Livestock Research Institute in April 2020 on Consumer perception of milk safety in Kenya (Mtimet & Karugia, 2020). Consumers play a big role in ensuring products maintain their good quality and remain safe for consumption, Consumers need to make sure that the food they buy is transported, handled, and prepared correctly in order to get the full nutritional value out of the food and avoid unnecessary health hazards. Poor food handling during food preparation and storage can reduce the nutritional value of the food, make it less nutritious, or contaminate it, resulting in a health hazard. (Zhou *et al.,* 2020). Studies have shown that Kenyans typically boil their milk before drinking it, reducing the amount of microorganisms' present. As evident, it's impractical to boil milk products such as ice cream, cheese, butter or yoghurt, therefore any pathogen present will end up being consumed (Mtimet & Karugia, 2020).

There are food legislation managing and controlling the handling and manufacturing processes in manufacturing industries and storage and handling in selling points however there are no controls on how the consumers handle, prepared and store food after purchasing. Therefore, it's possible that foodborne outbreaks could start when food is prepared and served in homes and not from the manufacturers. According to the findings of a number of consumer surveys regarding food safety, although consumers are concerned about food safety, they continue practices that have the potential to cause foodborne illnesses. Food handling, consumption, and storage practices vary among consumers based on factors such as income, gender, age, and ethnicity(Bolek, 2020).

To ensure safety and quality of milk, consumers must have good hygiene of the milk environment, boil, or pasteurization before consumption (FAO, 2013). However, such practices are not common with consumers and as a result milk is stored under unhygienic conditions leading to high accumulation of microbial load and spoilage which have health risks to the consumers. Though customers have their own parameters for checking good quality milk products, they rely on the expiry date, smell, colour and taste to confirm the quality of the product they have purchased, pathogens are not spoilage bacteria and as such may not have any change in the organoleptic properties of the milk products. Expiry date may also not be an indicator of good quality and safe milk product because contamination with pathogens can happens even on freshly made batches of products(Lu *et al*., 2013). According to Fischer, unsafe food consumption is the outcome of the interaction between actual food production, processing, and consumption methods, as well as public beliefs. when considering the other risk managers in food safety management including the manufacturers and policy makers, it's important to also regard the consumer as a risk manager, since inappropriate consumer food handling habits can lead to sickness and disability (Fischer *et al*., 2005). Consumers must ensure that the set temperatures requirements are maintained, it is important for consumers to make sure that no milk products they buy are kept at room temperature, as they may result in proliferation of bacteria, they should buy the products as they are leaving for home, rather than while they are still running errands. If the milk product is not going to be consumed right away, they should be refrigerated to prevent the growth of bacteria. Appreciating the role consumers plays in ensuring food safety, this study was therefore sort to demonstrate the knowledge and handling practices of consumers of milk and milk products in Nairobi County.

3.2 MATERIALS AND METHODS

3.2.1 Study Area

The study was done in Nairobi County. Nairobi is the capital city of Kenya, it's also the largest in terms of the population, as at 2019 census with a population of 4,397,073. Administratively, Nairobi has 17 sub-counties with Constituencies. Langata and Kibra constituency was purposely selected because of the accessibility since Langata constituency has common boundaries with Kibra constituency (Figure 3.1). The 2 constituencies also have the different income groups, High- and affluent-income group being Karen, both upper and lower Middle income being Langata and finally Low income being found in Kibra constituency this was important to finding people with different levels of education, exposures and purchasing patterns. The 2019-Kenya-Population-and-Housing-Census, showed that Kibera population is 185,777 people and Langata 197,489. Kibra constituency covers an area of about 12.10 km^2, and has five wards namely Makina, Laini-saba, Lindi, Woodley and Sarangombe. Langata constituency covers an area of 223 km^2 and also has 5 wards namely, Karen, Nairobi west, Mugumoini, South C and Nyayo Highrise as shown in figure 1, which were all included in the study. Figure 3.1 below show the area covered in the study.

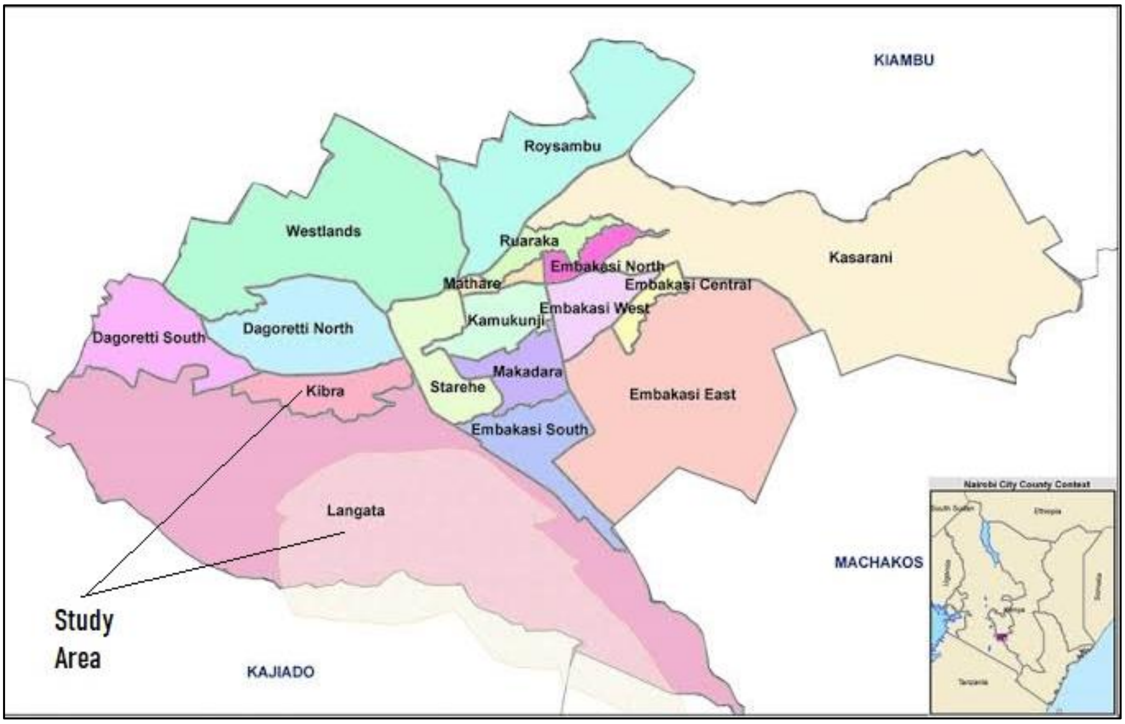

Figure 3.1: Map of Nairobi City County. Source: https://nairobi.go.ke/

3.2.2 Research Design

A cross sectional design was used to conduct this study. Consumers were randomly interviewed using a structured questionnaire on their knowledge and understanding of good quality milk products as well as their practices in handling the Milk products. The information was obtained from the consumers using face to face interviewing techniques.

3.2.3 Study population

The study population encompassed the members of the public within Langata and Kibra constituencies. The population was randomly picked for sampling and interviewed to understand their level of knowledge and awareness of milk quality and safety and specifically asked how they handle the milk prior to consumption.

3.2.4 Sample size

Using the Fisher's formula, a sample size of 426 consumers was obtained (Fisher, 1971)

$$n = \frac{Z^2 P(1-P)}{I^2}$$

Where:

n= Sample size [For population> 10,000]

Z= Normal deviation at the desired confidence interval at 95% = 1.96.

P= Proportion of target population to be interviewed (p=0.5)

I^2 = Degree of precision; was taken to be 5%

*Since the proportion of the population with the characteristic was unknown, then 50% was used.

Therefore,

$$n = \frac{1.96^2 * 0.5(0.5)}{0.05^2}$$

=384

The formula was adjusted for a situation where the milk consumers were less than 10,000. With an estimation of 4530 housing units in the area (Agayi, 2020), the estimated number households in the 10 wards were 453.

The formula becomes;

$$nf = \frac{n(1+n)}{N}$$

nf= Desired sample size

n=Sample size for and estimated population (384)

N=Estimated number of households (453)

We obtain: $nf = \frac{384(1+384)}{453} = 326.357 \approx 327$

By adding 10% attrition (+32.6 ≈33), the desired sample size was finally 327 + 33 = 360

An average of 120 respondents were randomly selected in each of the three sub-counties and questionnaires administered at their households, on the streets, and at milk vendor shops (40 respondents at each level).

3.2.5 Inclusion criteria

Any consumer over the age of 16 who participates in the preparation and or purchase of products and was willing and able to participate in the study was eligible to take part.

3.2.6 Exclusion criteria

Consumers below the age of 16 and those who purchase and consume unprocessed raw milk, unpackaged processed milk products including those sold at the milk ATMs and Milk bars were excluded from the study.

3.2.7 Method for Data collection of knowledge

Knowledge of consumers on food safety issues regarding Milk and milk products and their handling practices of the milk and milk products was established using a structured questionnaire in a face-to-face interview. Face to face interviews was conducted using developed questionnaires which had sections on demographics, food safety knowledge, and food safety practices. Knowledge of food safety topic included health and personal hygiene, such as hand washing, food handling, diseases related to food, milk handling practices and milk safety. The questionnaire was developed using the Open Data Kit (ODK) app accessible through smart phones. The questionnaire was divided into 2 sections namely A and B, with Section A mainly focusing on the demographic information with the main interest being in the age and education level, residence, milk products purchasing pattern and preferences and Section B focused in the knowledge on food safety and handling practices of Milk and milk products and consumers' knowledge on food borne diseases related to milk, had semi-structured questions.

3.2.8 Knowledge on milk handling practices and milk related diseases

To quantify the responses of each consumer on knowledge, the following formula by Singh and Gupta (2015) was used to measure the knowledge index of all aspects of milk handling practices

$$\text{Knowledge score} = \frac{\text{Score Obtained}}{\text{Maximum obtainable score}} \times 100$$

Knowledge on milk handling practices and milk related diseases was also obtained using a structured questionnaire in the face-to-face interview. A true-false set of questions was used to categorize consumers' knowledge which was categorized as high, medium or low.

3.2.9 Data analysis

Data from questionnaires were analysed in SPSS Statistics Version 20. The variables in the questionnaires were coded and descriptive statistics analysis done for all variables. Frequencies were determined for qualitative variables and mean, standard deviation. Values are given in the text as mean ± standard deviation. In addition, relationship between variables were examined using multiple regression.

3.3 RESULTS

3.3.1 Demographic characteristics of the respondents

The demographic characteristics of the consumers are summarized in table 3.1 below. Majority (51%) of the respondents were females while 49% were males. However, when looking at the population distribution per Sub County, Langata had the majority of females (18.1%) while Karen had the majority of males (17.3%). Majority of the consumers (47.4%) were in the age category of 29-38 years followed by those in the category of 39-48 years (23.7%). A few of the consumers were in the category of 59-68 years. The age distribution was normal and majority of the consumers from Karen were in the age category of 29-38 (17%).

The level of education was generally spread across the variables with 37% having undergone basic education (at least 12 years of schooling). Fascinatingly, 6.7% respondents had no education and 28% had primary level of education with a further 27.9% having attained college or university degree.

Table 3.1 and figure 3.2 below show the demographic characteristics and education levels of milk and milk products consumers.

Table 3.1: Demographic characteristics of respondents

Characteristics	Category	Percentage (n=426)			Overall
		Karen	Langata	Kibera	
Sex	Male	17.3	15.3	16.2	48.7
	Female	15.6	18.1	17.5	51.3
Age groups	18-28	5.3	7.2	8.9	21.4
	29-38	17.0	14.5	15.9	47.4
	39-48	8.1	8.9	6.7	23.7
	49-58	1.4	2.8	1.9	6.1
	59-68	1.1	0.0	0.3	1.4
Education	Illiterate	1.7	1.9	3.1	6.7
	Primary	10.3	6.7	11.1	28.1
	Secondary	10.6	13.1	13.6	37.3
	College /University	10.3	11.7	5.8	27.9

Out of the respondents who had a minimum of secondary school education, majority were employed (16%), (15.6%) self-employed while only 5.3% were unemployed. Of the respondents with tertiary education, 13% were employed, while 8.9% were in self-employment.

