Influence of physical state of farm housing and processing facilities on quality and safety of dairy milk products

by

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Declaration

I, Annah Shingirai Paraffin, declare that this dissertation has not been submitted to any other institution other than the University of KwaZulu-Natal and that it is my original work conducted under the supervision of Professor Michael Chimonyo. All the assistance towards production of this dissertation has been acknowledged. All the references used in this work has been duly accredited.

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List of Abbreviations

BTSCC	Bulk Tank Somatic Cell Counts
BF	Butterfat
DSU	Dairy Services Unit
DAFF	Department of Agriculture Forestry and Fisheries
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organisation
FSMS	Food Safety Management System
GAP	Good Agricultural Practices
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis Critical Control Point
LCI	Lower Confidence Interval
MCC	Milk Collection Centre
QA	Quality Assurance
QC	Quality Control
QMS	Quality Assurance Management Systems
SAS	Statistical Analysis Systems
SCC	Somatic Cell Counts
SD	Standard Deviation
SE	Standard Error
SNF	Solids Non-Fat
TBC	Total Bacteria Count
TS	Total Solids
UCI	Upper Confidence Interval

Abstract

Influence of physical state of farm housing and processing facilities on quality and safety of milk and dairy products

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Annah S. Paraffin

The broad objective of the study was to determine the influence of physical state of farm housing and milk processing facilities on the quality and safety of milk and its products. Data collected from urban areas (n =135) and non-urban areas (n =135) households were used to investigate consumer perceptions of milk safety and consumption preferences of dairy products. Data collected from large-scale dairy farmers (n=158) and small-scale dairy farmers (n=186) were used to investigate the perception of milk producers on milk quality and safety. Milk records collected from large-scale dairy farms (n =78) and small-scale farms (n =126) were used to determine the effect of physical state of farm housing and milking practices on total bacteria counts (TBC), somatic cell counts (SCC), protein, butterfat (BF), solids non-fat (SNF), lactose and total solids (TS). Milk records collected from large-scale (n =12) and small-scale (n = 15) dairy processors were used to estimate the influence of physical state of milk processing facilities on presence of *E. coli* and coliforms in buttermilk.

Urban households were 2.8 times more likely to consume fresh milk compared to their non-urban counterparts ($P < 0.05$). Households from urban areas were twice more likely to purchase fresh milk from kiosks, while households from non-urban areas were five times more likely to buy fresh milk from vendors. The likelihood of appearance, quality and nutritional value being

important to households during selection of milk products was higher in urban locations compared to non-urban locations (odds ratio estimates of 4.29, 4.49 and 6.75, respectively). Knowledge and awareness of milk safety issues was more important to urban households.

Large-scale farmers were three times more likely to consider breed affecting milk quality compared to their small- scale counterparts. Post milking contamination of milk was perceived to occur during transportation by small-scale farmers, whilst large-scale farmers ranked storage as an important source of contamination post-milking. The likelihood of milk safety being important was twice higher in large farms compared to small-scale farms ($P < 0.05$.

The majority (70%) of large-scale farms had milking parlour doors, windows and fly proofing in poor physical state. More than fifty percent of small-scale farms had milking parlour doors, windows and fly proofing in good physical state ($P < 0.01$). Most of the large-scale farms used pumps to deliver their milk to storage tanks whilst most of the small-scale farmers used the pouring method ($P < 0.05$). The TBC and SCC in milk from dairy farms where the wash rooms that had doors, floors, walls and ventilation were in a good physical state were higher than from those farms where the wash rooms were in poor physical state ($P < 0.05$). Farms that used machine milking and automatic milking cleanings system had lower TBC and SCC in milk compared to farms that used manual milking or hand washing ($P < 0.05$).

The butterfat and protein content in milk from dairy farms with milking facilities that had poor physical state of ceilings, ventilation and floors was lower than those in good physical state ($P < 0.05$). The butterfat, protein, lactose and solids non-fat (SNF) content in milk from farms that utilised hand milking was higher than dairy farms that used milking machines ($P < 0.05$). The likelihood of buttermilk from processors with buildings, processing and packaging areas that

had poor physical state of drains, roofs, fly-proofing, windows having *E. coli and* coliforms was 1.2 times higher than those facilities in good physical state. Processors without quality assurances systems or food safety training were twice more likely to produce buttermilk contaminated by *E. coli* and coliforms ($P < 0.05$). Poor physical state of ceilings, doors and floors and poor drainage systems at farms results in production of milk with high bacterial count and presence of *E. coli* and coliforms in buttermilk.

Key words: Consumer, *E. coli,* food safety, farm housing, milk quality, Somatic cell counts, Total bacteria count,

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Dedication

This thesis is dedicated to my two kids Ethan and Kathyrn Kamuti.

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Chapter 1: General Introduction

Milk is a wholesome animal product of high nutritive value, which is consumed across cultures in Africa and many parts of the world. Dairy products and milk play an important role in human nutrition by providing readily accessible animal protein (Ostan *et al.,* 2016). The demand for milk and dairy products has been growing at an average rate of 4 % per year (FAO, 2015). In Southern Africa, the demand for milk and dairy products is expected to continue rising as the population increase (Coetzee, 2015). With the increase in per capita consumption of dairy products, consumer interest in the safety and wholesomeness of milk and milk products is expected to rise (Papadopoulos *et al.,* 2012). Current food safety scares have driven quality control to the forefront of international trade agendas with emphasis on milk and processed milk products. Milk and its products that fail to reach comparable levels of quality, functionality and reliability will not survive in competitive global markets. The milking house and processing house physical state cannot be overlooked, as consumers are concerned about all aspects of how the milk they consume is produced and processed. As the demand for safe milk and dairy products increase, the importance of an integrated approach for ensuring milk safety throughout the whole supply chain becomes important.

Milk quality is described by its physio-chemical composition and bacteriological profile. The physio-chemical components such as butterfat (BF), solids non-fat (SNF) and protein contents are influenced by many factors including feeding practices, herd management, breed and stage of lactation (Swai and Schoonman, 2011). The bacteriological quality of milk is determined by the type, quantity and specific distribution of micro-organisms (Pantoja *et al.,* 2009). In dairy cows, enumeration of bacterial counts has been used to describe the microbiological quality of milk (Nagy *et al.,* 2013). Bulk tank somatic cell counts (BTSCC) is the most widely used indicator of raw milk quality. Somatic cell counts (SCC) from a healthy uninfected udder are usually lower than 100 000 cells/ml, while bacterial infections can cause the SCC levels to increase (Bytyqi *et al.,* 2010). High SCC in milk has a negative influence on the quality of milk, product quality, processing activities as well as shelf life of by-products e.g. yoghurt or buttermilk (Nada *et al.,* 2012; Olofsson, 2013).

While other factors such as breed of cow, location and season affect SCC in milk, it important to determine the effect of farm housing and milking practices on the quality and safety of milk because contamination of milk can originate from the milk facility and equipment in poor physical state. In poorly constructed or unmaintained milking facilities, milk can be contaminated by wind when it blows into the facility with poor windows, doors and ventilation. In addition, cracks, crevices and corners that cannot be easily cleaned can harbour milk spoilage micro-organisms (Holah, 2014). Buildings and equipment that are maintained in good physical state are also easy to clean.

Good quality milk can thus be described as milk that has been produced with minimum SCC, free of residues, antibiotics or pathogenic organisms that pose a health threat to the consumers and is safe for consumption. One of the biggest concerns of dairy farmers is the quality and safety of milk. Failure to meet quality assurance standards and regulatory requirement affects both farmers and consumers. Penalties imposed for production of poor quality milk reduces income for farmers. Consumers are exposed to potential public health threats and diseases such as listeriosis from consumption of contaminated milk (Lejeune and Rajala-Schultz, 2009) In developing countries such as Zimbabwe, the increase in the demand of milk has resulted in enormous changes and transformation of the dairy industry. There has been a rise in production and marketing of unregistered milk products via the informal dairy sector (Kyoba *et al.,* 2005; Swai and Schoonman, 2011). In most cases, these informal producers and middlemen may not necessarily pay attention to the physical state of production or processing facilities.

Contamination of milk by physical, chemical or microbiological elements is highly correlated to udder health and pre-milking hygiene conditions at the farm (Olofsson, 2013). Factors that contribute to the deterioration of milk quality for the whole value chain from the farm, through processors to consumers, are dynamic. The contribution of farm housing and management practices to SCC, BF, SNF and protein needs to be understood. Post-milking management, handling, transportation, time and distance to the milk collection points may alter the milk quality and should be understood. As with other developing countries, the informal milk marketing systems in Southern Africa continue to flourish because they provide a number of benefits that include high farm gate prices and employment, especially for smallholder farmers and milk vending agents (Kyoba *et al.,* 2005; Swai and Schoonman, 2011). Some of these informal milk marketing outlets operate under unhygienic conditions with facilities that have poor physical state of drains, siting, floors, walls, ceilings, ventilation and state of repair. In most cases, they may not be adequately regulated by the governments, posing a possible public health threat for consumers due to consumption of possibly contaminated milk.

Small herd sizes, lack of resources, low daily production volumes and distance to the processor limit most smallholder dairy farmers to supply milk directly to large processors. These circumstances force them to pool together their milk as groups of farmers and their milk is collected from one centralized collection point. The handling practices post-milking contribute to the deterioration of milk before processing. With bulk collection of milk, milk with high SCC can be mixed with milk with low SCC. As such, farmers with good quality milk can be penalised because of other farmer's poor milk quality from that consortium. It, therefore, becomes essential for the farmers involved to follow hygienic quality standards that allow them to produce clean milk. The maintenance and construction of farm milking and processing facilities may be important in ensuring production of good quality milk. There is a possibility that poorly constructed and unmaintained farms with buildings in poor physical state of drainage, ventilation, windows, fly/dust proofing could increase milk contamination. Although the relationship that exist between farm hygiene and milk quality among smallholder dairy farmers are well documented, effects of farm housing physical state on milk quality is not known. Therefore, it is vital to determine the contribution of physical state of farm housing and milk processor facilities on milk quality and safety.

1.1 Justification

The benefits of producing good quality milk and knowing how its quality has been assured throughout the whole supply chain are enormous for consumers, farmers and processors involved. Producing milk with low bacterial counts maximizes profits for farmers and reduces incidence of contamination of milk and by-products. Smallholder farmers play an important role in the supply of milk to the dairy industry. Yet, they continue to lose the much-needed income because of failure to meet the basic standards for supply of good quality milk.

Understanding these effects of farm housing and milk processing facility physical state enables the producers and processors to put in place systems that minimize risk or contamination of milk with pathogenic bacteria. Milk and by-products sold through informal milk marketing channels pose many public health threats if contaminated, not handled safely and thus increasing the risk of passing diseases to consumers. It, therefore, becomes important to explore the opportunities available to improve the processes from milk production by farmers through to consumption.

Understanding the contribution of farm and processor housing physical state allows farmers and processors to put in place good food safety management systems. Both producers and processors can realize the need to invest money on improving facilities or milking conditions if the benefits on improved milk quality can be recognized. On the other hand, knowledge of how consumers perceive milk quality help not only the farmers but the government and food safety agencies to formulate frameworks, training and awareness campaigns that can be used to improve quality and safety of milk.

1.2 Objectives

The broad objective of the study was to explore the influence of physical state of farm housing and processing facilities on the quality and safety of milk and milk products. The specific objectives were to:

1. Compare perceptions of urban and non-urban consumers on quality and safety of fresh milk and cultured buttermilk from different outlets;

2. Compare perceptions of large- and small- scale farmers on factors affecting milk quality and safety;
3. Determine the effects of physical state of farm housing and milking practices on somatic cell counts and total bacteria counts in milk from large- and small-scale farms;
4. To determine the effects of physical state of farm housing and milking practices on physico-chemical characteristics of milk; and
5. Determine the effect of physical state of milk processor housing, biosecurity and quality assurance systems on presence of *Escherichia coli* and coliforms in cultured buttermilk from large- and small-scale processors.

1.3 Hypotheses

The hypotheses tested were that;

1. Perceptions of consumers located in urban and non-urban settings on quality and safety of cultured buttermilk and fresh milk from different outlets are different;
2. Perceptions of large- and small-scale farmers on milk quality and safety differ.
3. Farm housing physical state and milking practices affect somatic cell counts and total bacteria counts in milk from large- and small-scale farms.
4. Farm housing and milking practices affect milk physico-chemical characteristics of quality.
5. Milk processor housing physical state and processing practices have an effect on the presence of *Escherichia coli* and coliforms in cultured buttermilk from large- and small-scale processors.

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Chapter 2: Literature Review

2.1 Introduction

Production of high quality milk is an important goal for most dairy farmers and processors. They face many challenges and losses in income from poor quality milk and contamination of milk and by-products from various sources. Milk quality and safety is affected by on-farm, cow, environmental, housing physical state and processing factors. To ensure safety of milk, there is need to assess the influence of farm housing physical state and milk processing practices on quality and safety of milk and by-products. This chapter reviews information on milk consumption trends, dairy milk production systems, physico-chemical characteristics of milk, consumer concerns on milk safety, farm housing physical state and the relevance of food safety and quality assurance systems in production and processing of milk.