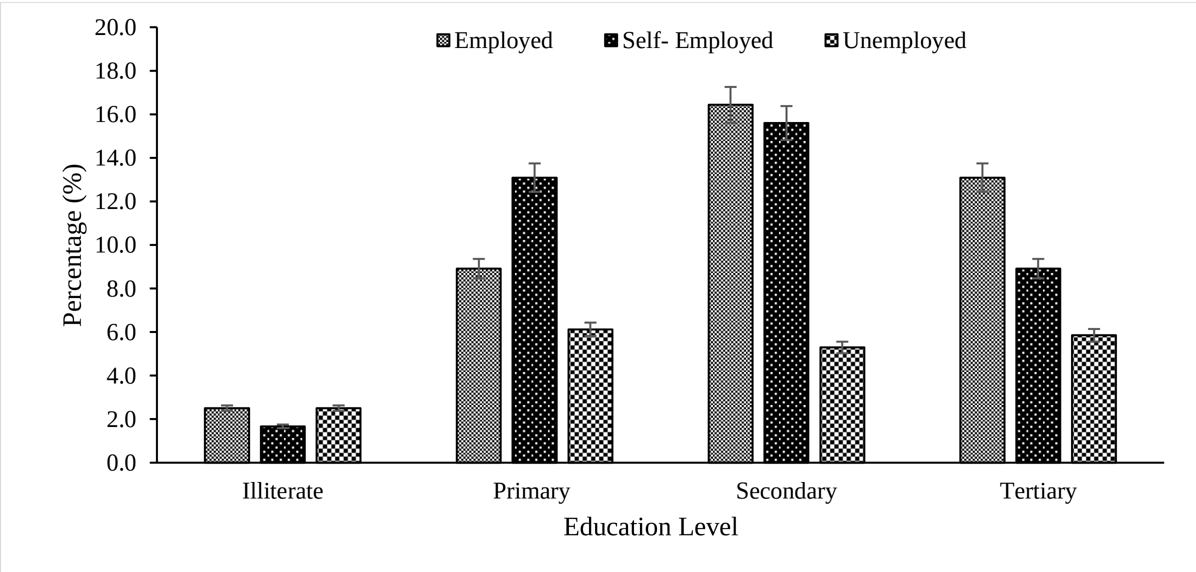

Figure 3.2: Employment status by level of education. The bars indicate prevalence (N=360)

3.3.2 Consumption of milk products

Nearly all the respondents consumed fresh milk (94%) and yoghurt (93.6%). Interestingly, 50% respondents consumed ice cream while only 15.8% consumed cheese. However, the consumption rate differed depending on the milk product. Figure 3.2 below is representative of consumption frequencies of milk and milk products.

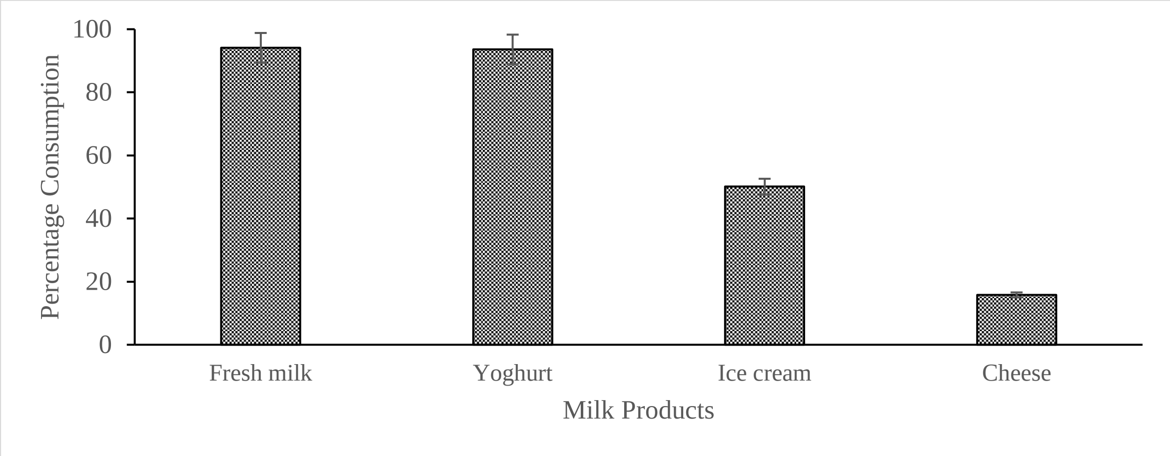

Figure 3.2: Percentage consumption of different milk products by consumers. The bars indicate consumption rate (N=360)

The vast majority of the respondents (69.9%) consumed fresh milk daily while only a few consumed milk on weekly basis (Figure 3.2). The least percentage of respondents (7.6%) indicated that they rarely consumed milk. Yoghurt was consumed by the majority of the respondents (53.7%) on weekly basis while quite a good number (37.3%) rarely had yoghurt. Just 27% of the respondents indicated that they had ice cream while overwhelming majority (65.2%) rarely had ice cream. A trend that can be reported for cheese, where nearly all the respondents (96%) did not consume cheese. Figure 3.3 below 3.3 below shows the consumption frequencies of milk and milk products in the study area.

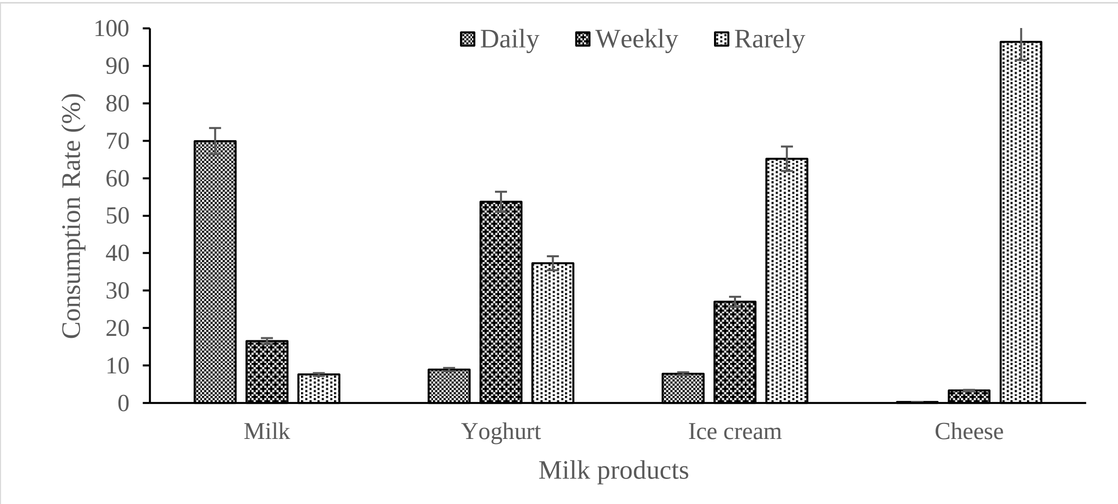

Figure 3.3: Frequency of milk products' consumption. The bars indicate rate of consumption (N=360)

3.2.3 Milk handling practices

Majority of the respondents (77.7%) reported to consume milk immediately after purchase while about 22.3% of them stored purchased milk in fridges for later use. It was also noted that more than 91% of the respondents boiled milk before use especially those with young children while nearly 90% of the respondents used milk for tea preparation (Table 3.2). Majority of the respondents (89%) consumed various milk products immediately after purchase, about 59% of the respondents stored the products in the fridge for later use while overwhelming majority (84%) did not use the products for preparation of other foods. The majority of the respondents (59%) owned a fridge and out of those who did own a fridge, 15.6% boiled milk to reduce microbial load while 39.6% used it immediately especially yoghurts and ice cream. The respondents also reported that they have in the previous occasions used milk that was not of good quality for use in making another food. For instance, some of the respondents used cheese for preparation of spaghetti while yoghurt was used in fruit salads. Table 3.2 below shows milk handling practices by consumers upon buying.

Table 3.2: Milk handling practices by consumers

Statement	**Response** (n=360)	
	Yes	**No**
Drink immediately after purchase (Direct consumption).	22.3	77.7
Stores in the fridge for later use	54.0	46.0
Boils before Use	8.9	91.1
Use for cooking (tea or other foods)	89.4	10.6
Take immediately after purchase (Direct consumption).	89.4	10.6
Stores in the fridge for later use	59.3	40.7
Use for Preparation of other foods	15.3	84.7
Do you have a fridge in the house?	59.3	40.7
Boil to keep fresh/ preserve	15.6	84.4
use immediately after purchase	39.6	60.4
Have you ever used any milk that was not good quality to convert to make another food?	89.4	10.6

3.3.4 Milk safety

The respondents were asked several questions on milk safety and the responses are detailed in the Table 3. A greater number of the respondents (78%) indicated that they knew how the packaged milk was produced, however some suggested that addition of chemicals as one of the ways of processing milk, 17% of the respondents were not sure and did not categorically indicate that they knew. When they were asked if processed milk can cause diseases, majority of the respondents (77%) implied that it was impossible while 20% of the respondents agreed to the statement and a few mentioned brucella while majority mentioned milk unrelated diseases, while approximately 3% were not sure. Majority of the respondents (86%) indicated that processed milk was safe for you use even without further action. It was also noted that 83% of the respondents could not name any disease related to consuming contaminated milk neither could they tell whether they have suffered from any foodborne disease caused by milk and milk products. It was also noted that majority of the consumers did not have any concern regarding safety of processed milk products. Table 3.3 is representative of the questions used to assess consumers' knowledge on milk and milk products' safety.

Table 3.3: Consumers knowledge on milk safety issues

	Response (%) (N=360)		
Statement	**Yes**	**No**	**Not sure**
Do you know how milk products are processed?	78.0	5.0	17.0
Do you know under which circumstances milk products cause diseases?	20.3	76.9	2.8
Do you understand how processed and packaged milk products can be kept safe?	86.9	13.1	0.0
Do you know any disease that can be caused by consuming contaminated milk products	5.0	83.0	12.0
Do you understand how processed milk products cause diseases to consumers?	93.04	2.23	4.74
Do you understand the microbiological mechanisms of milk spoilage leading to disease causage	97.21	2.79	0.0
Do you have any knowledge on public food safety concerns related processed milk products	31.2	68.8	0.0

3.3.5 Consumers knowledge on foodborne diseases related to milk products

Majority of the respondents (77.9%) had known how the packaged milk was produced, however, 14.5 did not know while 7.5% of the respondents were not sure (Table 4). It was also noted that majority (93%) indicated processed milk could cause diseases such as brucella, however, many confused allergies with milk related diseases, a few of the respondents indicated it was not possible while 4.7% indicated they were not sure. Majority of the respondents (97%) specified that processed milk was safe for you use even without further action while only approximately 3% suggested milk processed was not safe for drinking as it is. It was also noted that about 49% of the respondents did not know and could not name any disease related to contaminated milk, close to 35% were not sure and only 16.2% indicated they knew the disease but it was noted that they confused the allergies to milk related diseases. Majority (82%) indicated they had they have not suffered from any foodborne disease caused by milk products while a few (5%) reported they have suffered from milk related diseases. It was also noted that majority of the consumers (68%) did not have any concern regarding safety of processed milk and milk products but 31% of the respondents indicated they do.

3.3.6 Knowledge score regarding foodborne diseases related to milk

On food safety knowledge, it can be observed from Figure 3.4, that the majority of the respondents (60.4%) had medium knowledge of safety, followed by those (33.4%) having good knowledge on food safety. On foodborne disease related with milk, majority (53.4%) of the respondents had good knowledge level of foodborne diseases related to milk, followed by about 36.6% having medium knowledge level of foodborne disease related to milk. Chi-square analysis showed that there is an association between the education levels of milk consumers and their parametric choice on good quality milk (*P=0.000*). Figure 3.4 below shows knowledge assessment scores on foodborne diseases, and food safety.

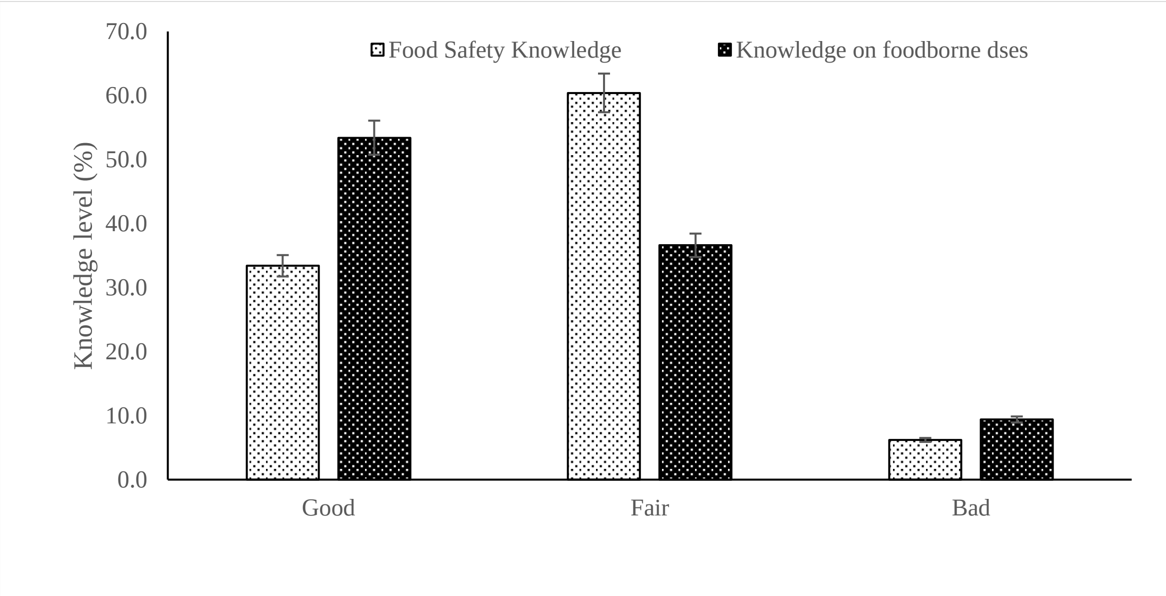

Figure 3.4: Knowledge score regarding foodborne diseases and food safety. The bars represent level of knowledge of consumers (N=360)

3.4 DISCUSSION

3.4.1 Demographic characteristics of the respondents

In the present study, using representative samples from Kibera and Langat Sub counties, we the current research aimed to report consumers' knowledge and handling practices of milk and milk products. Overall, large proportion of the respondents were females distributed across the study sites. This result is comparable to those of Rust *et al*., (2019), Selvakumar, (2018) and Ozdogan *et al*., (2017) where the proportion of female participants were more than men when assessing customer preference and satisfaction while purchasing raw milk. Majority of the consumers were in the age category of 29-38 years followed by those in the category of 39-48 years. This finding suggest that majority of milk consumers are young adults, a finding that is supported by those of Selvakumar, (2018) Ozdogan *et al*., (2017); Seker *et al*., (2012). The level of education was generally spread across the variables with 37% having undergone basic education (at least 12 years of schooling). Fascinatingly, 6.7% respondents had no education and 28% had primary level of education with a further 27.9% having attained college or university degree. The findings compare to those of Selvakumar, (2018) where all the age groups were represented, however, at different levels. Education level is linked with better milk and milk products consumption, a finding that has since been corroborated in numerous studies (Lee *et al*., 2002 and Kim *et al*., 2016).

3.4.2 Consumption of milk products

Nearly all the respondents consumed fresh milk and yoghurt. Interestingly, 50% respondents consumed ice cream while only 15.8% consumed cheese. This indicates an upward trend in milk and milk products consumptions among the city dwellers. This result is comparable to those of Shitu *et al*., (2008) where a large proportion of respondents consumed various quantities of milk because of the need for balanced diet. The same results were reported by Kubikoca *et al*., (2021) where in Slovakia among the consumers of milk and dairy products only 0.4% of the population do not consume milk and dairy products. Xu *et al*., (2019) and Hyera (2015) further indicated that majority of the respondents consume milk products. According to Ozdogan *et al*., (2017), milk is balanced food and contains a wide variety of vitamins, minerals and other nutrients (calcium, potassium, vitamin B2, vitamin B12, proteins, etc.). The majority of the respondents consumed fresh milk daily while only a few consumed milk on weekly basis. Yoghurt was consumed by the majority of the respondents on weekly basis while more than 37% of the respondents indicated they rarely had yoghurt. Majority rarely had ice cream (65.2%) and cheese (96%). Considering these results, it can be argued that milk products consumptions are at low level as majority of respondents consume milk and milk products less than once in two days on average. The consumption levels of milk product is influenced by factors such as monthly income, family size, education level, and food habits of the households. However, according to Kubendran and Vanniarajan, (2005), demand for the milk products depends the consumers capability to purchase Selvakumar, (2018) indicates that the socio-economic status of the consumers such as income status, occupation, education level and region as some of the major determinants of milk consumption. These findings contradict those of Kubikoca *et al*., (2021) where milk products consumption was at sufficient levels as many of the respondents (50.4%) reported consumption of milk products in the recommended levels.

3.4.3 Milk handling practices

The respondents had different ways of handling milk to ensure safety. Most of did not drink milk immediately after purchase while about 54% of them stored bought milk in fridges for later use. It was also noted that more than 91% of the respondents boiled milk before use while nearly 90% of the respondents used milk for tea preparation. The findings in this study corroborate those of Hyera (2015) and Wangalwa *et al*., (2016) where safe handling of milk products was practiced. Safe handling practices of milk were also highlighted by Sharma (2009) since milk gets easily contaminated because it is a great medium for the proliferation of bacteria. On the other hand, milk is perishable, and if it is not handled in a hygienic condition, its quality and safety may be compromised in a short period of time. Amenu *et al*., (2019) and FAO (2013) further clarifies that in ensuring safety of milk, good hygiene such as using milk grade containers, clean milking environment, refrigeration of milk, boiling before consumption must be practised.

Majority of the respondents consumed various milk products immediately after purchase while other respondents stored the products in the fridge for later use. It was also noted that majority of the respondents (59%) owned a fridge and out of those who did own a fridge, 15.6% boiled milk to keep it free of harmful micro-organisms while 39.6% used it immediately. The findings indicate that consumers majorly depended on refrigeration to cool milk. It is not possible to produce milk without some bacteria; therefore, efforts should be to prevent multiplication of the bacteria that have gained access through cooling the raw milk. Evidence from previous studies has shown that milk should be cooled at 4^{o}C to arrest the growth of bacteria and to maintain quality (Singh and Gupta, 2015). The results are similar to those of Wangalwa *et al*., (2016) where respondents endeavoured to reduce milk spoilage by cooling and boiling. A few of the respondents used boiling and used milk immediately as way of handling milk. The findings are similar to various studies in Kenya where majority of Kenyans boil their milk before drinking using it to reduce the number of microorganisms' that may be present. However, it's impractical to boil milk products such as ice cream, cheese, butter or yoghurt, therefore any pathogen present will end up being consumed (Mtimet & Karugia, 2020). The findings herein also mirror those of Amenu *et al*., (2019) where boiling as safe milk handling practice was not a common practice by the Borana pastoralists in Ethiopia. According to them as a community, boiling was not traditionally practiced, may destroy nutrient in milk and has no taste.

3.4.4 Knowledge on food safety and foodborne diseases

Majority of the respondents indicated they understand how packaged milk was prepared. However, this claim was not tested but according to Lucey, (2015) the most popular pasteurization method encompasses fast heating of milk to at least 63°C and holding it for at least 30 minutes, or fast heating at least 72°C and maintaining it there for at least 15 seconds followed by rapid cooling to 4°C with the aim of destroying all pathogens present in milk. The thermal treatment of milk is important in terms of high-quality final milk product (Kazimora, 2013). Majority of the respondents indicated that processed milk cannot cause diseases and that they were safe for you use even without further action. However, a few named brucellosis as one of the common diseases but in most cases confused them with milk allergies. As much the respondent had strong belief in processed milk, it is important to note that dairy processing facilities have many routes for entry of contaminating pathogens such as foot traffic from employees which can carry microbes (Koo, 2022). The findings mirror those of Deneke *et al*., (2021) where respondents indicated they knew the benefits of pasteurized milk but contradicts those of Angelilo *et al*., (2001) where a good number of respondents (36%) was aware of each of the six foodborne pathogens investigated but only 11.1% accurately named the six diseases. The consumption of pasteurized milk in this study is likely to be associated with availability of pasteurized milk in the study regions which resulted in the majority of people having access to them. Peoples' knowledge on pasteurization of milk as a means of preventing milk borne zoonosis is also developed. Majority indicated they had they have not suffered from any foodborne disease caused by milk and milk products and did have any concern regarding safety of processed milk products. This also points out that processed milk and dairy products are the best alternatives to improve quality and increase product value at every stage. Consumer preference for pasteurized and sterile liquid milk is positively correlated with household head income and education level, and negatively correlated with household size and household head age.

Consumers are key in ensuring that the safety of the milk products is maintained from the purchasing point to consumption, it's therefore critical that the consumer have some knowledge and have sufficient good handling practices that will ensure the quality of the milk is not compromised. In conclusion, the majority of respondents had a level of knowledge viewed as sufficient about the milk processing and temperature. In addition, many of the respondents also showed that they had a good knowledge of hygiene measures. However, knowledge of milk handling and milk-related food poisoning needs to be further improved to reduce disease incidence.

3.5 CONCLUSION

Most consumers within the Langata and Kibra sub counties had an acceptable knowledge on milk handling which is sufficient to ensure some degree of safety is observed. Coupled with the practice of immediately consuming milk products after purchase, this can be seen to greatly reduce chances of contamination due to poor storage or storage products beyond their use by dates. Inferentially, there is a relationship between the education levels of milk consumers and their parametric choice on good quality milk since the study has indicated that the higher the consumers' level of education, the better their knowledge on the probable health issues that can affect milk and milk products consumers as a result of the milk quality.

3.6 RECOMMENDATIONS

Therefore, the public health sectors and related stakeholders have a duty to sensitize and create awareness to the milk consumers on the risks and implications of consumption of milk contaminated with Listeria and other pathogens and ways of protecting the health of these consumers.

CHAPTER FOUR: PREVALENCE OF MICROBIOLOGICAL PATHOGENS IN PROCESSED MILK AND MILK PRODUCTS IN NAIROBI COUNTY

ABSTRACT

Milk has a good nutritional quality but it is also an excellent medium for bacterial growth and an important source of bacterial infection when consumed without pasteurization. This study aimed at establishing the prevalence of *Total Viable Count, Escherichia coli, Staphylococcus aureus* and *Listeria monocytogenes* contamination on processed milk and milk products. The study was carried out in Karen, Kibera and Langata Sub- Counties of Nairobi County which were purposively chosen because they have glaring contrasts in living standards. Samples of fresh milk, yoghurt cheese and ice creams were collected from supermarkets and prepared for analysis of microorganisms. Purposive sampling technique was used in selecting processors brands of milk and milk products at the point of sale in the 3 different study areas and a total of 36 samples were taken. All isolates were characterized and identified based on their morphological and cultural characteristics. The total viable counts (TVC) were detected in 100% of the samples collected and there was significant statistical variation ($P \leq 0.05$) in the contamination level among the products. Of the samples collected in Karen, Ice cream had the highest contamination level (3.26 $\log_{10}$ CFU ml^{-1}). Ice cream samples from Langata had the highest TVC contamination levels at 4.35 $\log_{10}$ CFU ml^{-1}. The overall prevalence of *E. coli* in milk and milk products was 41.6% with a mean count of 0.34 $\log_{10}$ CFU ml^{-1} in Karen, 0.07 $\log_{10}$ CFU ml^{-1} in Kibera and 0.11 $\log_{10}$ CFU ml^{-1} in Langata while *Staphylococcus aureus* was detected in 33.3% of the milk products. The occurrence and detection of *E. coli* and *S. aureus* foodborne pathogens in milk products pose a risk to customers' health. Therefore, there is need to enhance the milk products' microbiological quality by employing measures that will establish proper management practices to ensure improved hygiene, good manufacturing practices and food systems that will help to minimize microbial contamination.

4.1 INTRODUCTION

The demand for milk products in Kenya is among the highest in the East African region and in the developing nations. According to FAO, (2011), the annual per capita consumption of milk and dairy products is estimated at 19 kg in rural areas and 125 kg in urban areas. Milk is a healthy food product for humans, and it is obtained from a variety of animal sources, such as cows, goats, sheep, and buffaloes. The milk is processed into various products including milk powder, condensed milk, yogurt and cheese or traditional products fermented milk and *warankasi* (cheese) and *nono* (Jans *et al*., 2017). In Kenya, the majority of milk is consumed locally and only a small portion is sold commercially. This is due to the lack of appropriate infrastructure and qualified workers needed for milk processing on a commercial scale. However, the presence of harmful microorganisms like viruses, parasites, and pathogenic bacteria and yeasts may compromise the safety of milk and milk products. (Azad & Ahmed, 2016).

Various dairy products such as butter, cheese, ice cream, yoghurt and paneer are mainly made from cow's milk, but also from the milk of other dairy products such as buffalo, goat, sheep and camel. The unique composition of moisture and with an excellent richness of numerous nutrient that provide favourable environment for the growth and proliferation of microorganisms such as bacteria and fungi some of which are pathogenic to both human and animals. Milk-borne pathogenic bacteria make up roughly 90% of all diseases associated with dairy animals. (Ryser, 1998). The main microbiological hazards associated with consumption of raw milk include *Staphylococcus aureus, Salmonella* spp., *Listeria monocytogenes, Escherichia coli* O157:H7 and *Campylobacter*. Unless milk and dairy products are prepared under strict sanitary and hygienic conditions, these microorganisms can enter through various routes and cause spoilage, resulting in economic losses for the dairy industry. (Berhe *et al*., 2020). Again, it has been noted that low-quality milk products would result from improper hygiene procedures during the milking, handling, and storage processes (Merhawit *et al*., 2014). In many regions, milk processing is predominantly done at home and is characterized by improper use of sterilizers and insufficient hand washing, among other poor hygiene practices (Bereda *et al*., 2013; Akinyemi *et al*., 2020). Some of the pathogens such as *Listeria monocytogenes, Salmonella* species, *Staphylococcus aureus*, have been implicated as food poisoning agents (Pal, 2013). Depending on the concentration of these contaminants consumers of these products become exposed to disease such as listeriosis, shigellosis, hepatitis, compromised gut integrity etc.