2.2 Milk consumption trends

World milk production has been growing at approximately 3 % per year in recent years (Food and Agriculture Organisation (FAO, 2015). Meanwhile, the demand for milk and dairy products has been growing at an average rate of 4 % per year (FAO, 2015). Because of this increase in population and per capita consumption, the demand for milk and dairy products worldwide is expected to continue rising, as shown in Figure 2.1 (Coetzee, 2015). In Africa, consumption of milk and processed milk by-products such as cultured buttermilk has the potential to address challenges of food insecurity. As African regional trading and export of milk and milk products continues to rise, there is, therefore, a need for milk processors to meet the basic food safety requirements and standards needed for production of safe and quality milk products. The main products produced and consumed in the region include raw milk, yoghurt,

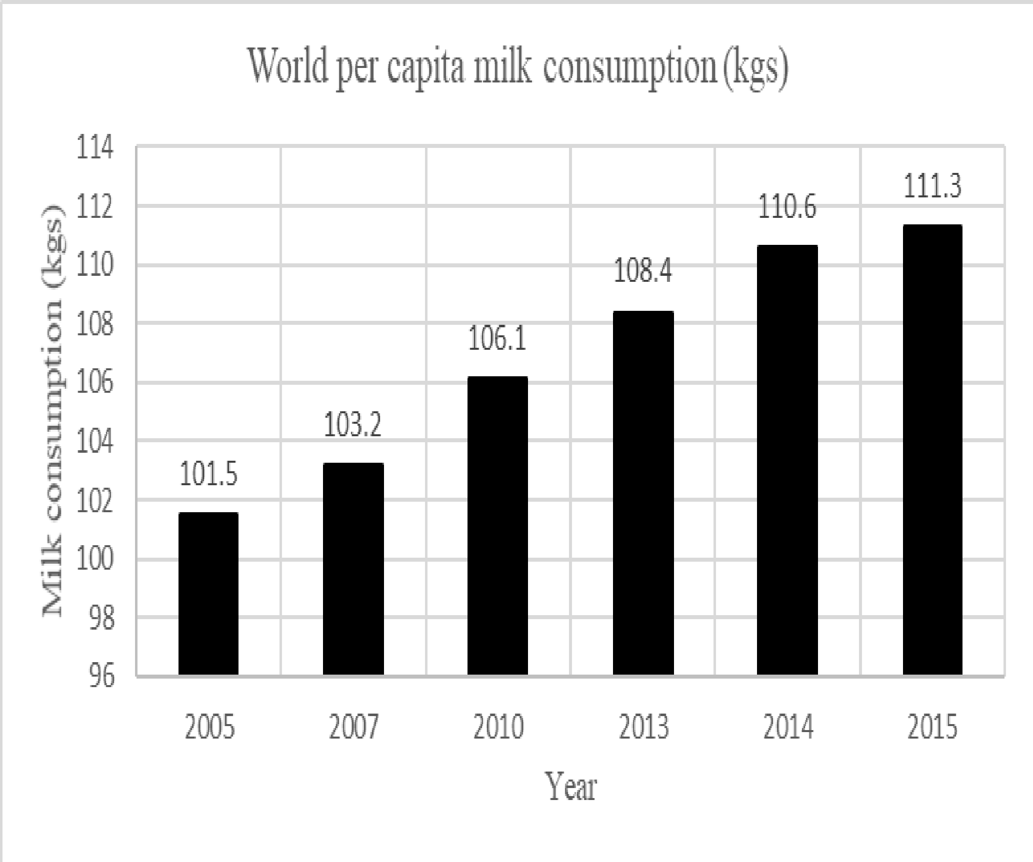

Figure 2. 1 World per capita milk consumption (kgs)

Source: Food and Agriculture Organization, 2015 cultured buttermilk, cheese, cream, fruit blends, fermented milk, pasteurised milk and long-life milk (DAFF, 2015). For example, in South Africa, the consumption of milk has been reported to be increasing, with more than a million cows producing greater than 2.65 million kg of milk in 2011/12 (DAFF, 2015). Figure 2.2 shows the consumption of fresh milk in South Africa from the year 2005 to 2015. The milk consumed in this region is produced by farmers who utilise different milk production systems. Similarly, consumption of milk and milk products has been increasing in Zimbabwe as the industry has been focussing on driving consumption of protein rich food. However, milk production from the formal dairy sector at 52 million kilograms still lags below the national demand of 180 million kg per annum (SNV, 2012). In Zimbabwe, this gap has filled through imports from other countries in the region like Zambia and South Africa.

2.3 Milk production systems in Southern Africa

Milk production in Southern Africa has been steadily increasing over the last decade. Economic hardships, frequent droughts, extreme temperatures and climate change have contributed to slow growth in milk production in Southern Africa (SNV, 2012). These effects of economic hardships on milk production are more pronounced in developing countries. The major dairy breeds are Holstein, Jersey, Ayrshire and Guernsey (DAFF, 2015). Although over the last decade the number of milking cows has been fluctuating in Africa, the demand for milk and dairy products is expected to continue growing. The contribution made by both small-scale and large-scale farmers will continue to be important. The infrastructure varies between the different production systems. Both large-and small-scale farmers have different layout of the dairy premises which can impact the quality and safety of milk produced and subsequently processed.

2.3.1 Large-scale farms and processors

The large-scale farming sector is characterised by production of milk on large farms with dairy herd sizes greater than ten cows per farm (Hahlani and Garwi, 2014). The large-scale farms traditionally use pure or exotic dairy cow breeds e.g., Holstein, Red Dane, Ayrshire and Jersey. The farmers utilise planted pastures and supplementary commercial feeds. Usually, milk is marketed through the formal milk marketing channels. The large-scale dairy sector has two sub-categories of commercial dairy farmers and company-owned dairy farms. Milk is produced in large volumes and processed into a diversity of products under commercialised and formal operating environment (SNV, 2012)

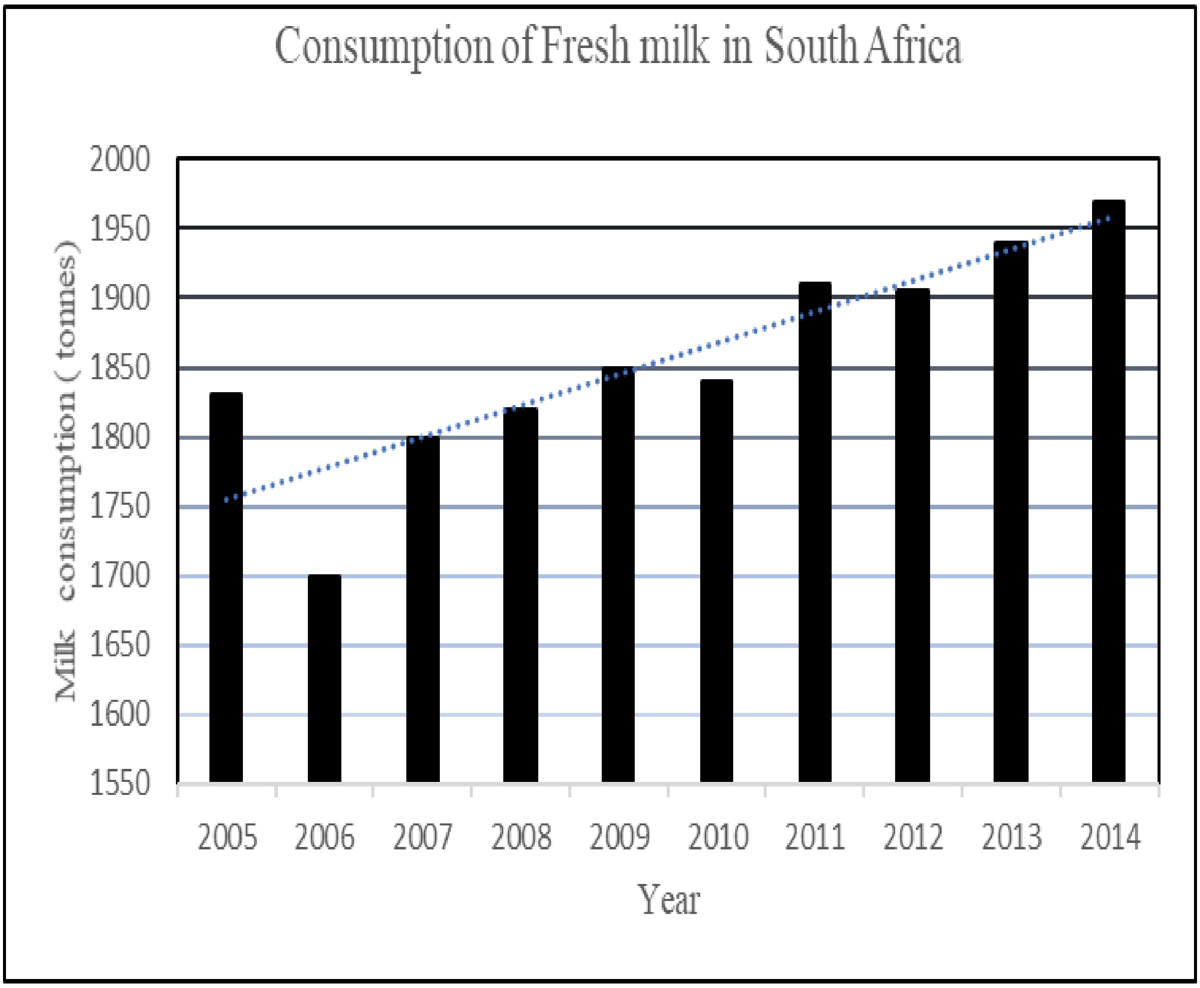

Figure 2. 2 Consumption of fresh milk in South Africa

Source: Department of Agriculture Forestry and Fisheries (DAFF), 2015

2.3.2 Small- scale farms and processors

The small-scale dairy sector consists of communal and resettled farmers. These farmers usually have small dairy herds ranging from three to ten animals per farmer smaller land holdings., (Hahlani and Garwi, 2014). Milk produced under this system is for sale to generate income and for household consumption. It is common for the small-scale farms and processors to be located near the urban areas or peri-urban areas. These farmers use cross-bred dairy breeds. The smallholder dairy sector usually sells their milk through the informal milk channels or transport their milk to Milk Collections Centres (MCCs). The milk is processed into limited varieties of products and at time these processors operate as cottage or home industrial operations (SNV, 2012). Although milk produced by small-scale farmers may be clean, there is a big challenge posed by lack of infrastructure, poor milk housing physical state and lack of cold chain facilities (Moffat *et al.,* 2016). Inevitably, milk begin to deteriorate in quality before it can be sold or further processed. Thus, channels used to market milk and milk products will have an impact on the quality and safety.

2.4 Milk marketing channels

The agri-food industry transformation of developing countries in the 1980s had resulted in formalisation of a greater percentage of milk and milk product suppliers (Reardon *et al.,* 2009). Continuous increase in the demand of milk and milk products, coupled with slow increase in milk production, has resulted in vast changes in the dairy industry. The emergence and growth of the informal dairy sector is being experienced in most developing countries. The informal milk marketing system involves producers selling milk products such as fresh milk, yoghurt and cultured buttermilk directly to consumers or indirectly through vendors (Swai and Schoonman, 2011). Sometimes milk and by-products produced are transported using non-refrigerated trucks with poor temperature control and, thus, safety of such products is questionable. A larger proportion of the informal milk processors have insufficient knowledge and lack of experience in processing dairy products safely (Moffat *et al.*, 2016). It is possible that the quality of products made via the informal systems may be adulterated or compromised. With the emergency of informal traders and milk vendors, it is possible that chemical quality of milk can be adulterated through adding water or other substances by individuals who would want to profiteer from high milk volumes (Aziz and Khan, 2014; Kyoba, *et al.*, 2005; Singh and Gandhi, 2015). The biggest challenge being that most of the informal milk processors do not comply with basic food safety standards required for milk processing (Nada *et al.*, 2012). Compliance to food safety standards ensures that milk products reach the intended consumer with characteristics and features required to satisfy them.

2.5 Milk quality and safety

The International Organisation for Standardization (ISO) defines quality as the 'the totality of features and characteristics of a product that bears its ability to satisfy stated or implied needs (WHO, 2003). Thus, milk quality refers to those features and characteristics of milk that bear its ability to satisfy the stated and implied needs of the consumers (WHO, 2003). Milk quality is often determined by the chemical composition and its bacteriological profile. The chemical components of milk include fat, lactose and protein (Srairi *et al.*, 2008). These components play a key role in the possible uses of the raw milk in product processing. The bacteriological profile is characterised by the contamination levels and specific distribution of micro-organisms (Nagy *et al.*, 2013).

The compositional quality of milk is variable. Table 2.1 shows physico-chemical compositional quality of cow milk. The major physio-chemical components of milk are butterfat (3.6%), protein (3.4%), lactose (4.9%) and solids non-fats (12.6%) (Negash, *et al.,* 2012; Dehinenet *et al.,* 2013). These components affect the milk processing suitability (Ogola *et al.,* 2007; Radkowska and Herbut, 2017). Chemical components such as fat and protein contents play a key role in the possible uses of the raw milk in product processing and influence shelf life of milk and by-products.

Changes in milk constituents can occur during handling, storage and processing on farm. Management of farm housing and milking practices may contribute to alter the bacteriological and physico-chemical characteristics of milk. The quality of milk, therefore, affects shelf life and the acceptability of milk products to consumers (Noordhuizen and Metz, 2005).

It is important to note that milk quality as defined by the consumer or producer include both subjective and objective measurements. These measurements include colour, purity, flavour, wholesomeness, nutrition, safety and other attributes of milk, which may be important to the consumer. Milk safety differs from the other quality attributes because it is difficult to observe. Milk may appear to be high quality having the right colour, flavour and smell yet can be unsafe if it has been contaminated by undetected pathogenic organisms or chemicals. Worldwide, consumers demand milk that is safe for consumption and that has been produced in a hygienic manner.

Table 2. 1 Physico-chemical compositional quality of cow milk

Main Constituent	Range (%)
Water	85.5-89.5
Total Solids	10.5-14.5
Fat	2.5- 6.0
Proteins	2.9-5.0
Lactose	3.6-5.5
Minerals	0.6-0.9

Source: Connor, 1995)

2.6 Consumer concerns on milk quality

Milk that is safe for consumption can be described as milk that has been produced with minimum somatic cell counts, free of residues, antibiotics, pathogenic organisms or contamination that pose a health threat to the consumers (Pantoja *et al.*, 2012). In dairy cows, enumeration of bacterial counts has been used to describe the microbiological quality of milk (Nagy *et al.,* 2013). Bulk tank somatic cell counts (BTSCC) is a good indicator of raw milk quality (Nagy *et al.,* 2013; Zucali *et al.,* 2011).

The concept of milk safety thus refers to the probability of not suffering some harm after consuming milk or specific milk by-products. Implementing robust milk safety and quality assurance systems helps to authenticate those attributes of milk that the consumers may not be able to measure at the time of purchase (Soderlund *et al.,* 2008). Although the problem of milk safety is a growing concern for many milk consumers in developed countries, at most times it is still largely a latent concern as other risk factors tend to affect how consumer perceive milk quality and safety. Consumers choose milk products based on many attributes including price, appearance, taste, convenience (Novoselova *et al.*, 2002). There is also a general perception by consumers that supermarkets and expensive high-end markets provide higher quality, low risk milk products as opposed to the cheaper small-end or traditional type markets. Traditional outlets such as on-farm milk purchase points, kiosks and open air roadside stalls, however, continue to serve as significant points for purchase of milk and milk products (SNV, 2012). In developing countries, resource-limited households with limited access to facilities such as electricity or refrigerators are forced to consume milk that has not undergone further processing. As consumers become health conscious, there is a willingness to pay more for healthier or organic milk and milk products which may be perceived as better and safer products. In most countries, it is illegal to market unprocessed milk to the public (Oliveria *et al.,* 2011). Nevertheless, people continue to buy and consume milk and milk products made from unpasteurised milk, despite the perceived safety concerns of consuming such. In developing countries, it is a common practice for consumers to utilise milk and milk products, that have not been processed or pasteurised. Milk quality and safety standards should be enforced at farm level.