It is difficult to estimate the incidence of foodborne infection by these contaminants because little is known about the magnitude of microbiological hazards associated with quality of raw bulk milk, especially with regard to contamination and the prevalence of foodborne pathogens. In 2005 close to 1.8 million children died because of diarrheal diseases because they are the most susceptible and are easily exposed as a result of their diet's high dairy product consumption, which includes both cow's milk and related byproducts. The microbiological safety is very important and is key in the quality control of milk and dairy products. This study focused establishing the prevalence of microbial contamination in fresh milk and milk products which are commonly consumed by majority of households in Kenya.

4.2 MATERIALS AND METHODS

4.2.1 Study area

This was as per chapter three, section 3.1. For each assessed milk processing company, random sampling technique was used in selecting their brands of milk and milk products at the point of sale in the 3 different study areas: Karen, Langata, and Kibera of Nairobi County.

4.2.2 Sample Size determination for Milk products

A total of 36 samples of milk and milk products were picked from the 3 different study areas, 9 samples for each category namely, fresh milk, yoghurt, cheese and ice cream. The supermarkets or the selling points were randomly selected from Langata and Kibera sub- County in the areas where the consumers' samples were also picked.

4.2.3 Sampling

Samples of fresh milk, yoghurt cheese and ice cream were collected from the points of sell in 500mls packages in Langata, Karen and Kibra and placed in a cooler box with ice packs and delivered to the laboratory. The samples were submitted to the lab on the same day of collection and stored 4 °C-6°C in a refrigerator until testing. Analysis commenced immediately under the guidance of the lab in charge.

4.2.4 Samples preparation

Samples of fresh milk, yoghurt were vortexed for 10 sec ensure they were homogenously mixed while the ice cream samples were prepared by first melting them in a fridge at 4°C-6°C. The melted ice cream was then blended at low speed for 1 minute to make a homogeneous mix. One ml was then pipetted and taken as the representative sample. Fifty gram of cheese samples was aseptically weighed and put into 450 mL of the required diluent then blended at low speed for 2 minutes to make a homogeneous mixture after which a serial dilution was done with 50 g: 450 ml taken as the primary dilution.

4.2.5 Making dilutions

A bottle with the 9mL buffered peptone was labelled with sample lab reference number. The prepared sample were then aseptically opened near a Bunsen burner flame, a sterile 1ml Pipette was attached to the micropipette and one ml of the sample was drawn. The one ml of the sample was aseptically transferred to the 9ml peptone water and then mixed by gently inverting the bottle. This formed the primary dilution (10^{-1}). Following the same procedure above serial dilutions were then made by transferring 1ml of the primary dilution (10^{-1}) into another 9 ml of buffered peptone water to make the second dilution (10^{-2}), subsequent serial dilutions were done up to the fourth dilution (10^{-4}), each time using a fresh sterile pipette. The prepared dilutions were then kept in refrigerated at 4°C-6°C.

4.2.6 Analytical Methods

4.2.6.1 Enumeration of Total Viable Counts

The enumeration of the total viable count was done following the KS ISO 4833-1: 2013 analysis method. Diluted samples of the fresh milk, yoghurt, cheese and ice-cream were tested and then inoculated by adding the samples into labelled sterile Petri dish. Using a sterile pipette, 1 ml of the sample of the dilutions was then aseptically transferred into sterile Petri dishes from the most dilute (10^{-4}). Approximately 15ml of Standard Plate Count Agar which had been tempered in a water bath at 47°C was aseptically added into each Petri dish containing the sample. The contents of the Petri dish were then mixed immediately by swirling gently the petri dishes repeatedly until the agar was properly mixed with the sample. This was done one plate at a time until all the samples were completed. The Petri were then left on a cool, flat surface to allow the mixture to solidify.

The Memmert incubator was set at 30℃, once it attained the set temperature and the agar poured in the petri dishes had completed solidified, the Petri dishes were then inverted and placed in the incubator undisturbed for 72 hours at 30°C. After the lapse of the 72hrs, the petri dishes were removed from the incubator and colonies in each petri dish were examined under subdued light and counted using colony counting device. The results were then recorded for each plate examined and counted as colony forming units per ml or g (cfu/ml or cfu/g).

4.2.7 Detection of *Escherichia coli*

The enumeration of the Escherichia coli was done following the KS ISO 7251: 2005 Horizontal method for the detection and enumeration of presumptive *Escherichia coli*. Samples of fresh milk, yoghurt, cheese and ice-cream were analyzed. Sterile HiCrome chromogenic agar was added to dilutions of 10^{-2} to 10^{-4} of the samples which were pipetted on to sterile plates in duplicates, the plate was then gently rotated clockwise and anti-clockwise to mix and then left to dry. After drying, the plates were inverted and incubated at 37 °C for 24 h. The plates were then examined for evidence of growth of blue/purple colonies which were interpreted as *Escherichia coli* colonies. For the plates that had *E. coli* present, an indole test was done to further confirm the presence of *Escherichia coli*. Escherichia coli is able to break down the amino acid tryptophan into Indole and form a red ring, which is a property of *Escherichia coli* to react with Kovac's (Indole) reagent to form a red ring. The results were either indicated as absent cfu/g or present cfu/g.

4.2.8 Enumeration of *Staphylococcus aureus*

Enumeration of *Staphylococcus aureus* in all the samples was done as per the procedure laid down in KS ISO 6888-1: 2021 method of analysis. The diluted samples starting by the highest dilutions were then inoculated by adding each of the samples into sterile Petri dishes with Baird-Parker agar. The inoculum was then quickly and carefully spread over the surface of the agar plate using a sterile glass spreader. Care was taken not to touch the sides of the Petri dish. The plates were then left to dry at room temperatures for about 15 minutes. Once the inoculated plates had dried, they were inverted and placed in the incubator set at 38℃ for 24 hours and examined for any growth, and re-incubate for a total of 48 hours. The plates were then removed and examined for evidence of growth of black-grey shinny colonies surrounded by thin white light borders an indication characteristic of Coagulase-positive *Staphylococcus aureus* colonies on Baird Parker media. A Coagulase test was then done on the colonies as a confirmatory test for *Staphylococcus aureus*, three of the black-grey colonies observed were transferred using a sterile loop into a sterile test tube with 0.5ml reconstituted plasma into the test tube which were then incubated at 37°C for 4hrs but observed at hourly intervals for any signs of clots formation which indicated positive results and vice versa.

4.2.9 Enumeration of *Listeria monocytogenes*

Enumeration of *Listeria monocytogenes* in all the samples was done as per the procedure laid down in KS ISO 11290-2: 2017 method of analysis. Twenty-five ml of the 10^{-1} dilution prepared sample was placed into 225mls of LEB (*Listeria* enrichment Broth) The solution was then uniformly mixed by slowly inverting the beaker and incubated at 30 °C for 24-26 hrs. After the lapse of the time set, 0.1ml of the pre-enriched sample above was added to 10ml of LEB (*Listeria* enrichment Broth) and incubated at 37ºC for 24hrs for selective enrichment. A streak (0.5ml) of the was then taken using a sterile loop wire and plated in a *Listeria* chromogenic agar, evenly distributing the inoculum throughout the surface of the plate using a sterile spreader while avoiding making contact with the plate's sides. This was then left to dry for 15minutes and incubated for 24hrs at 37ºC and a further 24 hours giving a total of 48hrs. Observation was then done for any growth of blue or blue-green colonies surrounded by an opaque cycle that would have been an indication of *Listeria spp* growth.

4.2.10 Statistical analyses

Excel was used to enter data from microbiological analyses and convert them to logarithms of colony forming units per milliliter of sample (log_{10} CFU/ml) and the results were presented as means of the three replicates. All the statistical analyses of the laboratory results were performed by of GenStat version 15 software (England) and the difference were considered significant when $P \leq 0.05$. T-tests and measures for central tendencies were carried out to interpret microbial findings. The bacterial contamination levels were compared with the Kenya standards relevant for each milk product (KEBs).

4.3 RESULTS

4.3.1 Total viable bacterial counts from fresh milk and milk products

The prevalence of TVC isolated from milk and milk products is shown in Table 1. The total viable counts (TVC) were enumerated and detected in 100% of the milk samples collected in all the sites. A significant statistical variation ($P \leq 0.05$) in the contamination level of TVC among the different milk products was observed in samples collected from Karen, Kibera and Langata. Of the samples collected in Karen, Ice cream had the highest contamination level (3.26 $\log_{10}$ CFU ml^{-1}) followed by fresh milk 2.79 $\log_{10}$ CFU ml^{-1}), while yoghurt samples collected from Kibera had the highest levels of contamination (3.04 $\log_{10}$ CFU ml $^{-}$1) followed by yoghurt (2.77 $\log_{10}$ CFU ml^{-1}). Ice cream samples from Langata had the highest contamination levels at 4.35 $\log_{10}$ CFU ml^{-1} followed by yoghurt samples with contamination levels of 3.24 $\log_{10}$ CFU $ml^{-1.}$ On average when comparing milk and milk product samples, ice cream samples were found to be contaminated (3.46 $\log_{10}$ CFU ml^{-1}) compared to other milk products. With the standard TVC for yoghurt, fresh milk and ice cream set at 6.0 log_{10}CFU by the Kenyan Bureau of Standards (KEBS) (Wanjala *et al*., 2017), the current findings indicated counts that were within the acceptable range. Table 4.1 below shows total viable counts in milk and milk products collected in the study area.

Table 4.1: Prevalence and contamination levels of TVC (log_{10} CFU ml^{-1}) in fresh milk and other milk products collected from various sites in Nairobi County

	Location			
Milk and milk Products	Karen	Kibera	Langata	Mean
Fresh milk	2.79 ± 0.08^{ab}	2.74 ± 0.23^{ab}	2.25 ± 0.07^{b}	2.59 ±0.30^{b}
Cheese	2.66 ± 0.13^{ab}	2.39 ± 0.12^{b}	2.41 ± 0.07^{b}	2.49 ± 0.15^{b}
Yoghurt	2.31 ± 0.10^{b}	3.04 ± 0.14^{a}	3.24 ± 1.3^{ab}	2.86 ±0.49^{ab}
Ice cream	3.26 ± 0.08^{a}	2.77 ± 0.12^{ab}	4.35 ± 0.78^{a}	3.46 ± 0.81^{a}
Mean	2.75 ± 0.39	2.74 ± 0.27	3.06 ± 0.96	2.85 ± 0.46
LSD ($P \leq 0.05$)	0.62	0.42	1.53	0.69
CV (%)	22.8	22.8	0.92	0.18

Values followed by the same letter (s) within columns in the whole table are not significantly different at $P \leq 0.05$ according to the Duncan's multiple range test.

4.3.2 Isolation of total *Staphylococcus aureus* from fresh milk and milk products

Table 4.2 illustrates the prevalence of *Staphylococcus aureus* investigated in the 36 samples examined.

Table 4.2: Levels of *Staphylococcus aureus* (log_{10} CFU ml^{-1}) in fresh milk and other milk products collected from various sites in Nairobi County

	Location		
Milk and Milk Product	**Karen**	**Kibera**	**Langata**
Fresh milk	Detected	Detected	ND
Cheese	ND	ND	ND
Yoghurt	ND	Detected	ND
Ice cream	ND	ND	Detected

ND- Not detected

Overall, *Staphylococcus aureus* was detected in 33.3% of the milk and milk products. However, in Karen, *S. aureus* was not detected in milk products such as cheese, yoghurt and ice cream while in Kibera *S. aureus* was not detected in cheese and ice cream. In Langata, *S. aureus* was only detected in ice cream samples. Table 4.2 shows enumeration of *S. aureus* in milk and milk products samples collected.

4.3.3 Isolation of total *E. coli* from fresh milk and other milk products

The overall prevalence of *E. coli* in milk and milk products was 41.6% with a mean count of 0.34 log $_{10}$ CFU ml $^{-1}$ in Karen, 0.07 log $_{10}$ CFU ml $^{-1}$ in Kibera and 0.11 log $_{10}$ CFU ml $^{-1}$ in Langata. A significant difference ($P \leq 0.05$) in the occurrence of *E. coli* among the different products was observed in samples collected from Karen. Nevertheless, there was no statistically significant variation in the contaminated levels of milk products collected from Kibera, and Langata wards. Of the samples collected in Karen, Ice cream had the highest contamination level of *E. coli* in all the sites with an average contamination level of 0.48 log $_{10}$ CFU ml $^{-1}$). Fresh milk, cheese and yoghurt samples from Kibera and Langata had no *E. coli* contamination. However, in Karen, only yoghurt was found to have no *E. coli* contamination. Table 4.3 shows contamination levels of milk and milk products by *E. coli*.

Table 4.3: Prevalence and contamination levels of *E. coli* (log $_{10}$ CFU ml $^{-1}$) in fresh milk and other milk products collected from various sites in Nairobi County

	Location			
Milk and milk Products	Karen	Kibera	Langata	Mean
Fresh milk	0.46^{ab}	0.00^{a}	0.00^{a}	0.15^{a}
Cheese	0.16^{ab}	0.00^{a}	0.00^{a}	0.05^{a}
Yoghurt	0.00b	0.00^{a}	0.00^{a}	0.00^{a}
Ice cream	0.73a	0.28^{a}	0.43^{a}	0.48^{a}
Mean	0.34	0.07	0.11	0.17
LSD ($P<0.05$)	0.58	0.58	0.58	0.58
CV (%)	200.70	200.70	200.70	200.70

Values followed by the same letter (s) within columns are not significantly different at P ≤ 0.05 according to the Duncan's multiple range test.

Milk samples from Langata had the highest proportion of TVC contamination when compared with those obtained from Karen and Langata. Samples from Karen had more *E. coli* contaminants compared to samples obtained from Kibera and Langata. Milk and milk product samples were of unacceptable microbial quality due to contamination with TVC). Table 4.4 represents average TVC, *E. coli,* and *S. aureus* enumeration from collected milk and milk products samples.

Table 4.4: Microbiological criteria for milk and milk products (Log_{10} CFU)

Microorganisms	Mean ($cfug^{-1}$)			Interpretation of microbiological quality
	Karen	Kibera	Langata	
TVC	2.75	2.74	3.06	Acceptable
E. coli	0.34	0.07	0.11	Satisfactory
S. aureus	ND	ND	ND	Satisfactory

The standard for TVC, and *E. coli* according to KEBS KS ISO 4833-1, and KS ISO 11290-1 test methods are 6.0 log_{10}CFU and NIL values respectively. For the case of KS ISO 4833-1 test for *S. aureus*, the standard is set at NIL value for sterilized and pasteurized milk products.

4.4 DISCUSSION

Food contaminants are important factors contributing to the high cases of food borne disease in developing countries. The Kenya standards for the milk products; KS EAS 69: 2019 Pasteurized milk specification , KS EAS 33: 2019- Yoghurt specification , KS EAS 70: 2019- Dairy ice cream specification, and KS EAS 28 1: 2019- Cheese general requirements specification, gives the microbiological limits for each of the products, the maximum allowable counts for TVC in any of the milk products, for ice cream it should not exceed 4×10^4 cfu/g and in pasteurized milk it's capped at 3×10^4 cfu/g respectively all the standards give the limit for *E.coli*, *Staphylococcus aureus* and *Listeria monocytogenes* are absent in 25g.

4.4.1 Total Viable Count

The current findings show that the total viable bacterial counts (TVC) were enumerated and detected in 100% of the milk product samples collected in all the sites. Even though the contamination levels differed among the products and between the sites they were all within the set limits by the KEBS standards with regards to TVC. This outcome depicts those of Nur *et al*., (2021) where all the pasteurized milk had high bacterial load ranging from 2.17×10^3 to 3.84×10^3 cfu mL-1. The same results were reported by Hasan *et al*., (2015) and Wanjala *et al.*, (2017) where various quantities of TVC were isolated from different sources. However, these results differ those reported by Wanjala *et al*., (2017) where the average TVC in raw milk collected from rural, urban and slum areas of Nairobi were 7.57, 7.52 and 8.18log10cfu/ml. The identical results stated above were reported by Bhatnagar *et al*., (2007); Karthikeyan and Dhanalakshmi, (2010); Karthikeyan and Pandiyan, (2013), however, the authors reported variations in number of total viable counts. According to Mendonca *et al.*, (2020) though TVC is not a pathogen, their presence increases the chances of the food having pathogenic microorganism because it raises doubts on the level of GMP implementation.

The occurrence of bacteria is of clinical significance and implies that these products can pose health risk to consumers. Milk processing handled in unhygienic conditions supports the growth of pathogenic microorganisms leading to contamination of milk products. Thus, this study indicates an improvement in the milk handling and hence improvement in milk quality. It is however important to note that the highest TVC contamination was observed in sampled collected from Langata and not Kibera however, there was not significant difference between the sites. The finding contradicts those of Wanjala *et al*., (2017) where the highest TVC contamination was recorded slums while the lowest count was detected in urban Nairobi. This implies that milk contamination may be starting from the farms and collection centres and as such milk and milk products within the county may have contaminated. However, companies manufacturing milk products must adhere to stricter inspection and better management practices. Mehmeti *et al*., (2017) suggests a frequent microbial analyses and the findings shared with farmers so that they can improve on their hygiene practices.

4.4.2 *Escherichia coli*

Findings from the current study show that the overall prevalence of *E. coli* in milk and milk products was 41.6% with a mean count of 0.34log $_{10}$ CFU ml $^{-1}$ in Karen, 0.07 log $_{10}$ CFU ml $^{-1}$ in Kibera and 0.11 log $_{10}$ CFU ml $^{-1}$ in Langata. However, significant difference ($P \leq 0.05$) in the occurrence of *E. coli* among the different products was only observed in samples collected in Karen. The results reported in this study are similar to those reported by Miranda *et al*., (2009); Berhe *et al*., (2020); Tanih *et al*., (2015) where *E. coli*, *S. aureus, L. monocytogenes* and *Salmonella* was detected. In their findings, Tanih *et al*., (2015) reported *E. coli* as the most detected pathogen followed by *S. aureus*. Rai *et al*., (2020) working with milk samples from Kathmandu District, reported that nearly half of the samples showed the presence of *E. coli*. Pathogenic *E. coli* has been shown to be an important pathogen causing outbreaks of acute diarrhoea especially in developing countries (Vugia *et al*., 2010; Boisen *et al*., 2012; Rai *et al*., 2020) and thus their presence in the milk should not be overlooked. According to Kwenda, (2015), *E. coli* should not be presents in a well-prepared milk product such as cheese as high acidity of the fermented product should restrict their survival. Therefore, the presence of *E. coli* and any other microorganisms suggest that slow acidity development may have allowed the build-up of *E. coli*. Notably all the milk products, ice cream samples had high incidences of *E. coli* than any other. According to Verraes *et al*., (2015) *L. monocytogenes*, *S. aureus* and *E. coli* are the main microbial hazards that are found in ice cream. The presence of *E. coli* and other microbes in ice creams indicates that the preparation process has not been done effectively or post process contamination might have occurred (Pal *et al*., 2016). According to Osamwonyi *et al.,* (2011) Potential origins of these harmful microbes in ice cream includes ingredients used in its processing, such as cream, separated milk and milk powder, flavouring, colouring agents, and stabilizers.

4.4.3 *Staphylococcus aureus*

Overall, *Staphylococcus aureus* was detected in 33.3% of milk and milk products. However, the numbers could not be quantified. In Karen, *S. aureus* was not detected in milk products such as cheese, yoghurt and ice cream while in Kibera *S. aureus* was not detected in cheese and ice cream. These findings are similar to those reported by Latha *et al*., (2017) and Dai *et al*., (2019) where high prevalence of *S. aureus* was reported, however, the prevalence of *S. aureus* in this study is lower. This may be due to the fact that the samples were branded samples sourced from various supermarkets. The results reported here concur with those of Rall *et al*., (2008); Gundogan *et al*., (2006) and Holi *et al*., (2021) where various samples were found positive for *S. aureus*. *Staphylococcus aureus* is a common environmental contaminant found on surfaces and may be the outcome of improper hygiene practices, such as using contaminated water to clean surfaces. *Staphylococcus aureus* is generally present in the skin and mucous membrane another pathogen that can be used to measure the sanitary conditions in which food is produced and handled.

4.5 CONCLUSION

The TVC counts isolated in all the samples were within the set limits by the KEBS standards. However, with the microbial counts for *E. coli* were above the set standards by food safety regulatory bodies. Consequently, the consumption of microbiologically unsafe milk products present a serious risk to customers' health due to their potential to cause illnesses. With a projected increase in the production and consumption of dairy products in Kenya and the whole of Africa, production and handling practices are most likely to be crucial to these products' safety. Detection of *E. coli* and *S. aureus* foodborne pathogens in milk and milk products, even if in few samples indicate possible lapses in industrial implementation of food safety management systems.

4.6 RECOMMENDATIONS

There is need to improve the microbial quality of milk and milk products by employing measures that will establish proper management practices to ensure improved hygiene, good manufacturing practices and food systems that will help to minimize microbial contamination. The processing plants need to improve on the implemented food safety management systems to ensure that the products processed are of the highest microbiological quality. Additionally, regulators need to intensify on market surveillance and product testing to protect the consumers from getting contaminated products.

CHAPTER FIVE: IMPLEMENTATION OF GOOD MANUFACTURING PRACTICES IN MILK PROCESSING COMPANIES IN NAIROBI COUNTY AND MICROBIAL CONTAMINATION OF MILK AND MILK PRODUCTS

ABSTRACT

Good manufacturing practice is a set of actions taken by the food industry to ensure food safety and compliance with specific regulations. Even though good manufacturing practices are vital systems in food safety and is associated with minimum sanitary and processing requirements for the food industry, only a few studies have reported GMP implementation by small milk processing companies. Therefore, the present study was undertaken in milk processing firms to evaluate the implementation of good manufacturing practices for control of microbial contamination in milk and milk products. Purposive, random and stratified sampling techniques was used to identify milk processing companies. Ten processing facilities were purposively sampled for the study. The representatives were interviewed, using a pretested questionnaire and data was collected and analyzed. All the processors had qualified personnel handling milk and milk products with a daily processing capacity of 20000-30000 litres. It was observed that the processors complied with all regulatory and licensing requirements and had in place critical process controls with majority indicating pasteurization at temperatures ranging from 80-90^{o}C as the most common method. The processors had several food safety management systems such as ISO 22000, GMPs, and HACCP which were handled by trained and competent staff. It was observed that all the processors tested for total viable counts (TVC), and *E. coli* while only 50% and 33.3% of the processors tested for *S. aureus* and *L. monocytogenes* respectively. Furthermore, the processors (33.3%) reported *E. coli* as the main contaminant while *L. monocytogenes* were not detected. A majority (83.3%) had well-documented cleaning programs and had a system of controlling cross contamination which was enforced through different colour codes (66.7%), memos and notices (16.7%) and through colour coding of processing equipment (16.7%). In conclusion, the present study discovered that milk processors had implemented good manufacturing practices (GMP) and conformed to good processing practices. Therefore, it would be important for the regulators to encourage and emphasize on the analysis of the other food pathogens such as the *S. aureus* and *L. monocytogenes* that are not routinely done by most of the processors.

5.1 INTRODUCTION

In Kenya, 5 billion litres of cow's milk is produced annually in Kenya and out of those, 600 million litres is processed and formally marketed in various towns. Nairobi accounts for the largest percentage of the formal market (KDB, 2018). In Oct 2020, milk consumed in Nairobi alone accounted for 59,710,445 litres of the total amount produced. Milk and milk products are main sources of dietary nutrition for all age groups especially, children, pregnant women, sick and the immune-compromised individuals (UNICEF, 2019). Since milk is considered by many to be one of the most important foods due to its nutritional value, the need for premium, safe milk has compelled manufacturers, retailers, and dairy producers to create and distribute safe milk products. (Reta and Addis, 2015).