2.7 Milk quality and safety at farm level

Failure to meet quality assurance standards and regulatory requirement affects both the consumer and farmer. Penalties imposed for production of poor quality milk reduces income for farmers. For example, there are regulatory standards for monitoring total bacteria counts (TBC) at the farm level and bulk milk is routinely sampled for the determination of fat content, protein, lactose, SCC, and antibiotic drug residues (Flores-Miyamoto *et al.,* 2014). Such systems pay farmers a premium for good quality milk. Thus, their perception of good quality milk is influenced by how much they meet those set standards. Those who do not meet the standards are paid a lower price and those who continue to supply high quality milk are paid a bonus (Flores-Miyamoto *et al.,* 2014; Velthuis and Van Asseldonk, 2011).

Farmers should clearly understand the relationship between changes in TBC and SCC with farm management practices. For example, high TBC is positively correlated with unsanitary conditions associated with dirty udders before milking, inadequate or poor teat sanitation, poor cleaning and sanitation of milking equipment and inadequate cooling of milk at the farm (Bytyqi *et al.,* 2010; Flores-Miyamoto *et al.,* 2014; Pantoja *et al.,* 2009). Other elements that influence TBC include health and hygiene of the cow, housing and management, cleaning and sanitizing procedures, farm milking environment and quality of cleaning water (Berry *et al.,* 2006; Elmoslemany *et al.,* 2009). All these factors have a bearing on how a farmer perceives the quality of milk they produce.

Quality of milk is influenced by various factors, which include farm hygiene, cow cleanliness, equipment and machinery, farm management practices, breed of cow, season, age, stage of lactation, environmental factors, diet and intra-mammary infections (Sant'anna and Paranhos da Costa, 2011; Nagy, 2013). Interactions of these factors are common for dairy cows (Zucali *et al.,* 2011; Hauge *et al.,* 2012). The microbiological hazards that are potentially present in milk include *Salmonella typhimurium, Campylobacter jejuni* and *Escherichia coli* (Lejeune and Rajala-Schultz, 2009: Ricci *et al.,* 2013). Milk contamination by pathogenic bacteria is a serious public health matter.

Mastitis is the most prevalent and costly disease of dairy cows with losses attributable to both subclinical and clinical forms of the disease. Subclinical mastitis occurs when disease-causing agents infect one or more quarters of the udder without resulting in enough disruption of the alveoli to produce visibly abnormal milk (Caravello *et al.,* 2005). Teats and udders become infected with environmental pathogens and bacteria from manure, water or dirt in the milking parlour. Dirty udders are a significant risk factor for the presence of *Klebsiella spp.* after the pre-milking routine (Munoz *et al.,* 2008; Nobrega and Langoni, 2011). Mastitis is one of the most dominant conditions of importance to farm milk hygiene. Mastitis can influence the total milk output and modifies milk composition (Sarkar, 2016). In cows with mastitis, an elevation of somatic cell counts decreases protein quality, fat composition, lactose and pH of raw milk

(Petlane, *et al.*, 2013). Infection by mastitis causes disruption of the blood-milk barrier that increases the activity and content of leucocytes in the milk, thereby disrupting the contents of milk constituents. The inflammatory process increases the activity of leucocytes which results in increased concentration of lipolytic and proteolytic enzymes. Bacterial contamination in milk due to poor hygiene may, therefore, cause the deterioration of milk proteins due to the increased activity of protease enzymes (Sarkar, 2016). Environmental mastitis pathogens include *E. coli* and *Klebsiella* species. Cows become infected by environmental mastitis when the teats and udders are wet and come into contact with mud or manure giving large number of bacteria the opportunity to infect the udder (Ruegg, 2004). Thus, farm hygiene will continue to play an important role in assuring milk safety by minimising risk of cow infection from mastitis causing bacteria.

2.8 Hygiene and physical state of farm and processor housing

Farm hygiene plays a crucial role in assuring milk safety as contamination can occur at any stage during the milk production process. Milk coming straight from the udder of a healthy cow is usually clean, containing very few bacteria, sometimes up to 50 000/ml (Pandey and Voskuil, 2011). Milk is an ideal medium for micro-organisms to grow and is easily contaminated during the milking process. Contamination may occur from the cow itself, the environment and unhygienic practices relating to the milkers, milking process and handling. The main source of contamination include faecal matter from soiled cows especially teats, udders and tails (Ellis, *et al.*, 2007; Verdier-Metz *et al.*, 2009). Physical contaminants such as dust, insects, animal hair, bedding and grass also spoil milk (Swai and Schoonman, 2011). Bacterial contamination comes from inadequate cleaning of milking equipment as well as other contributory factors such as ambient temperature, handling, storage conditions and transportation (Swai and Schoonman, 2011).

Poor hygiene is an important risk factor for reduced cow health, particularly udder health. Most farmers cite mastitis as the major herd health problem that contribute to poor milk quality (Verdier-Metz, 2009). The most common contagious mastitis pathogens are *Staphylococcus aureus*, *Streptococcus agalactiae* and *Mycoplasma bovis* (Munoz *et al.*, 2008). The udder of infected cows is the primary reservoir for these organisms. Uninfected cows are exposed when they come into contact with milk that originated from the udders of infected cows through milking liners, containers, shared towels, hands of the milkers and the milking machine. Management practices such as pre-milking teat washing or post milking teat dipping have been identified in several studies as potential risk factors to mesophilic bacteria contamination of milk (Costa *et al.*, 2013). In managing dairy cows, the general herd health, high levels of hygiene, the milk practices and the milk environment are all important factors that affect the quality of raw milk.

Cow cleanliness and general poor farm hygiene practices increase occurrence of environmental mastitis in dairy cows (Ellis *et al.*, 2007; Sant'anna and Paranhos da Costa, 2011; Schreiner and Ruegg, 2008). Sant'anna and Paranhos da Costa (2011) reported that farm hygiene and management practices such as poor cleaning of stalls, high moisture content in litter, poor hygiene of facilities and the use of contaminated water from ponds contribute to an increase in somatic cell counts in milk (Chassagne *et al.*, 2005; Sant'anna and Paranhos da Costa 2011 & Barnovin *et al.*, 2004). Udder cleanliness also influence both the quantity and type of bacteria present on the teats surfaces and thus dirty udders are an important source of environmental bacteria and contamination in milk (Schreiner and Ruegg, 2003). Chemical contamination can come from veterinary drugs or use of non-food grade cleaning products in the milking facility. The housing physical state, hygienic standard, handling of milking equipment and machinery at the farm level form the basis of the quality of the resultant products (Pandey and Voskuil, 2011). The effectiveness of milking machine and general cleanliness of the milking facility are important factors for determining balance between bacterial population in milk and quality (Verdier-Metz, 2009).

The design, construction and maintenance of milking facilities and housing physical state is important in ensuring both safety and quality of milk and by-products produced. Milk processing buildings must be designed in way that protects ingredients, packaging, raw material and finished products from contamination from the processing environment (Holah, 2014). Building features (doors, ceilings, walls, floors, windows and roofs) and service provisions (water, ventilation, lighting, compressed air, steam or electrical fittings) should neither form hazards themselves (e.g., foreign body or chemical) nor give rise to harbourage of pests or microorganisms (Holah, 2014).

Poor construction or failure to maintain milking facilities features such as doors, windows, ventilation, roofs promote the introduction of foreign matter that can contaminate milk. Sources of contamination differ with the physical state of the dairy operation (Sakar, 2016). The condition and state of repair of milking facility housing and milk handling practices at the farm level can influence not only the bacteriological quality of milk but possibly its physiochemical composition. Physiochemical alteration of milk can occur during handling, storage and processing on farm. The chemical components such as fat and protein contents play a key role in the possible uses of the raw milk in product processing and shelf life quality (Srairi *et al.*, 2008). Use of food safety standards and quality assurance systems may minimise the risk of undesired changes to the characteristics and quality of milk.

2.9 Milk safety and quality assurance

The risks of milk contamination can be managed using various tools such as Hazard Analysis Critical Control Point (HACCP), Good Manufacturing Practices (GMP) and Good Agricultural Practices (GAP) (Milios *et al.*, 2013; Tunalioglu *et al.*, 2012). Application of HACCP has positive results and benefits to milk safety (Consuelo *et al.*, 2006, Fotopoulos, *et al.*, 2011). HACCP provides preventative quality management systems for effectively ensuring milk safety by controlling microbial, chemical and physical hazards associated with milk (Kheradia and Warriner, 2013). Milk safety is defined as the assurance that milk will not cause harm to the consumer when it is processed or consumed (WHO, 2003; Fotopaulos *et al.*, 2011). In production of milk and milk by-products such as buttermilk, yoghurt or cheese, use of food safety management systems (FSMS) principles is important. These systems are designed to 'control hazards that are associated with milk and ensure compliance with food safety regulations' (Bailey and Garforth, 2014; Manning and Baines, 2004, Naugle *et al.*, 2006; Khatri and Collins, 2007). It involves the reduction of risks that may occur in milk or milk processing environments (Milios *et al.*, 2013). Quality Assurance (QA) systems are designed to ensure compliance to third party and retail standards (Mannings and Baines, 2004). Milk safety thus, requires transparent processes throughout the whole supply and value chain which instil confidence in the consumers who require authentic, unmodified and unpolluted milk or by-products. Unfortunately, the challenge faced by the dairy sector is that most producers and milk processors fail to fully comply with standards. Milk and by-products that may not be safe for consumption continue to be sold through informal milk marketing channels posing many public health threats to consumers.

2.10 Summary

As the demand for safe milk and dairy products increase, the importance of an integrated approach for ensuring safety from the farm level through to the consumer becomes important. Both large- and small-scale dairy farmers and dairy processors operate under highly challenging production and economic environments. Farm and processor housing physical state can affect bacteriological and physico-chemical quality of milk and milk by-products. Contamination of milk and by-products can occur during milking, processing or storage. Therefore, it is important for producers and processors of milk to have food safety and quality assurance systems implemented to minimise risk of contamination of milk and products such as buttermilk, from pathogenic micro-organisms. Milk quality and safety is likely to continue to increase in importance as globalization of milk trade expands and demand for authentic labels and wholesome milk rise. For this reason, it is important for the dairy industry to continue focusing on an integrated approach that assures milk safety from' farm-to-glass'. The broad objective of the study was to explore the influence of physical state of farm housing and processing facilities on the quality and safety of milk and milk products.

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Chapter 3: Household consumption preferences of dairy products and their perceptions of milk safety

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Abstract

The study investigated consumer perceptions of milk safety and consumption preferences of dairy products. Households randomly selected from urban areas (n =135) and non-urban areas (n =135) were surveyed using semi-structured questionnaires. Binomial logistic regression was used to estimate probability of households preferring to consume milk products and that of milk safety knowledge being important to households. Urban households were 2.8 times more likely to consume fresh milk ($P < 0.05$). Households from urban areas were two times more likely to purchase fresh milk from the kiosks, while households from non-urban areas were 5 times more likely to buy fresh milk from vendors. The likelihood of appearance, quality and nutritional value of milk products being important to households was higher in urban locations compared to non-urban locations. Consumers prioritised price and convenience over milk safety. Knowledge and awareness of milk safety issues was more important to urban households. Understanding consumption preferences and consumer perceptions enables regulatory agencies, policy-makers and the dairy industry to make informed decisions and to put in place awareness programmes on the risks of purchasing potentially contaminated milk through informal markets.

Key words: awareness, consumer, milk safety, vendors, urban, non-urban

3.1 Introduction

World milk production has been growing at approximately 3 % per year in recent years (Food and Agriculture Organisation (FAO), 2015). Meanwhile, the demand for milk and dairy products has been growing at an average rate of 4 % per year (FAO, 2015). As a result of the increase in population and per capita consumption, the demand for milk and dairy products worldwide is expected to continue rising (Coetzee, 2015). Slow growth in milk production has been attributed to economic hardships, frequent droughts, extreme temperatures and climate change. The effect of economic hardships on milk production is more pronounced in developing countries. For example, in Zimbabwe, overall milk production dropped from 260 to 50 million litres per annum between 1980 and 2012 (Stichting Nederlandse Vriwilligers (SNV), 2012). This decline was associated with the herd depletion that was exacerbated by the land reform programme (SNV, 2012).

The Agri-food industry transformation of developing countries in the 1980s had resulted in formalisation of a greater percentage of milk and milk product suppliers (Reardon *et al.,* 2009). Continuous increase in the demand of milk and milk products, coupled with slow increase in milk production has however, resulted in vast changes in the dairy industry. The emergence and growth of the informal dairy sector is being witnessed in most developing countries. Small-scale businesses, middlemen and milk vendors are taking advantage of the market gap to produce and process dairy products such as fresh milk, yoghurts, cheese and buttermilk through the informal milk marketing channels. Unfortunately, most of these products are unregistered (SNV, 2012). The number of informal milk suppliers continue to rise in developing countries (Kilelu *et al.,* 2017).

The informal milk marketing system involves producers selling milk products such as fresh milk, yoghurt and cultured buttermilk directly to the consumers or indirectly through vendors (SNV, 2012). Predominant dairy products in the informal market are fresh milk and cultured buttermilk (SNV, 2012). Production and marketing of dairy products such as cheese and yogurt is low in the informal market due to inefficient and inadequate milk processing materials (Gebreselassi *et al.,* 2012). Cultured buttermilk is fermented milk obtained through culturing milk with live beneficial bacteria (Parekh *et al.,* 2017). In the informal sector in developing countries, cultured buttermilk is usually made by churning naturally fermented sour milk in containers (Gebreselassi *et al.,* 2012). Some of the milk and cultured buttermilk is transported in cans on foot, by donkeys or using scotch-carts, on wheelbarrows or via public transport (Moffat *et al.,* 2016). These modes of transportation are characterized by lack of hygiene standards and, thus, subjecting the fresh milk and cultured buttermilk to physical contamination, adulterants and bacterial contamination (Makoni *et al*., 2013). As a result, fresh milk and cultured buttermilk from the informal market puts consumers at risk of infections.