Raw or processed milk is good medium for growth of numerous microorganisms, however, the presence of these hygiene indicator micro-organisms in processed milk and milk products is an indication of inefficient processing methods, poor handling and post processing contamination which then raises concerns on the safety of product for consumption (Buchanan & Oni, 2012). This shows that regardless of the kind of processing a food goes through if at the end of it all it's contaminated with the indicator microorganism the food carries with it the risk that can cause an illness. Worldwide, the presence of microorganisms has been used as hygiene indicator and as a measure of the suitability of the processing environment, personnel hygiene, effective pasteurization process, good manufacturing practices (GMP) , Good sanitation processes or proper post processing handling (Metz *et al*., 2019). The most common hygiene indicators microorganisms used for foods and drinking water include the *Total viable Count* (TVC), *coliforms*, *Enterobacteriaceae spp* including *Escherichia coli, Staphylococcus aureus, Listeria spp* and the yeasts and molds (Martin *et al*., 2016). *Total viable count* (TVC) is one of the most used hygiene indicator tests and TVC counts above a certain threshold typically signify inadequate or ineffective equipment or environment sanitation, which is generally a good guide in determining if good manufacturing practices have been implemented (Metz *et al*., 2019; and (O'Grady *et al*., 2020) . It's also used to gauge the organoleptic acceptability of the food. Total viable microorganisms in themselves are not pathogenic but may give a clear indication as to the safety level of the food. The higher the TPC levels, the higher the chances that the pathogenic microorganism can be present in the food because it puts doubts on the level of GMP implementation (Mendonca *et al*., 2020).

Combination of interventions is needed to control *E. coli, S. aureus,* and *Listeria monocytogenes* and the other hygiene indicator organism's contamination (CAC/GL 61, 2007). There is need to address the entire Milk processing systems not just focusing on the effectiveness of the pasteurization as a control, these include, management of sourcing and handling of the milk as a raw material, control of pasteurization, GMPs that control cross contamination, effective cleaning and sanitation procedures, verification methods for cleaning effectiveness, Trainings, Environmental pathogens control program and finally analysis of products prior to dispatch to the market as required by the codex guidelines on hygiene in milk processing (CAC/RCP 57-2004). Observation of the general layout of the facility is also critical because the flow of air is a contributing factor to *Listeria* spread within the facility (FDA, 2017; (Piet *et al*., 2016). The control and prevention of contamination of food products with indicator microorganism require a complete focus on the good manufacturing practices (GMPs): all food handlers must undergo a food handlers' medical exam at least once every six months, they should practice good hand hygiene ensuring that their hands are cleaned and sanitized before handling any food. Processing environment must be clean and equipment should also be clean and sanitized to avoid cross contamination (Lee *et al*., 2017). The main aim of the research was to determine if milk processing companies have implemented GMPs in milk processing systems necessary for the control of *TVC, E. coli, Staphylococcus aureus* and *Listeria monocytogenes* micro-organisms contamination in milk and milk products.

5.2 MATERIALS AND METHODS

5.2.1 Study area

As described in section 3.1 of chapter 3, the study was carried out in Karen, Kibera and Langata Sub-Counties of Nairobi County, Kenya.

5.2.2 Study population and sampling

The population of the study included the processors in Nairobi County. Purposive, random and stratified sampling techniques were used. These milk processing plants: large, mid-sized and mini processors process milk products: (Fresh milk, yoghurts, Ice cream and Cheese) meant for sale within Nairobi County.

5.2.3 Sample Size determination for Processors

Simple random sampling technique was used in selecting the sample for the milk processing systems for milk products. Cluster sampling per sub-county was used to obtain ten processing facilities registered by Kenya Dairy Board (KDB) within Nairobi and its environs. Exhaustive sampling was done for cheese and Ice cream processors, because the population size was small, all of them were included in the study.

5.2.4 Inclusion criteria

The eligible participants were all processing facilities that are licensed by KDB, are within Nairobi County and its environs. Processes and packages milk and milk products mainly meant for sale in Nairobi County.

5.2.5 Exclusion criteria

Any Milk and milk products processers not licensed by KDB, not within the Nairobi County and its environs and whose products are not packaged for sale in the retail market within Nairobi County.

5.2.6 Data collection

Questionnaires were distributed in each of the factory located in Nairobi. The questionnaire was divided into two sections with the first one associated with general information, and the second one included the entire Good Manufacturing Practices (GMP) check-list related to the Kenyan standard. The representatives were interviewed, to determine the implementation of the GMPs in the processing systems on the facility. A Pretested questionnaire using the Open Data Kit (ODK) developed by Get ODK on a Samsung mobile phone that recorded the information online was used. Data was collected to assess processors' knowledge on *hygiene indicator microorganisms* and their occurrence in the different milk products. Conformity to milk regulatory requirements was also determined through enquiry of the food systems management systems in place.

5.2.7 Statistical Data analysis

Both quantitative and qualitative data collected were coded and entered the computer using Excel data sheet management and analyzed by SPSS version 20.0. Data analysis was done to determine the food safety management systems in place, such as HACCP, ISO 22000, and GMPs. Inferential analysis was done to determine the processors' knowledge on these systems to their level of education.

5.3 RESULTS

5.3.1 Milk processors profile

Survey on implementation of good manufacturing practices revealed that most of the respondents were working as quality assurance analysists (50%) followed by quality control managers (Table 5.1). These companies were involved in the manufacture of various milk products with majority of them being involved in the manufacture of fresh milk and yoghurt (66.7%). Other products include cheese, butter, ice cream and whipping cream. The results also show that many of the company had processing capacity of between 20000 – 30000 litres of milk per day. Table 5.1 below shows technical profiles of milk processors.

Table 5.1: Milk processors profile

Statement	Parameter	Percentage	STD. Dev
Employee position	QAM	33.3	0.98
	Quality Control	16.7	
	QAA	50.0	
Company Location	Kiambu	33.3	0.51
	Nairobi	66.7	
Female employees	1-100	50.0	1.16
	101-200	33.3	
	201-300	0.0	
	over 300	16.7	
Male employees	1-100	16.7	1.03
	101-200	16.7	
	201-300	50.0	
	over 300	16.7	
Products	Cheese	50.0	1.96
	Fresh milk	66.7	
	Yoghurt	66.7	
	Butter	16.7	
	Ice cream	16.7	
	Whipping cream	33.3	
Quantity of milk	1000-10000	33.3	1.16
	11000-20000	33.3	
	21000-30000	16.7	
	31000-40000	16.7	
Qualified Personnel	Yes	100.0	0.00
	No	0.0	

5.3.2 Compliance and regulatory requirement

On compliance with regulatory requirements, all the facilities were licensed by public health, Kenya Dairy Board, and their products approved by Kenya Bureau of Standards and were also regularly inspected by the regulatory bodies (Table 5.2). On the other hand, the results show that all the workers within the facilities had undergone food handlers' medical tests and it was also a requirement that employees who fail medical test isolate themselves. Table 5.2 represents the regulatory compliance assessment questionnaire for milk processors in Nairobi.

Table 5.2: Compliance to regulatory and licensing requirements by milk processors in Nairobi

Statement	Yes (%)	No (%)
Is the facility licensed by public health	100.0	0.0
Is the facility licensed by Kenya Dairy Board	100.0	0.0
Are the products approved by KEBS	100.0	0.0
All workers undergone food handlers' medical tests	100.0	0.0
Do you isolate employees who fail medical tests	100.0	0.0
Are you inspected by regulatory bodies	100.0	0.0

5.3.3 Process controls

Observations with regard to critical controls showed that majority of the companies (50%) identified pasteurization, closely followed by freeze storage (33.3%) as a measure to inhibit microbial growth. It was also noted that all the staff in the critical areas were trained on various parameters to take note of. All the raw milk was pasteurized at either temperature ranging from 80-85^{o}C (50%) or 86-90^{o}C (50%). When they were asked about pasteurized efficiency, 66.7% of the respondents indicated it was efficient while 33.3% suggested it was not. The respondents (83.3%) also indicated incidences of pasteurization failures. All the respondents indicated that temperatures were monitored, records maintained and the tools for monitoring temperatures were calibrated by accredited laboratories. Majority (66.7%) of the respondents specified that the equipment calibration was done annually, and the record of every calibration conducted maintained. Process controls undertaken by milk processors were assessed using questions in table 5.3 below.

Table 5.3: Various process controls undertaken by milk processors in Nairobi

Statement	Yes (%)	No (%)	y
Have you identified critical processes in your facility	100.0	0.0	0.0
Staff in critical areas trained on parameters to observe	100.0	0.0	0.0
Are all raw milk used pasteurized?	100.0	0.0	0.0
Pasteurization temperature: 75-79	18.5	81.5	0.0
Pasteurization temperature: 80-85	30.0	70.0	0.0
Pasteurization temperature: 86-90	51.5	48.5	0.0
Is pasteurization efficiency tested	66.7	33.3	0.5
Are there incidents of failure of the pasteurization efficiency tests	83.3	16.7	0.4
Monitoring of processing temperatures	100.0	0.0	0.0
Are records of monitoring maintained	100.0	0.0	0.0
Are temperature monitoring devices calibrated by accredited labs?	100.0	0.0	0.0
Are records of calibration maintained?	66.7	33.3	0.8

5.3.4 Safety of milk processing systems

The results of the safety of milk processing systems are in table 5.4. All the companies had implemented food safety management systems. The most popular systems in place were ISO 22000 (50%), GMP (33.3) and HACCP (16.7%). All the companies identified the most critical points in the systems and had their staff trained on critical control points. Table 5.4 shows questions that were used to assess level of implementation of food safety management systems among milk processors.

Table 5.4: Milk processing systems and their safety

Statement	Yes (%)	No (%)	y
Has the plant implemented Food Safety Management system	100.0	0.0	0.0
Are there critical control points identified in the systems	100.0	0.0	0.0
Staff in operations trained on CCPs	100.0	0.0	0.0

5.3.5 Microbial contamination

Out of the products sampled for microbiological analysis, 50% and 33.3% of the processors tested for *S. aureus* and *L. monocytogenes,* respectively (Table 5.5). Furthermore, when the respondents were asked if samples had been contaminated by either *E. coli* or *S. aureus* in the last six months, 33.3% of the respondents agreed to this statement and half of them reported *E. coli* as the main contaminant isolated. It was also noted that all the equipment installed for milk processing in the companies were tested for *L. monocytogenes* pathogen but were found not to have been contaminated.

However, only 50% of the respondents performed *Listeria monocytogenes* testing on equipment. It was also observed that only 33.3% of the companies had facilities in place for testing and only 16.7% had received complaints from customers about food poisoning. All the staff were trained on the pathogenic microbes that would contaminate milk and milk products. Table 5.5 below shows questions used to assess the type of micro-organisms analyzed by milk processors.

Table 5.5: Tests on identification of various microorganisms contaminating milk and milk products

Statement	Yes (%)	No (%)	y
Are all end products tested for microbiol contamination	100.0	0.0	0.0
Is *TVC* analyzed	100.0	0.0	0.0
Is *E. coli* tested	100.0	0.0	0.0
Is *Staphylococus aureus* tested	50.0	50.0	0.5
Is *Listeria Monocytogenes* tested	33.3	66.7	0.5
Has any sample tested positive to *E. coli, S. aureus* in the last 6 months?	33.3	66.7	0.5
Has any product or equipment tested positive to *Listeria monocytogenes*	0.0	100.0	0.0
Does the facility have a pathogen testing program in place	33.3	66.7	0.5
Is *Listeria Monocytogenes* testing done on Equipment?	50.0	50.0	0.5
Have you ever received complaint from customers about Food Poisoning	16.7	83.3	0.4
Are the staff trained and aware of microbiological contamination	100.0	0.0	0.0

5.3.6 Cleaning and sanitation

Majority of the respondents (83.3%) agreed to have documented cleaning program and applied food grade cleaning and disinfecting agents (Table 5.6). All the processors cleaned the processing equipment on daily basis while only 83.3% verified the efficiency of the cleaning done. However, all the processors (100%) had records of every cleaning done maintained. All the processors used water from the municipal council while 50% used water obtained from the boreholes. It was noted that water used was portable and was tested for microbial quality in the laboratory. On a positive note, results of water testing in the last six months had not been found to be contaminated with any microbial contaminant. Analysis was mainly done on coliforms (100%), TVC (66.7%) and on yeast and molds (16.7%). Cleaning and hygiene implementation was assessed using questions contained in table 5.6 below.

Table 5.6: Documentation of cleaning and sanitation programs

Statement	Yes (%)	No (%)	y
Is there a documented cleaning program in place?	83.3	16.7	0.4
Do you use food grade cleaning and disinfecting agents?	83.3	16.7	0.4
Is cleaning efficiency verified?	83.3	83.3	0.4
Are Records of cleaning maintained?	100.0	0.0	0.0
Is the water quality tested in the lab for microbiological quality?	100.0	0.0	0.0
Has the water failed the tests in the last 6 months?	0.0	100.0	0.0

5.3.7 Measure to control cross contamination

All the processors had a system to control cross contamination and was enforced through means such as the use of different colour codes (66.7%), memos and notices (16.7%) and through colour coding of processing equipment (16.7%) (Table 5.7). It was also noted that movement restrictions were imposed on personnel and equipment within the facility in all the premises surveyed. All the premises surveyed had a separate area for handling raw milk and pasteurized products, used disposable food grade gloves for handling open foods and installed designated hand washing areas. Table 5.7 shows control measures put in place by milk processors to prevent cross contamination.

Table 5.7: Various control measures in place to manage cross contamination

Statement	Yes (%)	No (%)	y
Do you have a system for controlling cross contamination	100.0	0.0	0.0
Movement restriction in the facility and colour coding practiced.	100.0	0.0	0.0
Do you have a separate area for handling raw milk and pasteurized products?	100.0	0.0	0.0
Are food grade gloves used in handling open food?	100.0	0.0	0.0
Are there designated hand wash areas?	100.0	0.0	0.0

5.3.8 Conformity to good manufacturing practices

Various areas were considered when implementing GMP based on the essential parameters established by KEBS. The preliminary assessment of the milk processing plants on the GMP implementation revealed an average of 78% of conformity. Among the areas that were assessed, licensing and hygiene showed the highest conformance percentages(Table 5.8). In addition, cleaning and sanitation, cross contamination, milk safety, microbial contamination and process control all had conformed to the standards requirement albeit at different levels. Table 5.8 shows conformity of milk processors in Nairobi to good manufacturing practices.

Table 5.8: Mean percentage of conformities found in various milk processing firms during the implementation of GMP

Areas of conformity	Conformity	Non-Conformity
Process control	60.8b	39.2a
Microbial contamination	63.2ab	36.8ab
Milk safety	66.7ab	33.3ab
Cross contamination	77.8a	22.2b
Cleaning and sanitation	78.1a	21.9b
Licensing	100.0a	0.0c
Hygiene	100.0a	0.0c
Mean	78.1	21.9
LSD (*P= 0.05)*	15.2	15.2

5.4 DISCUSSION

5.4.1 Profiles of milk processors

A survey regarding the implementation of good manufacturing practices found that the majority of the staff responsible for monitoring of the GMPs implementation for the milk processing were quality assurance analysts and quality control managers. This finding is in line with those reported by Idrees *et al*., (2016) where the employees graduated and had hazard analysis critical control point (HACCP and GMP) with a working experience of more than two years. Milk processing and operations personnel are required to have the necessary qualifications to ensure safety of food and that it has the appropriate identity, purity, strength, and meets consumer quality demands (FDA, 2011).

5.4.2 Processing of milk products

Of the total milk products, yoghurt and fresh milk were the most commonly processed products. Other products include cheese, butter, ice cream and whipping cream. These findings relate to those reported by Schneider (2018) who highlighted yoghurt and fresh milk as the most processed milk products in Nairobi. The dominance of these two products suggests that new milk processing companies must therefore advance the two products to attract more consumers. The majority of processors had a processing capacity ranging from 10000-20,000 litres of milk per day. This capacity seemed manageable suggesting that chances of contamination by pathogenic microbes was low.

5.4.3 Compliance to regulatory requirements

All the milk processing facilities were licensed by public health, Kenya Dairy Board, and their products approved by Kenya Bureau of Standards. The results found in this study is an indication of conformity to laid down regulations to ensure milk and milk products satisfy the highest expectation of the manufacturers and ultimately the consumers. According to the Kenya Dairy Board, the licensing of milk processing facilities is an important activity in regulating the dairy industry as it facilitates regular inspections of facilities to ensure compliance with milk quality and safety requirements. The dairy industry in Kenya is regulated by various acts, regulations and guidelines and the enforcement of dairy standards and regulations involves operations against non-conformities. Requirements for hygienic and safe production of milk and milk products are obtained from Kenya Bureau of Standards and other international bodies such as Codex Alimentarius, the Food and Agriculture Organization (FAO) and international dairy federation. On the other hand, the employees had undertaken food handlers' medical tests and those who failed the medical tests were required to isolate. This result is comparable to those of Tesfaye *et al*., (2020) where workers in a milk processing facility are required to yearly undertake health check and obtain the health certificate. The law should be such that medical examination of the employees should be carried out epidemiologically otherwise medical check-up should be done bi-annually and personnel found to be infected should stay away from designed areas until medically fit.

5.4.4 Process controls

Observations with regard to critical controls showed that all the companies had in place critical processes such as pasteurization, cleaning and sanitation, cold storage and sterilization and all the staff were trained in each critical area. The dairy industry is composed of various interlinked processes such as pasteurizing, homogenizing, ageing, flavouring, freezing and packaging. (Georgieva *et al*., 2002). The implementation of processes such as pasteurization to improve the milk process optimization is of importance in each facility handling milk (Burke *et al*., 2018). For instance, pasteurization is one of the main critical control points (CCPs) in the milk industry that helps in destroying potential harmful pathogens. It is also important that milk is stored at low temperatures below 10^{o}C to arrest the growth of bacteria. Cooling milk has special significance since freshly drawn milk is about 38^{o}C which is highly suited for bacterial growth.

All the raw milk was pasteurized at either temperature ranging from 80-85^{o}C (50%) or 86-90^{o}C. On pasteurization efficiency, 66.7% of the respondents indicated it was efficient while 33.3% suggested it was not. The respondents (83.3%) also indicated incidences of pasteurization failures. All the respondents indicated that temperatures were monitored, records maintained and the tools for monitoring temperatures were calibrated by accredited laboratories. Cifeli *et al*., (2010) defines pasteurization as the process of heat treatment of milk at 72^{o}C and holding 15 seconds followed by fast cooling while according to Dhotre, (2014) pasteurization is recognized by specific temperature and time combination. Therefore, the combination of temperature and time adopted should be high enough to kill all pathogenic microorganisms in the milk, but low enough not to damage the heatsensitive components of the milk. When pasteurization is carried out effectively, practically all non-pathogenic bacteria, yeasts, molds, and pathogenic bacteria that could be connected to unpasteurized milk are eliminated (Ewaschuk and Unger, 2015). Thus, this process is considered very efficient and effective method of increasing milk shelf life.

5.4.5 Food safety management systems

The results of the safety of milk processing systems shows that all the companies had implemented food safety management systems such as ISO 22000, GMP and HACCP. All the companies identified the most critical points in the systems and had their staff trained on critical control points. This shows that majority of the milk processors conformed with the required good manufacturing practices, therein ensuring the identity, strength, and quality of their milk and milk products while reducing facility losses associated with microbial contaminations. This finding concurs with those of Tutu and Anfu (2019) where majority of the food manufacturing companies had some form of food safety systems (FSMS) and operated on either operated system based on ISO 22000 standards or Good Manufacturing Practices. Milk safety systems are linked to practises such as good hygienic practices, good manufacturing practices and Hazard Analysis and Critical Control Point System (HACCP) (Merwan *et al*., 2018). Rotaru *et al*., (2005) indicated that among the Quality Assurance (QA) systems, Good Manufacturing Practices (GMPs), Good Hygiene Practices (GHPs), Good Agricultural Practices (GAPs) and Hazard Analysis are the most utilized currently. Having a functional quality control system is of significant importance since they bring about improvement in food safety (Abdelgadir *et al*., 2016; Birhanu *et al*., 2017). Critical Control Points are the commonly applied systems in both food and dairy industries. Integrated Management systems such as ISO 22000:2005 are also accessible for producers. Tamine (2009) further clarifies that the science-based HACCP approach is a quality control system intended for use in the food and dairy industries while good manufacturing practices are the bare minimum hygienic and processing standards for businesses that process food.The GMPs guarantee compliance with all fundamental standards for quality and safety, including the eradication, prevention, and reduction of product failures and consistent product safety(Rotaru *et al*., 2005). The implementation of these systems by the milk processors indicated an improvement in the performance of by these milk processors. For instance, a better and more efficient implementation of the entire quality system is ensured by integrating HACCP into the system, which also produces safe food products. This is something that ISO 22000: 2005 also offers. (Efstratiadis & Arvanitoyannis, 2010).

5.4.6 Measures to control cross contamination

All the companies had put in place personal hygiene, cleaning and sanitation, waste management and pest control facilities. The results herein are supported by findings of Pal *et al*., (2015) which emphasized the importance of hygienic practices in processing which improved the microbial quality standards of milk and milk products. The results also conform to those of Parafin *et al*., (2019) where large scale milk processors had facilities for disinfection, rodent control, and access control. However, our results contradict those of Abdegadir *et al*., (2016) where they reported lack of regular cleaning and sanitation, collection of waste, and insect control in milk processing plants. Stringent administration of hygienic practices involving personal hygiene, sanitation, waste management and pest control are important to improve the microbial safety of the milk products, and ultimately reduce the hazards related to microbes. It is also important that proper packaging and storage are done under strict hygienic conditions. Mortajeni *et al*., (2014) believe that milk and dairy products can be produced and consumed safely as long as hygienic precautions are taken to prevent pre-, post-, and even cross-contamination. According to Te Giffel, (2010) stages in milk processing must be properly and hygienically handled to assure quality of milk and milk products. Adherence to these basic practices such as good agricultural practices and good manufacturing practices are the first steps towards achieving food safety in the dairy industry.

With regards to microbial contamination, the results showed that all the products were tested for total viable counts (TVC), and *E. coli*. However, only a few of the processors tested for *S. aureus* and *L. monocytogenes* respectively. It was also noted that some samples were contaminated by either *E. coli* or *S. aureus* in the last six months and *E. coli* was isolated from samples as the contaminant. Our findings agree with those of Pal *et al*., (2013) where a large number of microbes causing quality degeneration in milk and milk products were identified. According to Pal *et al*., (2013) microbial contamination of milk and milk products can occur as a result of contaminated utensils, environment, handlers, and even additives. Microbial identification in milk products offer evidence regarding the hygienic practices implemented during the product preparation, and subsequent packaging, handling, storage, and distribution (Pal, 2013). The isolation and identification of *E. coli* pathogen in the current study indicates risks associated with milk and milk products and suggests failure in quality assessment systems. The contamination of samples with *E. coli* was probably contributed by different handlers whose hygiene and cleanliness varied, water or inefficiency in the use of globally recognized testing to guarantee the application of accepted standards and practices (Merwan *et al*., 2018). However, Parafin *et al*., (2019) credited the presence of E. coli and other microbes to ineffective disinfection for personnel and equipment. Yuen *et al*., (2012) showed that presence of *E. coli* in milk products is likely to occur when employees use inadequate cleaning and hygiene practices something that contradicts our findings similarly, products manufactured under unsanitary conditions are expected to be contaminated.

It was also observed that only a few of the companies had facilities for testing and only 16.7% had received complaints from customers about food poisoning. All the staff were trained on the pathogenic microbes that would contaminate milk and milk products. The current study findings indicate that milk processors perceived *L. monocytogenes* as very risky and conducted tests to determine if it contaminated the equipment. This shows that the identified milk processors heed Mtimet *et al*., (2015) call of processors having abundant knowledge on various pathogenic microbes and the need to observe standards to prevent milk contamination.

5.4.7 Conformity to good manufacturing practices

Majority of the milk processors had well documented cleaning program, used food grade cleaning and disinfecting agents, and cleaned the processing equipment on daily basis. The results found herein concurs with those of Tesfaye *et al*., (2020). The authors indicated that all equipment and contact surfaces should be clean and should properly maintained so as to minimize accumulation dirt and in return reduce the growth of microorganisms. However, this finding contradicts those of Sucipto *et al*., (2020) where sanitation facilities were not adequate. Careful and frequent hand washing coupled with clean equipment, environment, and personnel are necessary to maintain a sanitary environment for milk processing. Personnel hygiene (handwashing, uniforms) as well as Good Manufacturing Practices (GMPs) are important in combating hygiene problems in these processors (Wirtanen *et al*., 2002). It is also important that location and the sanitizing stations are maintained to ensure good hygiene practices.

All the processors obtained water from the municipal council while others (50%) supplemented with water from the boreholes. It was noted that water used was portable and was tested for microbial quality in the laboratory. On a positive note, results of water testing in the last six months had not been found to be contaminated with any microbial contaminant. Analysis was mainly done on coliforms, TVC and on yeast and molds. These findings contrast to those of Sucipto *et al*., (2020) where periodical was not practiced and according to Cabral, (2010) water quality for food processing should be done at least twice per year. According to Canadian Food Agency it is important that water is safe and adequately supplied in processing applications. If the source of water poses contamination risk like the borehole water, it is necessary to treat the water.