Challenges faced by most of the informal, small and medium scale dairy enterprises include lack of equipment and refrigeration facilities, insufficient knowledge and skills in hygienic practices and lack of experience in processing dairy products (Moffat *et al.,* 2016). The informal and unregulated nature of the marketing structures in these dairy enterprises may compromise quality of dairy products. It is possible that milk from such channels may be adulterated or compromised in quality. In most cases, milk safety standards are not followed (Nada *et al.,* 2012). Despite these concerns, there is no information on the quality of dairy products produced in the ever-growing informal, small and medium scale dairy enterprises. Since some of these producers may not be registered, it is difficult for government agencies and/or experts to advise and monitor dairy producers. In some cases, farmers deliver milk to

Milk Collection Centres (MCC) where their milk is pooled (Javaid *et al.,* 2009). The pooling poses a challenge as potentially clean milk can be mixed with contaminated milk.

Assessment of the safety of dairy products forms the basis of intervention programmes to ensure production of safe milk that provide protection to consumers. The existence of many informal and unregulated selling outlets such as kiosks (tuckshops and small corner shops) in both urban and non-urban residences poses yet another challenge as these selling outlets may not meet quality assurance standards for dairy products. There is need to assess perceptions of consumers on safety of dairy products purchased from informal and unregulated retail outlets.

Perceptions of consumers on food safety from different outlets in urban settings may differ from those in rural environments (Weatherell *et al.,* 2003). In developing countries, resource-limited households who rely on subsistence farming live in rural settlements and may have limited access to facilities such as electricity or refrigerators. The objective of the study was, therefore, to compare perceptions of urban and non-urban consumers on quality and safety of cultured buttermilk and fresh milk. It was hypothesised that perceptions of consumers located in urban and non-urban areas on sources of contamination, quality and safety of cultured buttermilk and fresh milk from different outlets are different.

3.2 Materials and Methods

3.2.1 Study site

Data were collected from households residing in urban and non-urban areas of Bindura, Mazowe and Harare districts, Zimbabwe, in December 2016. The residential areas located around the central business district (CBD) were elected to represent urban settlements and non-urban settlements included households outside the city and those located in the rural areas. Bindura and Mazowe districts are situated at 17.3013° S, 31.3198° E. and 17.2004° S, 30.9876° E, respectively. Agricultural practices in the districts consist of field crops, vegetables and extensive livestock production. Commercial, small-scale and cooperative dairy production are pronounced in these districts. Harare district is situated at 17.8252° S, 31.0335° E. The main agricultural industries include livestock production, peri-urban farming and horticulture with a few commercial dairy farms located near urban parts of Harare.

3.2.2 Sampling procedure and data collection

Four focus group discussions with at least four key informants each and a trained interviewer were used to develop a structured questionnaire. Stratified random sampling was used to select respondents for the focus group discussions (agricultural extension officials, informal milk traders, small-scale milk producers and local farmer organisations). The focus group discussions gave an insight on the type of information which was included in the structured questionnaire and the presentation of the questionnaire. Face validity of the questionnaire was established by comparing the questions with theoretical constructs based on literature review and expectations. The questionnaire was then pilot-tested on 10 randomly selected households. Face-to-face interviews conducted by trained enumerators using the structured questionnaires were then conducted on urban (n =135) and non -urban (n =135) randomly selected households.

One member (aged 18 years or above) of each of the households was randomly selected for the interview. Respondents aged 30 years and below were regarded as young (UNDESA, 2014).

The questions on the survey included socio-demographic and economic characteristics, milk consumption patterns, location where milk is purchased, perceptions on milk safety, knowledge and awareness of food safety systems. Households were also asked to rank their preferred outlets for purchasing dairy products. The study was granted the ethical clearance certificate AREC/080/016D by the University of KwaZulu-Natal's Research Ethics Committee.

3.2.2 Statistical analyses

Data were analysed using Statistical Analysis System 9.2 (SAS, 2008). Preliminary analysis of data showed that effect of city was not significant and thus classification was based on residency type urban vs non-urban. Chi-square tests were computed to determine the association between location and gender, age, household size, level of education and household income.

Descriptive statistics and frequency distributions for categorical variables were used to describe data. Binomial logistic regression was used to model the determinants of dichotomous variables (preference of a particular milk product; purchasing of a particular milk product from a particular outlet; considering milk safety knowledge and awareness being important). The Binomial logistic regression (Proc Logistic) model was used to estimate the probability of households preferring to consume particular milk products, the probability of a household purchasing a particular milk product from a particular outlet and the probability of milk safety knowledge and awareness being important to households. The logit model fitted predictors, gender, location (urban; non-urban), age and household size. The logit model used was:

$$Ln\ [P/(1-P)] = \beta 0 + \beta 1X1 + \beta 2X2 \ldots + \beta tXt + \varepsilon$$

Where;

P = probability of households (preferring to consumer particular milk product; purchasing a particular milk product from a particular outlet; considering milk safety knowledge and awareness being important)

[P/(1-P)] = odds of a household (preferring to consumer particular milk product; purchasing a particular milk product from a particular outlet; considering milk safety knowledge and awareness being important);

$\beta 0$ = intercept;

$\beta 1X1 \ldots \beta tXt$ = regression coefficients of predictors;

ε = random residual error.

3.3 Results

3.3.1 Socio-demographic characteristics

The socio-demographic characteristics of respondents in urban and non-urban areas are shown in Table 3.1. The majority of participants were females. More than 70 % of respondents in both urban and non-urban areas were adults aged over 30 years. Less than 20 % of the respondents in both urban and non-urban areas had no formal education. More than 50% of urban households had high monthly income. The majority of non-urban dwellers had low monthly income.

3.3.2 Consumption patterns of fresh milk and cultured buttermilk

The odds ratios of households preferring to consume fresh milk to cultured milk products are shown in Table 3.2. Households from urban locations were 2.8 times more likely to

Table 3.1: Socio-demographic characteristics of the respondents

	Frequency (%)		
	Urban	Non-urban	Chi-square test (χ^2)
Gender			ns
Males	48.2	47.1	
Female	51.8	52.9	
Age			ns
Young (≤ 30years)	17.3	27.4	
Old (≥ 30 years)	82.7	72.6	
Household Size			ns
Small (≤ 4 people)	29.1	36.9	
Large (≥4 people)	70.9	63.1	
Level of education			ns
No formal education	8.2	17.9	
Primary school	21.8	30.8	
Secondary school	44.5	38.5	
Tertiary	25.5	12.8	
Household Monthly Income			*
Low (< 250 USD)	41.2	56.9	
High (>500 USD)	58.8	43.1	

ns: not significant ($P > 0.05$); * $P < 0.05$.

Table 3.2: Odds ratios estimates, lower (lci) and upper confidence interval (uci) of households preferring fresh milk to cultured buttermilk

Predictor	Odds	LCI	UCI	Significance
Location (urban vs non-urban)	2.84	1.53	5.29	*
Gender (male vs female)	1.02	0.57	1.82	NS
Age (old vs young)	3.39	1.67	6.87	*
Household size (large vs small)	1.39	0.72	2.68	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$

Higher odds ratio estimates indicate greater difference in preference levels of predictors.

consume fresh milk compared to their non-urban counterparts. Those aged over 30 years were three times more likely to consume fresh milk than respondents below the age of 30.

The odds ratios of households purchasing fresh milk, buttermilk from straight from the farm, vendors, kiosks, and supermarkets are shown in Table 3.3. Households from urban areas were two times more likely to purchase fresh milk straight from farms and kiosks, while households from the non-urban areas were five times more likely to purchase fresh milk from vendors. Males were two times more likely to purchase fresh milk straight from farms. Young respondents were three times more likely to buy fresh milk from supermarkets and females were two times more likely to purchase fresh milk from supermarkets. Households from non-urban areas were two times more likely to buy buttermilk from vendors. Young respondents were two times more likely to buy buttermilk from supermarkets.

3.3.3 Importance of milk product characteristics

The odds ratio estimates of characteristics of milk products being important to households are shown in Table 3.4. The likelihood of appearance, freshness, quality, taste, nutritional value and availability being important to households during selection of milk product was higher in urban areas compared to non-urban locations. The odds ratio estimates ranged from 2.83 to 6.75 for these attributes. The likelihood of packaging being considered important did not differ with location. For all attributes, size of the household did not make significant difference to preference or purchase of milk products. Females were two times more likely to consider nutritional value as being important. Respondents aged over 30 years were five times more likely to consider the presence of labels as being an important characteristic when purchasing dairy products.

Table 3.3: Odds ratio estimates lower (LCI) and upper confidence interval (UCI) of households purchasing fresh milk and cultured buttermilk from different selling outlets

Outlet	Predictors	Fresh milk			‡Sig.	Buttermilk			Sig.
		Odds	LCI	UCI		Odds	LCI	UCI	
Straight from farm	Location (Urban vs. Non-urban)	2.64	1.40	5.00	*	0.92	0.36	2.36	*
	Gender (Male vs. Female)	1.75	1.00	3.20	*	1.59	0.59	4.32	NS
	Age (Young vs. Old)	0.62	0.29	1.34	NS	0.17	0.02	1.33	NS
	Household size (Small vs. Large)	0.90	0.46	1.78	NS	1.05	0.34	3.21	NS
Vendors	Location (Urban vs. Non-urban)	0.21	0.10	0.44	*	0.46	0.26	0.80	*
	Gender (Male vs. Female)	1.25	0.59	2.63	NS	1.20	0.67	2.15	NS
	Age (Young vs. Old)	0.62	0.24	1.59	NS	0.44	0.20	0.96	*
	Household size (Small vs Large)	1.49	0.65	3.39	NS	1.37	0.71	2.65	NS
Kiosks	Location (Urban vs. Non-urban)	2.07	1.17	3.66	*	1.24	0.64	2.38	NS
	Gender (Male vs. Female)	0.95	0.55	1.64	NS	0.97	0.51	1.86	NS
	Age (Young vs. Old)	1.47	0.77	2.82	NS	1.11	0.51	2.41	NS
	Household size (Small vs. Large)	0.89	0.48	1.66	NS	0.89	0.43	1.86	NS
Supermarket	Location (Urban vs. Non-urban)	0.53	0.24	1.15	NS	0.63	0.29	1.39	NS
	Gender (Male vs. Female)	0.42	0.18	0.96	*	0.71	0.32	1.59	NS
	Age (Young vs. Old)	3.67	1.55	8.67	*	2.47	1.01	6.04	*
	Household size (Small vs. Large)	0.71	0.29	1.76	NS	0.59	0.23	1.53	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant (P>0.05), *P<0.05.

Higher odds ratio estimates indicate greater difference in preference levels of predictors

Table 3.4: Odds ratio estimates of characteristics of milk products being extremely important to households

Characteristics	Predictors															
	Location (Urban vs Non-urban areas)				Gender (Male vs. Female)				Age (Young vs. Old)				Household size (Small vs. Large)			
	Odds	LCI	UCI	Sig	Odds	LCI	UCI	Sig.	Odds	LCI	UCI	Sig.	Odds	LCI	UCI	Sig.
Appearance	4.29	1.48	12.41	*	1.39	0.60	3.21	NS	0.96	0.40	2.30	NS	0.59	0.24	1.44	NS
Freshness	3.72	1.76	7.87	*	1.37	0.71	2.62	NS	0.59	0.28	1.23	NS	0.62	0.31	1.25	NS
Quality	4.49	2.22	9.52	*	1.23	0.65	2.32	NS	0.49	0.24	1.02	NS	0.65	0.32	1.31	NS
Taste	5.14	2.37	11.14	*	1.34	0.69	2.57	NS	0.72	0.33	1.61	NS	1.08	0.52	2.26	NS
Nutritional value	6.75	2.69	16.94	*	0.50	1.24	1.42	*	0.81	0.35	1.87	NS	0.66	0.28	1.50	NS
Brand name	2.08	0.96	4.51	NS	0.73	0.36	1.49	NS	0.59	0.26	1.36	NS	0.78	0.35	1.75	NS
Availability	2.83	1.26	6.37	*	1.26	0.61	2.63	NS	0.58	0.25	1.32	NS	0.72	0.32	1.64	NS
Packaging	2.89	0.94	8.84	NS	0.75	0.33	1.69	NS	0.71	0.29	1.73	NS	1.42	0.57	3.54	NS
Presence of labels	2.37	0.38	14.95	NS	0.73	0.28	1.92	NS	0.29	0.10	0.85	*	1.03	0.40	3.00	NS
Environmental friendliness	2.33	0.53	10.22	NS	0.49	0.19	1.24	NS	1.29	0.51	3.31	NS	1.01	0.37	2.77	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$

Higher odds ratio estimates indicate greater difference in preference levels of predictors.

3.3.4 Reasons for purchasing fresh milk and cultured buttermilk

Frequencies of reasons for purchasing fresh milk and cultured buttermilk from various selling outlets are shown in Table 3.5. The majority (> 40 %) of households from urban areas who bought fresh milk from the farm did so because it was convenient. More than 50 % of the urban households who bought fresh milk from the kiosks said it was because it was cheap. About 34 % of households from urban locations who bought fresh milk from supermarkets did so because it was perceived to be safe for consumption. The majority (> 50 %) of non-urban households who bought buttermilk from vendors and kiosks did so because it was cheap. Forty-five percent of households from non-urban areas who bought buttermilk from supermarkets did so because of the perception that it has a longer shelf life. The majority of the urban households who bought buttermilk straight from the farm did so in order to avoid paying extra for packaging, while more than 60 % of those who bought buttermilk from vendors was because it was cheap.

The majority (> 50 %) of the households in non-urban areas who purchased fresh milk from vendors and kiosks did so because it was cheap. More than 60 % of the non-urban households who bought butter milk straight from farms was because it was convenient to do so. On the other hand, households from the non-urban locations who purchased buttermilk from supermarkets did so because it was considered to have a longer shelf life while others had no specific reason.