All milk processors had a system to control cross contamination and was enforced through means such as the use of different colour codes, memos and notices and through colour coding of processing equipment. The measure taken to prevent cross contamination were also highlighted by Food Standards Agency. According to FSA, other measures include efficient methods for cleaning and disinfecting, maintaining good personal hygiene, especially when washing your hands, and having efficient management controls and training. Colour coding is primarily an effective measure in controlling cross contamination and become one of the preventive controls to protect food against direct contamination, cross-contact, and cross-contamination incidences. A color-coding plan stipulates the colours for handling different milk products within a processing plant and therefore

reduces the risk of cross contamination. According to WHO, (2002) and Merwan *et al*., (2020) by practicing hygiene before handling milk and ensuring the cleanness of all equipment and surfaces, cross contamination can prevent cross contamination. It was also noted that movement restrictions were imposed on personnel and equipment within the facility in all the premises surveyed. All the premises surveyed had a separate area for handling raw milk and pasteurized products, used disposable food grade gloves in handling open foods and installed designated hand washing areas.
The first assessment of the milk processing plants on the implementation of GMP showed an average of 78% of conformity. Among the areas that were assessed, licensing and hygiene showed the highest conformance percentages. These results show better conformity levels in the areas assessed compared to Costa-Dias *et al*., (2012) working on GM implementation in cheese factory. The authors reported an average of 32% conformity. In their work they reported high non-conformity in personal hygiene something that was found to be handled well in the current study. However, having non-conformity in areas such as process control, microbial contamination and milk safety can severely compromise the safety of food, so corrective action is needed to raise the standard of GMP implementation at processing facilities.

5.5 CONCLUSION

The present study has demonstrated that the implementation of GMP practices was above average. However, with detection of contamination pathogens continuous improvement in GMP practices will ensure food safety. This study has shown that the milk processors have implemented the necessary systems capable of ensuring safe products are delivered to the final consumer, the employees in charge of and spearheading the food safety controls and fully qualified on the requirements and the staff are adequately trained to be able to understand what is required of them in terms of GMPs.

5.6 RECOMMENDATIONS

The regulators should encourage and emphasize on the analysis of the other food pathogens such as the *Staphylococcus aureus* and *Listeria monocytogenes* that are not routinely done by most of the processors. Additional efforts should be put in place to enhance controls of *E. coli* contamination.

CHAPTER SIX: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENATIONS

6.1 GENERAL DISCUSSION

Majority of Nairobi city dwellers consume milk and milk products, specifically fresh milk and yoghurt. Moreso, more than 50% of the assessed population consume ice cream while cheese is consumed by 15.8% of them. According to Ozdogan *et al*., (2017), milk is balanced food and contains a wide variety of vitamins, minerals and other nutrients (calcium, potassium, vitamin B2, vitamin B12, proteins, etc.) The consumption of milk product is influenced by factors such as monthly income, family size, education level, and food habits of the households. However, according to Kubendran and Vanniarajan, (2005), demand for the milk products depends the consumers capability to purchase Selvakumar, (2018) indicates that the socio-economic status of the consumers such as income status, occupation, education level and region as some of the major determinants of milk consumption. While taking into consideration the safety aspect of milk and milk products, most of the consumers not drink milk immediately after purchase while about 54% of them stored buy milk in fridges for later use. It was also noted that more than 91% of the respondents boiled milk before use while nearly 90% of the respondents used milk for tea preparation. This practice is attributed to the probable negative effects of poor handling as elucidated by Sharma, (2009) since milk gets easily contaminated because it is good medium for the proliferation of bacteria. On the other hand, milk is perishable, and if it is not handled in a hygienic condition, its quality and safety may be compromised in a short period of time. Further evidence from previous studies has shown that milk should be cooled at 4^{o}C to arrest the growth of bacteria and to maintain quality (Singh and Gupta, 2015). The results are similar to those of Wangalwa *et al*., (2016) where respondents endeavoured to reduce milk spoilage by cooling and boiling. Whereas majority of the respondents indicated they understand how packaged milk was prepared, majority of the respondents do not have the technical knowledge on the appropriate pasteurization temperature as described by Kazimora, (2013). The consumption of pasteurized milk in this study is likely to be associated with availability of pasteurized milk in the study regions which resulted in the majority of people having access to them. Consumer preference for pasteurized and sterile liquid milk is positively correlated with household head income and education level, and negatively correlated with household size and household head age.

Food contaminants are important factors contributing to the high incidence of food borne disease in developing countries and is not an exception in the study area. Current findings show that the total viable bacterial counts (TVC) were enumerated and detected in 100% of the milk product samples collected in all the sites. However, the contamination levels differed among the products and between the sites they were all within the set limits by the KEBS standards with regards to TVC. This outcome depicts those of Nur *et al*., (2021) where all the pasteurized milk had high bacterial load ranging from

2.17×10^3 to 3.84×10^3 cfu mL-1. The same results were reported by Hasan *et al*.,(2015) and Wanjala *et al.*, (2017) where various quantities of TVC were isolated from different sources. Milk processing handled in unhygienic conditions supports the growth of pathogenic microorganisms leading to contamination of milk products. Thus, this study indicates an improvement in the milk handling and hence improvement in milk quality. It is however important to note that the highest TVC contamination was observed in sampled collected from Langata and not Kibera however, there was not significant difference between the sites. The finding contradicts those of Wanjala *et al*., (2017) where the highest TVC contamination was recorded slums while the lowest count was detected in urban Nairobi. This implies that milk contamination may be starting from the farms and collection centres and as such milk and milk products within the county may have contaminated. Notably all the milk products, ice cream samples had high incidences of *E. coli* than any other. The presence of *E. coli* and other microbes in ice creams indicates that the preparation process has not been done effectively or post process contamination might have occurred (Pal *et al*., 2016). According to Osamwonyi *et al.*, (2011) possible sources of these pathogenic microorganisms in ice cream include raw materials used for the composition of ice cream such as separated milk and milk powder, cream, flavouring, colouring substances, stabilizers. Overall, *Staphylococcus aureus* was detected in 33.3% of milk and milk products. In Karen, *S. aureus* was not detected in milk products such as cheese, yoghurt and ice cream while in Kibera *S. aureus* was not detected in cheese and ice cream. These findings are similar to those reported by Latha *et al*., (2017) and Dai *et al*., (2019) where high prevalence of *S. aureus* was reported, however, the prevalence of *S. aureus* in this study is lower.

An evaluation on implementation of good manufacturing practices revealed that most of the employees responsible for monitoring of the GMPs implementation for the milk processing were quality assurance analysists and quality control managers. This is in line with the technical requirement of whereby milk processing and operations personnel are required to have the necessary qualifications to ensure safety of food and that it has the appropriate identity, purity, strength, and meets consumer quality demands (FDA, 2011). Of the total milk products, yoghurt and fresh milk were the most commonly processed products. Other products include cheese, butter, ice cream and whipping cream. These findings relate to those reported by Schneider, (2018) who highlighted yoghurt and fresh milk as the most processed milk products in Nairobi. Observations with regard to critical controls showed that all the companies had in place critical processes such as pasteurization, cleaning and sanitation, cold storage and sterilization and all the staff were trained in each critical area. The dairy industry is composed of various interlinked processes such as pasteurizing, homogenizing, ageing, flavouring, freezing and packaging. (Georgieva *et al*., 2002). All milk processing companies assessed in the study implemented food safety management systems such as

ISO 22000, GMP and HACCP. This shows that majority of the milk processors conformed with the required good manufacturing practices, therein ensuring the identity, strength, and quality of their milk and milk products while reducing facility losses associated with microbial contaminations.

6.2 CONCLUSIONS

Most consumers within the Langata and Kibra sub counties had an acceptable knowledge on milk handling which is sufficient to ensure some degree of safety is observed. Inferentially, there is a relationship between the education levels of milk consumers and their parametric choice on good quality milk.

The TVC counts isolated in all the samples were within the set limits by the KEBS standards. However, with the microbial counts for *E. coli* were above the set standards by food safety regulatory bodies. Detection of *E. coli* and *S. aureus* foodborne pathogens in milk and milk products, even if in few samples indicate possible lapses in industrial implementation of food safety management systems.

In addition to examining the variables that may affect the way food safety management systems are implemented, the study has demonstrated that the implementation of GMP practices was above average. Milk processors have implemented the necessary systems capable of ensuring safe products are delivered to the final consumer.

6.3 RECOMMENDATIONS

1. There is need to improve the microbial quality of milk and milk products by employing measures that will establish proper management practices to ensure improved hygiene, good manufacturing practices and food systems that will help to minimize microbial contamination. This can be done through investing in knowledge intensive approaches.
2. Although the implementation of FSMS in milk processing industries is above average, a significant number of milk processors do not conform to these standards. With new modernized methods in the detection of contamination pathogens, continuous improvement in GMP practices will ensure food safety.
3. Regulators need to intensify on market surveillance and product testing to protect the consumers from getting contaminated products.
4. The regulators should encourage and emphasize on the analysis of critical food pathogens such as the *Staphylococcus aureus* and *Listeria monocytogenes* while also putting in place controls on *E. coli* contamination.

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APPENDICES

Appendix one: Study tools

Data tools instruments

Data	Instruments/ Equipment	Manufacturer-name	Tool	Data recording space
Specific Objective 1: To determine consumers knowledge and handling practices of Milk and milk products.				
Consumers Knowledge.	Mobile phones	Samsung/Android	Open data kit questionnaire	online
Handling practices	Mobile phones	Samsung/Android	Open data kit questionnaire	online
Specific Objective 2: To determine implementation of good manufacturing practices (GMP) in milk processing systems by the processors for control of *Listeria* contamination.				
GMP Implementation to control *Listeria*	Mobile phones	Samsung/Android	Open data kit Questionnaire	online
Specific Objective 3: To establish the prevalence of *Listeria Monocytogenes* contamination on processed Milk and Milk products				
Isolation of *Listeria Monocytogenes*	Enrichment Broth – Horizontal Methods.	-	ISO 11290-1:2017 Microbiology of the food chain — Horizontal method for the detection and enumeration of *Listeria monocytogenes* and of *Listeria spp.* — Part 1: Detection method	Forms- Lab Reports.

Appendix Two: Participants Consent Forms

INFORMED CONSENT INFORMATION SHEET

RESEARCH TITLE: KNOWLEDGE AND HANDLING PRACTICES OF MILK PRODUCTS CONSUMERS, SAFETY OF MILK PROCESSING SYSTEMS AND PREVALENCE OF HYGIENE INDICATOR MICROORGANISMS IN PROCESSED MILK PRODUCTS SOLD IN NAIROBI COUNTY.

You are being invited to take part in this research to assess knowledge and handling practices, safety of milk processing systems and prevalence of hygiene indicator microorganisms on processed milk and milk products sold in Nairobi. The research aims at creating awareness and providing continuous education especially for vulnerable groups regarding the risks associated with listeria in Milk and Milk Products. The study purposes to generate data that would influence the regulatory bodies to make hygiene indicator microorganisms testing critical for all processed milk and milk products offered for sale.

In this study, you will be expected to provide truthful information regarding your household to the enumerator assigned to you. Once you consent to participate in the study, the enumerator will ask you questions and the responses you give will be captured in this questionnaire. It's our expectation that the interview will be completed within 15 minutes.

The data collected shall only be seen by members affiliated with the study, and will not be linked to any identifying information such as name, address or other personal details that you will supply. The data collected shall be averaged over many participants and therefore, your individual data shall not be identifiable. This study poses no known risk(s) whatsoever to you or to your family. You may decide to stop Participating in the study at any time however we encourage you to remain in the study and respond to all questions. You have the right to demand that any data provided until that point be withdrawn/destroyed. If you have any questions with regards to this information sheet, you should ask the before the study begins.

Appendix three: Consent Form

Researcher (name): _________________________contact: _______________

RESEARCH TITLE: KNOWLEDGE AND HANDLING PRACTICES OF MILK PRODUCTS CONSUMERS, SAFETY OF MILK PROCESSING SYSTEMS AND PREVALENCE OF HYGIENE INDICATOR MICROORGANISMS IN PROCESSED MILK PRODUCTS SOLD IN NAIROBI COUNTY.

Kindly tick where appropriate:

1. I confirm that I have read (or been read to) and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had the questions answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my legal rights being affected. ☐

3. I understand that relevant sections of information and data collected during the study may be looked at by other members of this research team. ☐

4. I give permission for these individuals to have access to these records. ☐

5. I agree to take part in the study without any demands and of my own free will. ☐

Name of respondent: ……………………………………………….

Date: ……………………………………………………………………

Signature: ……………………………………………………………

Appendix four: RESEARCH LICENSE

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NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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RESEARCH LICENSE

This is to Certify that Ms.. Lilian Adhiambo of University of Nairobi, has been licensed to conduct research in Nairobi on the topic: KNOWLEDGE AND HANDLING PRACTICES, SAFETY OF MILK PROCESSING SYSTEMS AND PREVALENCE OF LISTERIA MONOCYTOGENES ON PROCESSED MILK AND MILK PRODUCTS SOLD IN NAIROBI. for the period ending : 03/November/2022.

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