3.3.5 Perceptions of consumers on sources of milk contamination

Mean rank scores of consumer perceptions on sources of milk contamination are shown in Figure 1. The ranking of sources of contamination differed with location. In non-urban areas,

Table 3.5: Frequencies (%) of reasons for purchasing fresh milk and cultured buttermilk from different outlets

Milk product	Reasons	Urban				Non-urban			
		Farm	Vendors	Kiosk	Super market	Farm	Vendors	Kiosk	Super market
Fresh milk	Convenient	43.5	20	28.9	21.1	57.9	29.0	30.2	16.7
	Cheap	17.4	40	57.8	0	26.3	51.1	55.8	0
	Avoid paying for extra packaging	15.2	20	6.7	0	0	0	2.3	0
	Variety	15.2	1	4.4	33.3	1.9	12.9	11.6	16.7
	Safe for consumption	0	0	0	34.4	6	3.2	0	16.7
	Long shelf life	6.5	0	2.2	2.5	5.2	0	0	45.8
	No reason	2.2	19	0	8.7	2.6	3.2	0	4.2
Buttermilk	Convenient	0	9.5	30.4	27.3	61.5	22.2	20.8	6.8
	Cheap	7.7	67.2	34.8	27.3	15.4	53.3	40.2	1.8
	Avoid paying for extra packaging	41.3	9	4.4	0	0	2.2	1.5	0
	Variety	46.1	0	17.4	9.1	7.7	8.9	8.3	12.6
	Safe for consumption	4.9	0	0	27.3	7.7	4.4	4.2	47.1
	Long shelf life	0	0	4.4	0	0	4.4	12.5	21.8
	No reason	0	14.3	8.7	9.1	7.7	4.4	12.5	9.9

Table 3. 6: Odds ratio estimates of milk safety knowledge and awareness being important to households

Component	Predictors															
	Location (Urban vs non-urban areas)				Gender (Male vs. Female)				Age (Young vs. Old)				Household size (Small vs. Large)			
	Odds	LCI	UCI	Sig	Odds	LCI	UCI	Sig.	Odds	LCI	UCI	Sig.	Odds	LCI	UCI	Sig.
Milk safety knowledge	2.07	1.02	4.19	*	0.97	0.49	1.96	NS	0.92	0.43	1.96	NS	0.35	0.17	0.72	*
Manufacturing environment safety	1.01	0.6	1.70	NS	1.47	0.86	2.53	NS	0.57	0.29	1.05	NS	0.74	0.41	1.34	NS
Traceability	2.21	1.07	4.59	*	1.08	0.51	2.2	NS	1.74	0.76	4.01	NS	1.59	0.71	3.59	NS
Ingredients in milk	0.80	0.383	1.60	NS	2.42	1.09	5.38	*	3.89	1.72	8.79	*	0.91	0.38	2.19	NS
Labelling and declaration	0.45	0.19	1.01	NS	0.47	0.21	1.03	NS	1.21	0.51	2.87	NS	1.47	0.64	3.38	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$

Higher odds ratio estimates indicate greater difference in preference levels of predictors.

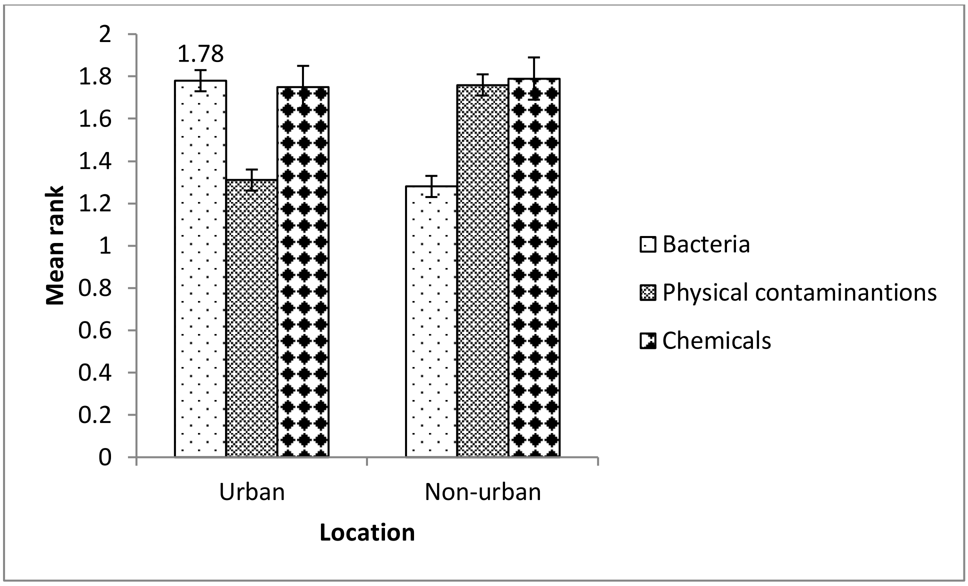

Figure 3. 1 Mean rank score of consumer perceptions on sources of milk contamination from urban and non-urban locations

bacteria were ranked highest, followed by physical contaminants then chemicals ($P < 0.05$). In urban locations, physical contaminants were ranked highest ($P < 0.05$).

3.3.6 Milk safety knowledge and awareness

The odds ratio estimates of milk safety knowledge and awareness being important to households are shown in Table 3.6. Households from urban locations were twice more likely to consider knowledge and awareness of milk safety issues being important. The likelihood of milk safety knowledge and awareness being important was 2.9 times higher for the large households (>4 persons) compared to smaller ones (<4 persons). The likelihood of safety of manufacturing environment being considered important did not differ with location. Respondents from the urban areas were two times more likely to consider traceability being important when buying milk products compared to non-urban counterparts. Males were twice more likely to consider the awareness and knowledge of ingredients in milk products being important when purchasing dairy products. The likelihood for knowledge and awareness of milk product ingredients being important was 3.9 times higher for the young compared to the old.

3.4 Discussion

Understanding perceptions of consumers on milk quality and safety will assist policy makers and dairy service organisations to put in place interventions and awareness programmes that educate consumers on the risk of buying potentially contaminated dairy products. Consumers need to be informed and educated about milk safety and quality, especially when accessing such products from the informal milk marketing sector so that their decisions are not limited to price or convenience alone. Participants in the study were almost equally distributed, in terms of gender, in both urban and non-urban locations.

The finding that households from the non-urban locations preferred consuming fresh milk to cultured buttermilk, is in agreement with findings by Weatherell et al. (2003) who reported that choice of food is associated with place of residence. This could also be attributed to accessibility and differences in prices. Cultured buttermilk is fermented milk that has been produced through culturing milk with live beneficial bacteria (Parekh *et al.,* 2017). Dairy products such as yoghurt are mainly processed in urban areas (SNV, 2012) and additional costs are incurred when transporting them to the non-urban areas. If transported to non-urban areas, the dairy products will be expensive due to transport costs and reduced supply. Some non-urban households do not have refrigeration facilities to store dairy products for longer periods of time before these products go off. Moreover, in non-urban areas, consumption of products such as yoghurt and buttermilk is sometimes considered as a luxury. The finding that older people were more likely to consume fresh milk tallies with findings by Weatherell et al. (2003). This could be because old people think that fresh milk is healthy (Mitsostergios and Skiadas, 1994).

The findings that the households from non-urban locations more likely to buy fresh milk from the vendors indicates that informal markets of milk are more pronounced in the non-urban locations. Because of the high number of dairy farms in non-urban areas, milk vendors tended to purchase milk directly from the nearby farms and then go around on their bicycles or ox drawn carts selling to consumers even in neighbouring towns (SNV, 2012). This makes milk to be easily accessible to households who may not have transport to go to the local townships or bigger supermarkets. On the other hand, the majority of urban consumers also bought buttermilk from the vendors because it was cheap, and these vendors come into the urban locations to retail their products. The findings that young females from urban locations were more likely to buy fresh milk and buttermilk from the supermarkets is consistent with results from studies by Weatherell *et al.*, (2003) who reported that a majority of consumers prefer to purchase their food from supermarkets as their first choice. The adult males in this study were more likely to purchased fresh milk straight from the farms. Similarly, Van fleet and Van Fleet (2009), reported that older males purchase food from different selling outlets without necessarily confining their purchases to the local shops. However, it is important to remain conscious of the fact that there will always be difference in perceptions and attitudes towards safety of foods depending on the consumers' previous exposure, experience, location or demographic characteristics (Worsley and Lea, 2008)

In agreement to the finding, Van Loo *et al.*, (2013) also found attributes like taste, appearance, availability and nutritional value are important to consumers when selecting food. Surprisingly, male respondents in our study were more likely to consider nutritional value to be an extremely important attribute when selecting milk products. Our expectation was that females would be the ones to be most commonly concerned about the nutritive value of foods because women tend to be involved more in dieting programmes and are concerned about nutritive value of foods compared to males (Van Loo *et al.*,2013). The reasons for this unexpected result might have been as result of the numerous health campaigns being done in the developing world and possibly males in our study were more informed or aware of the need to pay attention to the nutrient content of milk and by products.

The majority of households both in urban and non-urban locations who purchased buttermilk and fresh milk from kiosks did so because of convenience and products being cheap, without necessarily prioritising milk safety. Milk and milk products handling practices and the ability to control temperature may differ for all four outlets (farm, vendors, kiosks, and supermarkets), which would in turn affect microbiological milk quality and, thus, safety (SNV, 2012). Supermarkets which monitor cold chain processes and have quality assurance systems in place tend to have better control of temperatures as compared to the kiosks or traditional markets. Households in both urban and non-urban areas, however, still preferred purchasing fresh milk, buttermilk from vendors and kiosks because it was both cheap and convenient suggesting that possibly bacterial or microbial safety is, thus, not a priority for households in both urban and non-urban areas. For this reason, informal marketing of milk and milk products in developing countries is likely to continue because consumers will be inclined to buy from these places due to their perceptions.

Since the majority of consumers in both the urban and non-urban locations preferred the kiosks and vendors, because it was cheap and convenient and, this route of accessing products cannot be completely disregarded since most people are resource poor and thus price of milk is an important consideration. Similarly, other researchers have reported that price is an important consideration to be made when making purchases (Zanoli and Naspetti, 2002; Grebitus *et al.,* 2007; Soderlund *et al.,* 2008). Therefore, next best alternative could be educating the informal traders on proper production and storage methods and the importance of quality assurance. Consumers also need to be educated on the risks about buying potentially contaminated milk (Swai and Schoonman, 2011). On the other hand, a sizable percentage of urban households who purchased buttermilk from the farm did so because they did not want to pay for extra in packaging and they also wanted variety. This is in agreement with Yayar (2012) who reported that some consumers prefer unpacked milk because it is cheaper and can be delivered at the doorstep without the additional costs incurred for packaging. The finding that urban households who buy from supermarket prefer to do so because they believe such products have a guarantee of safety and long shelf life agrees with similar findings by Weatherell *et al.,* (2003) and Yayar (2012).

The finding that mean ranking of bacteria and physical contamination as a source of contamination of milk differed is supported by other researchers who have found that dairy products contamination can occur via microbiological, chemical and physical means (Ellis *et al.,* 2007). Bacteria was ranked higher in non-urban areas possibly because the participants in this study thought most milk contamination occurs from the disease-causing agents from the cow or environment. This line of thinking is supported by research that confirm that hygienic profile of milk is characterised by the contamination levels and specific distribution of micro-organisms. These levels are highly correlated to udder health and pre-milking hygiene conditions (Ellis *et al.,* 2007). The finding that physical contamination was ranked highest in urban areas as compared to non-urban areas was unexpected. One of the leading public health hazards from poor milk safety in non-urban areas is physical contamination (Girma, Tilahun and Haimanot, 2014). The unexpected result is possibly because non-urban areas are not aware of the presence of physical contaminants in milk. Contrary to the finding that there was no difference in perception on chemicals as source of milk contamination in both urban and non-urban areas, Novoselova *et al.,* (2002) found that a majority of consumers in their study ranked chemical contamination high and considered chemicals to have a long term detrimental health effect (Novoselova *et al.,* 2002).

The finding that consumers from urban areas are more likely consider awareness and knowledge of milk safety being important tallies with the finding that they are more likely to buy milk and milk products from reputable outlets such as supermarkets. Comprehensive awareness efforts should be made on milk safety in non-urban areas. It may be possible that households from urban areas in our study had better access to food safety information provided through media, food manufacturers and researchers compared to the non-urban counterparts. Perception on food safety vary depending on availability of information (Röhr *et al.*, 2005). The finding that traceability of milk products was more important for the urban households could be have been influenced by their awareness on milk safety. Traceability is a way of responding to potential risks and, thus, knowing how quality has assured through the whole value chain is important to the consumers. While the male respondents in our study seemed to be interested in information about milk ingredients, other authors have reported that usually females are the ones more concerned about health and healthy food *(*Aertsens *et al.*, 2009; Van Fleet and Van Fleet, 2009).

3.5 Conclusions

Households from urban areas preferred buying fresh milk from kiosks whilst non-urban dwellers preferred purchasing fresh milk from vendors, kiosks and farms. Households preferred to buy fresh milk from kiosks, farms and vendors were because it was cheap and convenient. Knowledge and awareness of milk safety issues, traceability and declaration of milk ingredients was more important to urban households. Considering that consumers prefer buying milk and its products straight from the farm and informal milk marketing systems (kiosks and vendors), it is important to ensure that these outlets meet quality assurance standards for dairy products. It is, thus, essential to understand the perceptions of the small- and-large-scale milk producers on factors affecting its quality and safety as a basis for any intervention and/or correction programmes.

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Chapter 4: Perceptions of factors affecting milk quality and safety among large and small-scale dairy farmers in Zimbabwe

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Abstract

The study investigated the perceptions of milk producers on factors affecting milk quality and safety. Randomly selected large-scale farmers (n=78) and small-scale farmers (n=126) were surveyed using semi-structured questionnaires. Binomial logistic regression was used to estimate the probability of farmers considering milk quality and safety being important. Large-scale farmers were 3 times more likely to consider breed affecting milk quality compared to small- scale counterparts ($P < 0.05$). Farmers aged over 30 years were 3 times more likely to indicate that hygiene affected milk quality ($P < 0.05$). The likelihood of milk transportation affecting its quality was 4 times higher in small-scale farmers compared to the large-scale producers ($P < 0.05$). Post milking contamination of milk was perceived to occur during transportation by small-scale farmers, whilst commercial farmers ranked storage as the important source of contamination post-milking ($P < 0.05$). Udder diseases were ranked first by large-scale farmers while small-scale farmers ranked milking environment as the major cause of milk spoilage ($P < 0.05$). The likelihood of milk safety being important was two times higher in large farms compared to small-scale farms ($P < 0.05$). Intervention programmes on milk safety should mainly target small-scale dairy farmers since they are less concerned about milk quality and safety. One of the biggest concerns in the dairy industry is the quality and safety of milk. Although contamination of milk can occur at various stages in the value chain, most of the contamination is usually associated with the farm. Understanding farmer perceptions on factors affecting quality and safety of milk will not only form the basis of intervention programmes for clean milk production but assists farmers to put in place mechanisms that ensure safe and profitable milk production.

Key words: contamination, clean milk, farmers, milk safety, intervention, udder diseases.

4.1 Introduction

Dairy production plays a vital role in numerous national economies through provision of employment, food security and sustainable income (Moffat *et al.*, 2016). For example, in Sub-Saharan Africa, the dairy industry is a major contributor to gross domestic product. Milk and dairy products play a crucial role through provision of healthy food and balanced diets. In Sub-Saharan Africa, dairy products are easy to access as a source of nutrients compared to meat. The industry, in general, is made of different sized farms and processors ranging from small to large-scale operations. Smallholder dairy farming refers to the economic activity of keeping dairy cows with an average herd size of less than seven milking cows on less than one hectare of land (Hahlani and Garwi, 2014).

Both large- and small-scale dairy farmers operate under highly uncertain production and economic environments. One of the biggest concerns of dairy farmers is the quality and safety of milk production. Failure to meet quality assurance standards and regulatory requirement affects both farmers and consumers. Penalties imposed for production of poor quality milk reduces income for farmers. As discussed in Chapter 3, Consumers are exposed to potential public health threats and diseases from consumption of potentially contaminated milk sources (Chapter 3). At the same time, farmers also face other challenges such as increased production costs, low productivity, low milk prices, lack of liquidity or capitalization and poor input support (SNV, 2012). For example, in Zimbabwe, the drop in milk production over the last decade has been attributed to liquidity crunch, small herds and lack of cheap lines of credit (SNV, 2012) The dairy industry has not been spared from the adverse effects of drought and extreme temperatures. Despite these challenges the farmers are still expected by all stakeholders to produce good quality milk, that is free from microbial, physical and chemical contamination (Pantoja *et al*., 2009).

Milk and its products are rich in nutrients, contain high moisture and neutral pH. Milk, thus, easily favour the growth and multiplication of bacteria and other disease-causing agents. Contaminated milk may cause tuberculosis, brucellosis, listeriosis, gastrointestinal disorders and salmonellosis. Milk contamination can originate from different sources such as the milking environment, wind, milking equipment, feeds, soil, faeces, farm personnel and housing (Swai and Schoonman, 2011). Although contamination of milk can occur at various stages including, during handling, transportation or storage at farm, during processing or at the market, most of the contamination is usually associated with the farm. Therefore, it is important to put in place sound quality control measures at the farm level.

Poor hygiene practices at the farm level has been reported to be the main cause for poor productivity and income losses for the small holder sector (SNV, 2012) Research shows that high total bacteria count (TBC) is positively correlated with unsanitary conditions associated with dirty udders before milking, inadequate or poor teat sanitation, poor cleaning and sanitation of milking equipment and inadequate cooling of milk (Pantoja *et al*., 2009; Verdier-Metz *et al.*, 2009). Other elements that influence TBC include health and hygiene of the cow, housing and management, cleaning and sanitizing procedures, farm milking environment and quality of cleaning water (Nada *et al.*, 2012).

In most countries, there are regulatory agencies that monitor the quality of milk delivered and processed by various processors. Milk is routinely checked for TBC, somatic cell counts (SCC), fat content, protein, lactose and solids non-fat (SNF). For example, in Zimbabwe farmers are paid a premium based on the quality of milk. Most of the small-scale dairy farmers in Zimbabwe do not have facilities for bulk milk collection due to low milk volumes produced. They deliver their milk to nearby Milk Collection Centres (MCCs) where their milk is pooled. Farmers in such cases have their premium based on the group milk quality. This means that farmers with good production systems may be disadvantaged by the poor performers. These resource poor small-scale farmers' milk quality issues are further compounded by transportation time and mode, distance to milk processors.

As the demand for safe milk and dairy products increase, the importance of an integrated approach for ensuring safety throughout the whole supply chain becomes important. To ensure production of quality milk, it is necessary to understand the various causes and sources of milk contamination at the farm level. The use of food safety and quality assurance systems at the farms is important to reduce contaminants in milk and dairy products. Policy makers, and regulators should be in touch with the sources of contamination of milk products so as to implement long term planning for clean and safe milk production.

Understanding farmer perceptions and attitudes towards clean and safe milk production contribute to clean milk production practised on farms. Factors affecting consumer perceptions on general food safety are fairly well understood (Aertsens *et al.*, 2009; Grunert, 2011; Schleenbecker and Hamm, 2013). There is limited information on dairy farmers in Sub-Saharan Africa. Given that many dynamic and complex factors affect quality of milk, it is crucial to determine those elements which farmers are likely to consider to be important. Understanding this will not only form the basis of intervention programmes for clean milk production but assists farmers to put in place mechanisms that ensure safe and profitable milk production. The current study was conducted to compare perceptions of large- and small-scale farmers on factors affecting milk quality and safety. It was hypothesised that perceptions of factors affecting milk quality and safety of large- and small-scale farmers differ.

4.2 Materials and methods

4.2.1 Study site

Data were collected from dairy farmers from Mashonaland and Manicaland provinces of Zimbabwe in December 2016. These two provinces are in agricultural regions 1 to 3, with average rainfalls of between 600 and 1200 mm per annum have largest concentration of small-scale and large-scale dairy farmers and Milk Collection Centres (MCC). Manicaland province is situated at 18.9216° S, 32.1746° E. Mashonaland is subdivided divided into three regions namely Mashonaland Central, East and West provinces that are situated at 16.7644° S, 31.0794° E, 18.5872° S, 31.2626° E and 17.4851° S, 29.7889° E, respectively. Large-scale farmers deliver the bulk of their milk to the dairy processors. The milk from small-scale farmers that is not sold directly to the public is supplied to MCCs and various processors that manufacture long life milk, pasteurised milk, cheese, cream, butter, fermented milk, buttermilk and fruit blends. The other agricultural practices in these two provinces include intensive and extensive livestock production, peri-urban farming, horticulture and field crop production. Small-scale dairy farming involves keeping a small herd of dairy animals, usually less than ten milking cows on less than hectare of land (Hahlani and Garwi, 2014).

4.2.2 Sampling procedure and data collection

Data were generated using a survey conducted by interviewing farmers selected from two production systems, large-scale and small-scale farmers. A database containing all registered large and small-scale dairy farmers and their contact details and addresses was obtained from

Dairy Services Unit Limited. A total of 158 small-scale farmers and 186 large-scale farmers were randomly selected from the data base. Table 4.1 shows socio-demographic characteristics, mean herd size and the number of respondents from each production system.

The selected farmers were visited and interviewed by trained enumerators at their homesteads using a pretested questionnaire. The questionnaire had been pilot-tested on 14 randomly selected farmers. The survey captured aspects on socio-demographic and economic characteristics, milk production patterns, perceptions on milk safety, concerns on milk safety, factors affecting milk quality. Sociodemographic characteristics captured included household size, age, gender and educational level of farmer. A farmer was considered as educated if he or she had received education above primary school level. Farmers who had primary school level education or less were considered uneducated. Each farmer was asked to rank causes of milk spoilage during milking and sources of contamination of milk post-milking. Farmers were also asked whether they are concerned or not concerned about milk safety and whether they considered milk quality as important or not important. The farmers were also asked whether they thought factors such as milking method, breed of cows, hygiene and mode of transport affected milk quality. The study was granted the ethical clearance certificate AREC/080/016D by the University of KwaZulu-Natal's Research Ethics Committee.

Table 4.1: Socio-demographic characteristics, mean herd size (± SD) and the number of respondents from each production system

Class	Large-scale	Small -Scale
n	158	186
Age (%)		
Young (< 30 years)	35.5	13.5
Old (> 30 years)	64.5	86.5
Household size (%)		
Small (< 4 people)	40.8	37.3
Large (> 4 people)	59.2	67.1
Marital status (%)		
Married	8.2	50.0
Single	21.8	42.9
Divorced	44.5	6.4
Widowed	25.5	0.8
Highest education level (%)		
No formal education	16.9	19.8
Primary	33.8	17.5
Secondary	35.1	41.3
Tertiary	14.3	21.4
Cow herd size		
	184 ± 18.7^{a}	10 ± 6.3^{b}

4.2.3 Statistical analyses

Data were analysed using Statistical Analysis System 9.2 (SAS, 2008). Descriptive statistics and frequency distributions for categorical variables were used to describe data. The effect of production system (large vs small-scale) on mean rank scores for the causes of milk contamination and spoilage were determined using PROC GLM of SAS (SAS, 2008). Binomial logistic regression (PROC LOGISTIC) model was used to estimate the probability of farmers perceiving specific milk quality attributes being important. The logit model tested effects of production system (large; small-scale), household size, age, gender and educational level of farmer.

The logit model used was:

$Ln [P/(1-P)] = \beta_0 + \beta_1X_1 + \beta_2X_2 \ldots + \beta_tX_t + \varepsilon$

Where;

P = probability of farmers (considering a particular factor affecting milk quality)

[P/(1-P)] = odds of farmers' households (considering milk quality important; concerned about the milk safety);

β_0 = intercept;

$\beta_1X_1 \ldots \beta_tX_t$ = regression coefficients of predictors;

ε = random residual error.

4.3 Results

4.3.1 Factors affecting milk quality

The odds ratio estimates of factors affecting milk quality are shown in Table 4.2. Large-scale farmers were 3 times more likely to consider breed to affect milk quality, when compared with small-scale farmers ($P < 0.05$). Farmers aged over 30 years were 3 times more likely to indicate that hygiene affected milk quality ($P < 0.05$). Small-scale farmers were 4 times more likely to consider transport as a main contributor to poor milk quality when compared with large-scale farmers.

4.3.2 Causes of milk spoilage and source of contamination

Table 4.3 shows the farmers rankings of reasons for causes of milk spoilage during milking for large-scale and small-scale dairy farms. Whilst the large-scale farmers ranked udder diseases highest as the major cause of milk spoilage, small-scale farmers ranked milking environment as the highest contributor to milk spoilage during milking. Udder diseases were ranked second by small-scale farmers. For both production systems personnel were considered the least cause for milk spoilage. The mean rank scores of sources of contamination post-milking are shown in Table 4.4. Mean rank scores of sources of contamination from transportation and processing differed with production system ($P<0.01$). While small-scale farmers ranked transportation as the most important source of post-milking contamination, large-scale farmers ranked it least. Storage was ranked as the most important source of post-milking contamination by large-scale farmers. The small-scale farmers considered milking machinery as the least contributor to post-milking contamination.

Table 4.2: Odds ratio estimate, lower (LCI) and upper confidence interval (UCI) of farmers indicating that different factors affect milk quality.

Factor	Predictor	Odds	LCI	UCI	Sig.
Milking Method	Production system (large vs small-scale)	0.70	0.38	1.27	NS
	Gender (female vs. male)	1.29	0.77	2.17	NS
	Age (young vs. old)	1.56	0.83	2.96	NS
	Household size (small vs. large)	1.00	0.98	1.02	NS
	Education (uneducated vs. educated)	0.87	0.53	1.43	NS
Breed	Production system (large vs small-scale)	3.05	1.66	5.62	*
	Gender (male vs. female)	0.73	0.44	1.23	NS
	Age (young vs. old)	1.08	0.57	2.04	NS
	Household size (small vs large)	0.99	0.97	1.07	NS
	Education (uneducated vs. educated)	1.43	0.87	2.36	NS
Hygiene	Production System (large vs small-scale)	1.04	1.57	1.91	*
	Gender (male vs. female)	0.83	0.49	1.41	NS
	Age (young vs. old)	0.54	0.34	0.98	*
	Household size (small vs large)	1.17	0.69	1.97	NS
	Education (uneducated vs. educated)	0.74	0.45	1.23	NS
Transport	Production system (large vs small-scale)	0.46	0.25	0.84	*
	Gender (female vs. male)	1.29	0.76	2.18	NS
	Age (young vs. old)	0.83	0.43	1.58	NS
	Household size (small vs. large)	0.95	0.74	1.21	NS
	Education (uneducated vs. educated)	0.69	0.42	1.13	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$. Higher odds ratio estimates indicate greater difference in preference levels of predictors.

Table 4.3: Mean rank score (ranks) for causes of milk spoilage during milking in commercial and small-scale dairy farms

Source	Large-scale	Small-scale	Significance
Personnel	3.21(4)	3.08(4)	NS
Containers	3.04 (3)	2.93 (3)	NS
Milking environment	2.14 (2)	1.97(1)	NS
Udder diseases	1.70 (1)	2.17 (2)	**

The lower the mean rank score (rank) the more important the cause of spoilage

* P < 0.05; ** P < 0.01; NS – Not Significant (P>0.05).

Table 4.4: Mean rank score (ranks) for sources of contamination post-milking in commercial and small-scale dairy farms

When contamination occurs	Large-scale	Small-scale	Significance
Milking machinery	2.72 (3)	2.79 (4)	NS
Storage	2.14 (1)	2.32 (2)	NS
Transportation	2.79 (4)	2.16 (1)	**
Processing	2.29 (2)	2.75 (3)	*

The lower the mean rank score (rank) the more important source of contamination

* $P<0.05$; ** $P<0.01$; NS – Not Significant ($P>0.05$).

4.3.3 Milk quality and safety

The odds ratio estimates of farmers being concerned about milk quality are shown in Table 4.5. Small-scale farmers were 4.5 times more likely to be concerned about milk quality than large-scale farmers. Table 4.6 shows the odds ratios of farmers considering the importance of milk safety. The likelihood of milk safety being important was two times higher for large-scale farmers compared to small-scale farmers ($P < 0.05$). Educated dairy farmers were more likely to consider milk safety important than their uneducated counterparts ($P < 0.05$).

4.4 Discussion

The study was designed to explore factors affecting milk quality and perceptions of farmers on causes of poor milk quality in large and small-scale farms. Understanding perceptions of farmers on milk quality and safety assists policy makers and stakeholders in the dairy industry to put in place interventions for clean, safe and profitable milk production.

Majority of farmers in the study were adults above 30 years of age. It could be possible that fewer younger farmers are engaged in dairy farming, especially in Southern Africa. Dairy enterprises require huge capital investments for purchasing heifers, equipment or feeds, which may not be easily available to younger farmers (Pantoja et al., 2009). It is also likely that, owing to the prevailing economic hardships in most developing countries there are few financial institutions that offer credit facilities that can be easily by resource poor youth (Salami et al., 2010; SNV, 2012). Therefore, challenges hindering the youth from participating in dairy farming need to be explored.

Table 4.5: Odds ratios estimates, lower (LCI) and upper confidence interval (UCI) of farmers being concerned about milk quality

Predictor	Odds	LCI	UCI	Significance
Production system (large vs small-scale)	0.22	0.09	0.51	*
Gender (male vs. female)	0.83	0.43	1.63	NS
Age (young vs. old)	0.99	0.41	2.43	NS
Household size (small vs large)	0.93	0.47	1.82	NS
Education (uneducated vs. educated)	1.13	0.60	2.13	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$

Higher odds ratio estimates indicate greater difference in preference levels of predictors.

Table 4.6: Odds ratios estimates, lower (LCI) and upper confidence interval (UCI) of farmers considering milk safety to be important

Predictor	Odds	LCI	UCI	Significance
Production system (large vs small-scale)	2.19	1.17	4.08	*
Gender (male vs. female)	1.29	0.71	2.37	NS
Age (young vs. old)	0.99	0.48	2.07	NS
Household size (small vs large)	1.12	0.61	2.05	NS
Education (uneducated vs. educated)	13.61	6.79	28.80	*

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$

Higher odds ratio estimates indicate greater difference in preference levels of predictors.

The finding that large-scale farmers were more likely to consider breed of cows an important factor affecting milk quality when compared to small-scale farmers agrees with Huipjs *et al.*, (2008) who reported that breed type can affect milk quality. A lot of work has gone into selection of dairy breeds based on milk production potential and disease resistance (Nóbrega and Langoni, 2011). Majority of large-scale farmers consider the breeds to use on their farms based on resistance to diseases such as mastitis plus other milk production characteristics. Mastitis is the most common and costly disease which can contribute to economic losses from penalties for dairy farmers (Huijps *et al.*, 2008; Nóbrega and Langoni, 2011). These large-scale farmers preferred Jersey and Holstein while the small-scale farmers had mixed breeds. The finding that large-scale and older farmers who had more years of experience in dairy farming considered hygiene to be an important factor affecting milk quality agreed with findings by several authors (Ellis *et al.*, 2007; Pantoja *et al.*, 2009; Verdier-Metz *et al.*, 2009). These authors reported that the production of high quality milk is positively correlated with maintenance of hygienic standards in the milking facilities and the cow cleanliness during milking. Following strict hygienic standards prevents intra-mammary infections during milking and ensures lower total bacteria counts in milk (Hassan *et al.*, 2001). The finding that the older farmers, aged over 30 years, were more likely to indicate that hygiene affected milk quality could also have been influenced by those farmers' exposure, knowledge and experience in dairying. It is possible that over the years of being involved in dairy farming, older farmers could have seen the impact that poor hygiene has on productivity and profitability. Therefore, they could be more likely to consider hygiene as an important factor compared to the younger farmers with less dairy farming experience.

The finding that small-scale farmers considered transportation as the main contributor to poor milk quality when compared to commercial farms could be have been influenced by the facts that small-scale farmers' lack of access to good transportation modes and road network facilities. Most of the small-scale farmers transport milk on foot, scotch carts, bicycles and public transport (SNV, 2012; Moffat *et al.*, 2016). It is possible that milk quality will deteriorate because of the distances and time it takes to reach the processor, due to lack of adequate cooling facilities. Yet for most large-scale farmers, milk is bulk transported in refrigerated trucks with good temperature control mechanisms. The finding that transportation was ranked highest as the major source of milk contamination by small-scale farmers was, therefore, expected. Most small-scale farmers in this study transported their milk via public transport, commuter omnibuses, own vehicles and animal drawn scotch-carts.

The finding that large-scale farmers ranked udder diseases as the main cause of milk spoilage is supported by other researcher's finding, which confirm that presence of udder diseases such as mastitis in cows is the main contributor to poor milk quality as evidenced by high level of somatic cell counts (Ellis *et al.,* 2007). For this reason, it would be expected that farmers would rank udder diseases high. The finding that small-scale farmers ranked milking environment as the biggest source of contamination is consistent with findings by Swai and Schoonman (2011) who reported that milk spoilage will occur due to micro-organisms from different sources including the animal itself and its surrounds. These micro-organisms may be found in the environment arising from animal faeces, air, milking equipment, grass, soil or from the animal feed (Swai and Schoonman, 2011). Although both large-scale and small-scale farmers ranked personnel as the least cause of spoilage, other findings indicate that personnel cleanliness during milking and handling affects milk quality. The reason why both large-scale and small-scale farmers ranked personnel hygiene least as source of milk contamination could be that farmers in our study were reasonably confident with their personnel's hygiene and milking practises on farm but did not necessarily have the same level of confidence with other players in the milk supply chain like transporters or processors. Thus, they would attribute deterioration of milk quality to handling by others in the supply chain. Contamination was, therefore, perceived to occur during storage or transportation. The major cause of poor milk quality for MCCs is expected to come from the use of unhygienic storage containers and during transportation (Moffat *et al.,* 2016). Overall, the farmers' perception in this study indicate that there are many sources and causes of milk contamination.

The finding that small-scale farmers were three times more concerned about milk quality could be attributed to the existence penalty and premium based milk payment systems in developing countries. Milk quality would be a major concern as it affects profitability and small-scale farmers are affected by milk pooling at the MCCs. In such cases, farmers with good quality milk are affected by those with poor quality milk. For this reason, it was expected that the small-scale farmer would be more concerned about the milk quality in absence of the individualised milk quality testing as done in commercial farms. The adulteration of milk by one small-scale farmer can easily affect others in the consortium.

The finding that large-scale farmers considered milk safety to be important shows that the large-scale dairy farmers are not just interested in pushing milk volumes but safety of the milk they produce for human consumption. The small-scale farmer may on the other hand prioritize quantity of milk produced to safety. The high odds ratio estimate for the effect of education level on perceptions on milk safety can be attributed to differences in understanding of the importance and determinants of milk quality. Dairy producers who attain some level of formal education are more likely to have a better understanding on the importance and determinants of milk quality compared to the less educated. Education increases farmer's ability to obtain, analyse and interpret milk quality issues. The lack of differences in the likelihood of small-scale and large-scale farmers to consider milk quality to be important shows that although small-scale farmers are less likely to consider milk quality important, they are particular about its safety. Raw milk has been implicated for causing foodborne diseases and as a source of zoonotic bacteria such as Campylobacter, *Escherichia coli* and Listeria (Young *et al.,* 2010; Nada *et al.,* 2012; Ricci *et al.,* 2013).

4.5 Conclusions

Farmers' perceptions on factors affecting milk quality differed with milk production system. Though ranked differently, factors such as production system, hygiene, breed and age of farmers affected perceptions on milk quality. Small-scale dairy farmers perceived that contamination during milking was mainly due to milking environment whilst commercial farmers said it was mainly due to udder diseases. Small-scale farmers were concerned about milk safety. There is need to substantiate the farmer perceptions on sources of contamination of milk. It also essential to evaluate the effect of physical state of farm housing and milking practices on the bacteriological quality of milk basing on the conclusion that farmers perceived that contamination of milk came from the farm environment and the milking process.

4.6 References

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Chapter 5: Effects of physical state of farm housing and milking practices on bacteriological quality of cow milk

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Abstract

The objective of the study was to determine the effect of physical state of farm housing and milking practices on bacteriological quality of cow milk. Milk records collected by research assistants at Dairy Services Unit from randomly selected commercial dairy farms (n =78) and small-scale farms (n =126) were analysed. A chi-square test was used to determine the association between physical state of ceilings, doors, ventilation, walls, drains, fly-proofs, windows and roof and production type. The effect of the physical state of ceilings, doors, ventilation, walls, drains, fly-proofs, windows, roof type, production type, milking system, milk delivery methods and machine cleaning system on total bacterial count in milk (TBC) and somatic cell count (SCC) was determined using PROC GLM of SAS (2008). The majority of large-scale farms (> 70 %) had milking parlour doors, windows and fly proofing in poor physical state whilst more than 50 % of small-scale farms had milking parlour doors, windows and fly proofing in good physical state ($P < 0.01$). Most large-scale farms used pumps to deliver milk to storage tanks whilst most small-scale farmers used the manually poured milked into storage containers ($P < 0.05$). A larger percentage of large-scale farms (> 80 %) utilised automatic circulation to clean milking machines whilst most small-scale farmers used manually cleaned milking equipment ($P < 0.05$). The TBC and SCC in milk from dairy farms where the wash rooms that had doors, floors, walls and ventilation were in a good physical state were higher than from those farms where wash rooms were in poor physical state ($P < 0.05$). Farms that used machine milking and automatic milking cleanings system had lower TBC and SCC in milk compared to farms that used manual milking or hand washing ($P < 0.05$). Poor physical state of ceilings in milking parlour, wash rooms and bulk tank rooms resulted in production of milk with high TBC and SCC. Poor physical state of doors and floors of the milking parlour also results in high TBC and SCC in milk. Ventilation in the bulky tank room is important as poor ventilation results in high TBC and SCC in milk. Floors, doors and ceilings of milking houses should be kept in sound physical state and good repair in order to minimise TBC and SCC in raw milk. Proper ventilation in the bulk tank room is also required in order to minimise TBC and SCC in raw milk.

Key words: bacteriological quality, milk, housing physical state, somatic cell count, hygiene

5.1 Introduction

Milk and its products play an integral role in addressing food and nutrition challenges, especially in developing countries. Although milk and its products are easily accessible and highly nutritious, they possess a huge challenge in terms of safety to consumers due to them being an excellent medium for growth of microorganisms such as fungi and bacteria. As a result, most countries have strict regulations on the quality and safety standards for milk and its products. Milk quality and safety is usually a product of its physicochemical and microbial characteristics (Dehinenet *et al.,* 2013). Although there is a wide array of contaminants of dairy foods, bacterial contamination is the leading cause of spoilage (Samaržija *et al.,* 2012).

Farm management practices and quality control measures ensures production of bacteriologically safe milk. Milk contamination can occur from different sources such as the animal environment, air, milking equipment, feeds, soil, dung, farm personnel and housing (Elmoslemany *et al.,* 2010; Olofsson, 2013). Post-milking bacterial contamination arise from poor handling, transportation, storage and processing in both large-and small-scale dairy farms

(Moffat *et al.,* 2016). Milk production conditions are the major sources of bacteriological contamination of milk and its products (Kelly *et al.,* 2009).

Cold storage and pasteurisation of milk as obligatory technological steps improve its bacteriological quality. Small-scale production and informal trade in milk and milk products is, however, predominant in developing countries (Kilelu *et al.,* 2017). Milk from these small-scale farms is sold directly from the farm to the consumers. Compliance with quality and safety standards for milk and its products by small-scale producers and informal processers and traders is still low. The level of knowledge of good milking practices and hygiene among small-scale producers is often low (Abera *et al.,* 2012). There is, thus, an increased exposure of milk to bacteria during milking and, thus, a possibility of high bacterial loads and somatic cell counts (SCC). The SCC is a predictor of intermammary infection by bacteria and is also a major indicator of milk quality. Thus, there is a need to reduce bacterial loads and contamination at the farm level. Strategies to reduce bacterial loads at farm level could include capacity-building and offering group concessions in bacterial quality certification practices.

Studies conducted on reducing bacterial loads at farm level have focused on milkers and cows. High TBC and SCC in milk have been mainly blamed on contamination from dirty teats, udders and tails of cows, dirty hands, dirty clothes and milking equipment (Múnera-Bedoya *et al.,* 2017). Although most milk producers meet the standards of hygiene required to conform to the legislation as it applies to the hygiene of milkers and cows, TBC and SCC in raw milk is still considerably high (Belay and Janssens, 2015). This indicates that there are other often-overlooked sources of hygiene related contaminations of milk at farm level. A few, if any, studies have investigated the effects of farm environment other than milkers and cows on TBC and SCC. Housing features such as doors, floors, walls and windows can be sources of harmful microorganisms such as bacteria if they are not constructed and managed properly. For example, door, floors, walls and/or windows that are broken or made of rough material can be difficult to clean and, thus, can be a hub of bacteria due to dust accumulation, vermin accumulation and holding moisture. Poor ventilation hinders clean air circulation and promotes condensation and, thus, bacterial contamination. Poor drainage can result in muddy surroundings, accumulated manure and urine and, thus, contributing to increased TBC and SCC.

Understanding how farm housing and management practices affect bacterial quality of milk enables farmers to put in corrective action in place before the milk gets into the informal markets. Good farm and management practices ensure that bacterial contamination of milk during milking and handling is reduced and, thus, quality and shelf-life of the milk is improved. Such knowledge enables dairy regulatory agencies to develop appropriate intervention programmes to produce milk that meets acceptable standards for TBC and SCC. The objective of the study was, therefore, to determine the effect of physical state of farm housing and milking practices on somatic cell counts and bacteria counts in milk from large- small-scale and commercial farms. It was hypothesised that physical state of farm housing and milking practices do not affect somatic cell counts and total bacteria counts in milk from large- and small-scale farms.

5.2 Materials and Methods

5.2.1 Study site

Data were obtained from records collected by trained technical officers at the Dairy Services Unit (DSU) of the Department of Veterinary Services in Zimbabwe, from 78 large-scale dairy farms and selected 126 small-scale farmers. Dairy farms with less than seven milking cows were considered as small-scale (Hahlani and Garwi, 2014). Table 5.1 shows the identities of the production type, location, climatic conditions and the number of farms from each province. Mashonaland and Manicaland provinces are where most of the large and small-scale dairy farms are concentrated.

5.2.2 Data collection

Records on butterfat, protein, lactose, total solids, solids non-fat, TBC and SCC of raw milk were collected from DSU. Records were generated from milk samples submitted to and analysed by DSU over a 10-year period from 2006 to 2016 for 126 small-scale and 78 large-scale farms located in Manicaland and Mashonaland provinces. Farmers submitted milk samples for testing to DSU once a month. Each farm provided two samples every month over the 10-year period. A total of 48 960 milk samples were sent for laboratory analyses over the 10-year period.

Physical state of farm housing, management practices and hygiene data were collected three times a year by trained DSU technical officers. These officers worked in close collaboration with senior lecturers and professors. The technical officers were allocated to specific farms, which they followed up on routinely. Standardised checklists and recording sheets were used to assess the physical state of milking parlour areas, floors, roof, drains, doors and walls. The physical state of milking house and equipment was classified as either good or poor by the technical officers following the guidelines set by DSU. Table 5.2 gives the attributes used to assess the physical state of milking houses and hygienic state of milking equipment during inspection.

Any milking house feature which did not meet any of the required attributes was recorded as poor and those that met all required attributes were recorded as good. Farm roof type, milking system used, method of milk delivery and machine cleaning system were also recorded. The washing basins and buckets were visually assessed and recorded as either clean or dirty.

Table 5.1: Climatic conditions and the number of farms used in large-scale or small-scale farmers used in the study

Production type	Location	n	Coordinates	Altitude	Mean Annual rainfall (mm)	Mean Annual Temperatures (ºC)
Large-scale	Mashonaland Central	19	16.7644° S, 31.0794° E	1319	850	21.3
	Mashonaland East	15	18.5872° S, 31.2626° E	1026	789	19.4
	Mashonaland West	11	17.4851° S, 29.7889°E	1216	838	20.2
	Manicaland	33	18.9216° S, 32.1746° E	1756	1133	18.6
Small-scale	Mashonaland Central	34	16°4554°S 31°34.30°E	1211	812	20.8
	Mashonaland East	30	19.0742° S, 31.1624° E	1037	789	19.4
	Mashonaland West	21	18.1380° S, 30.1474° E	1196	838	20.2
	Manicaland	41	20.0330° S, 32.8708° E	1648	1123	18.6

Source: Meteorological Services of Zimbabwe

Table 5.2: Attributes used to assess milking house physical state

Milking housing feature	Required attributes
Ceilings	• Not lower than 2.7-3.3 m. • Easily cleanable material.
Doors	• Made of easily cleanable material. • Able to secure and facilitate easy movement with the milking facility.
Ventilation	• Good natural ventilation.
Floors	• Constructed of cement or concrete or other impervious material. • Smooth easy to clean, not slippery and coved. • Floors must be two-way sloped to enable appropriate drainage. • Should have manure channels that are wide and shallow.
Walls	• Plastered and painted with light and easily washable material to a height of at least 1.6m from the floor. • Stall divisions should not be of wood.
Drains	• Good drainage, situated on well drained ground.
Fly-proofing	• Made of material that restricts entry of insects into the milking facility.
Windows	• Insect and vermin proof. • Burglar barred, and window sills sloped. • Preferably not glass. • Providing good natural ventilation.

5.2.3 Data structure and preparation

Data obtained from DSU routine farm visits and laboratory data were merged into a single database. Incomplete and mismatching records were excluded from the final analyses. Out of the 48 960 records on butterfat, protein, lactose, total solids, solids non-fat, TBC and SCC from milk samples sent for laboratory analysis, 7 980 had complete and matching entries with physical state of housing, management practices and hygiene data.

5.2.4 Laboratory analyses

Milk samples for total bacteria counts and SCC determination were collected using sterile 50ml containers and stored in below 4^{0}C then analysed within at the Dairy Services Aglabs using the standard method of examination of dairy products (Wehr and Frank, 2004). Somatic cell counts per ml were measured by cytometry using an infrared Somato Counter 300. Total bacteria counts were determined using the plate count method (Wehr and Frank, 2004). One ml of milk was cultured directly on petrifilm dishes and incubated at 35-37^{o} C for 24 hours. All bacterial cells were read using an automatic counter and expressed as counts.

5.3.5 Statistical analyses

All data were analysed using Statistical Analysis System 9.2 (SAS, 2008). The PROC UNIVARIATE (SAS, 2008) was used to examine the distribution of total bacteria and somatic cell counts. The data were normally distributed. A chi-square test (PROC FREQ procedure) was used to determine the association between proportions of farms that had ceilings, doors, ventilation, walls, drains, fly-proofs, windows and roof type in poor and bad physical state with production type (SAS, 2008). The chi-square test was also used to determine the association between cleanliness of milking equipment, milking system used, milk delivery method, machine cleaning system and production type. The effect of the physical state of ceilings, doors, ventilation, walls, drains, fly-proofs, windows and roof type, production type, milking system, milk delivery methods and machine cleaning system on TBC and SCC was determined using PROC GLM of SAS (2008). Data were pre-analysed and all first order interactions they were not significant were excluded from the final model. Means were separated using pdiff.

5.3 Results

5.3.1 Physical state of milking house features and equipment and levels of significance of fixed factors

More than 50 % of small-scale and large-scale farms who used hand washing basins used them whilst dirty. Majority (more than 60 %) of both small-scale and large-scale farms used milking machines. A considerable number of small-scale farms (more than 36 %) used hand milking. More than 90 % of large-scale farms used pumps to deliver their milk to storage tanks whilst the majority of small-scale farmers used the poring method ($P < 0.05$). About 80 % of large-scale farmers used automatic circulation to clean their milking machines whilst the majority of small-scale farmers (more than 95 %) cleaned manually ($P < 0.05$). Associations between physical state of milking house features and production type are shown in Table 5.3. Most of the large-scale farms (more than 70 %) had milking parlour doors, windows and fly proofing in poor physical state whilst more than 50 % of small-scale farms had milking parlour doors, windows and fly proofing in good physical state ($P < 0.01$). More large-scale farms (98 %) had good ventilation in milking parlours than small-scale farms (42 %) ($P < 0.01$). More than 50 % of both small-scale and large-scale farms had ceilings in poor physical state. The majority (more than 70 %) of small-scale and large-scale farms had floors, walls and drains in good physical state.

5.3.2 Effect of production type and roof type, milking system and cleanliness of handwashing equipment on somatic cell count and total bacterial count.

The effect of production type, farm roof type, milking system, cleanliness of hand washing basins and milk buckets on total bacteria counts and somatic cell counts in milk is shown in Table 5.4. The TBC and SCC in milk from commercial dairy farms were lower than those in milk from small-scale dairy farms ($P < 0.05$). The TBC and SCC in milk from dairy farms that had asbestos roofs were higher than those in milk from dairy farms with iron roofs ($P < 0.05$). The TBC and SCC in milk from farms that use machine milking was lower than dairy farms that hand milk ($P < 0.05$). The TBC and SCC in milk from farms that had clean milking buckets and hand washing basins was lower than dairy farms that had dirty milking buckets and hand washing basins ($P < 0.05$).

5.3.3 Effect of physical state of bulk tank room on somatic cell counts and total bacterial counts

The effect of physical state of bulk tank room on total bacteria and somatic cell counts in milk is shown in Table 5.5. The TBC in milk from dairy farms with bulk tank rooms that had poor physical state of ceilings was higher than those farms with bulk tank rooms with good ceilings. Those farms which had bulk tank rooms with doors, floors and walls in good maintenance physical state had higher TBC and SCC ($P < 0.05$). There was no significant difference in milk from farms with bulk tank rooms that had poor physical state of ventilation compared to those that had good ventilation. ($P< 0.05$).

Table 5.3: Frequencies (%) of physical state of milking house features of small-scale and large-scale dairy producers

	Small-scale		Large-scale		Significance
	Good	Poor	Good	Poor	
Ceiling	4.8	95.2	15.5	84.5	NS
Doors	52.4	47.6	18.1	81.9	**
Ventilation	42.1	57.9	97.8	2.2	**
Floor	79.2	20.8	87.8	12.2	NS
Walls	78.9	21.1	95.8	4.2	NS
Drains	88.3	11.7	85.6	14.4	NS
Fly-proofing	54.9	45.1	4.5	95.5	*
Windows	56.8	43.2	23.8	76.2	**

**P < 0.01; *P < 0.05; ^{NS}P > 0.05

Table 5.4: Effect of production type, farm roof type, milking system, cleanliness of hand washing basins and milk buckets on total bacteria counts and somatic cell counts in milk

	Total bacteria count	Somatic cell count
Production type		
Commercial	129.8 ± 19.60 [a]	333.3 ± 51.39 [a]
Small-scale	166.3 ± 20.06 [b]	553.4 ± 50.97 [b]
Roof type		
Iron	86.7 ± 30.72 [a]	108.0 ± 80.55 [a]
Asbestos	283.7 ± 19.32 [b]	514.9 ± 50.42 [b]
Milking system		
Hand milking	270.6 ± 75.23 [c]	671.5 ± 196.24 [c]
Machine milking	161.4 ± 70.39 [d]	496.3 ± 183.90 [d]
Hand washing basin		
Clean	91.9 ± 27.30 [e]	186.8 ± 67.94 [e]
Dirty	313.3± 27.59 [f]	668.3 ± 69.34 [f]
Milking buckets		
Clean	165.8 ± 32.65	632.9 ± 158.83 [e]
Dirty	256.1 ± 73.06	935.3 ± 187.22 [f]

Values in the same column with different superscripts differ (P<0.05).

Table 5.5: Least square means for effect of physical state of bulk tank room on total bacteria and somatic cell counts in fresh milk

	Total bacteria count (x 10^3cfu/ml) (TBC)		Somatic cell counts (x 10^3cfu/ml) (SCC)	
Bulk tank room area	Good	Poor	Good	Poor
Ceiling	258.0 ± 148.82 [a]	600.8 ± 173.75 [b]	96.0 ± 39.30	138.9 ± 52.35
Doors	282.1 ± 149.77	237.7 ± 138.57	153.2 ± 42.19	124.6 ± 62.02
Ventilation	176.8 ± 67.33	732.0 ± 255.21	533.4 ± 148.80	949.0 ± 275.14
Floor	161.6 ± 11.06 [a]	81.0 ± 31.85 [b]	553.9 ± 29.31 [a]	224.0 ± 83.23 [b]
Walls	154.4 ± 10.00 [a]	84.8 ± 31.80 [b]	573.8 ± 27.96 [a]	235.6 ± 83.02 [b]

Values of the same parameter (TBC and SCC) in the same row with different superscripts differ ($P<0.05$).

5.3.4 Effect of physical state of milking parlours on somatic cell counts and total bacterial counts

The effect of physical state of milking parlour on total bacteria and somatic cell counts in milk is shown in Table 5.6. The TBC in milk from dairy farms with milking parlour that had good ceiling and door physical state was higher than those farms with milking parlour with ceilings and doors in poor physical state ($P < 0.05$). The TBC and SCC in milk from dairy farms with milking parlours that had poor physical state of ventilation was lower than those farms with milking parlour that were in good physical state ($P < 0.05$). Farms which had milking parlours with poor physical state of floors had higher TBC compared to milk from farms with floors in good physical state ($P < 0.05$). The SCC in milk from farms with milking parlour that had poor physical state of doors was higher compared to farms that had good doors ($P < 0.05$). The physical state of walls, drains and windows did not have an effect on TBC, nor did the physical state of ceilings, floor and walls have an effect on SCC ($P< 0.05$).

5.3.5 Effect of physical state of washrooms on somatic cell counts and total bacterial counts

The effect of physical state of washrooms on total bacteria and somatic cell counts in milk is shown in Table 5.7. The TBC and SCC in milk from dairy farms with wash room that had good doors, floors, walls and ventilation was higher than those farms with wash room with poorer physical state ($P < 0.05$). The SCC in milk from dairy farms with wash rooms that had poor physical state of ceilings was higher than those farms with wash room that had good ceilings ($P < 0.05$). Farms which had wash room with floor in poor physical state of fly proofing and windows, had milk with higher SCC compared to milk from farms with good fly-proofing and windows ($P < 0.05$). The physical state of drains, ceilings, fly-proofing and windows in washrooms had no effect on TBC ($P>0.05$). The physical state of windows did not influence SCC ($P>0.05$).

Table 5.6: Effect of physical state of milking parlours on total bacteria and somatic cell counts in milk

Milking parlour area	Total bacteria count (x 10^3cfu/ml)		Somatic cell counts (x 10^3cfu/ml)	
	Good	Poor	Good	Poor
Ceiling	311.9 ± 55.62 ^{a}	134.2 ± 11.57 ^{b}	516.4 ± 52.37	586.9 ± 28.32
Doors	202.3 ± 19.76 ^{a}	108.7 ± 12.31 ^{b}	445.8 ± 48.89 ^{a}	561.0 ± 30.56 ^{b}
Ventilation	141.2 ± 10.82	91.9 ± 27.85	571.6 ± 26.42 ^{a}	186.9 ± 67.98 ^{b}
Floor	134.6 ± 9.90 ^{a}	1000 ± 133.40 ^{b}	520.5 ± 25.04	578.5 ± 45.96
Walls	134.4 ± 10.00	186.3 ± 18.60	518.6± 25.26	652.3 ± 68.61
Drains	16.3 ± 3.07	3.9 ± 2.45	519.7 ± 25.33 ^{a}	640.2 ± 82.16 ^{b}
Fly-proofing	108.3 ± 25.84	133.6 ± 11.51	242.4 ± 61.34 ^{a}	587.2 ± 28.17 ^{b}
Windows	90.5 ± 19.94	141.9 ± 11.42	577.9 ± 97.55 ^{a}	1507.5 ± 138.81 ^{b}

Values of the same parameter (TBC and SCC) in the same row with different superscripts differ ($P < 0.05$).

Table 5.7: The effect of physical state of washrooms on total bacteria count and somatic cell counts in fresh milk

Washroom Area	Total bacteria count (x 10^3cfu/ml)		Somatic cell counts (x 10^3cfu/ml)	
	Good	Poor	Good	Poor
Ceiling	204.2 ± 19.21	190.0 ± 47.18	454.3 ± 47.61 ^{a}	705.4 ± 110.46^{b}
Doors	316.4 ± 27.26 ^{a}	123.0± 22.70 ^{b}	692.8 ± 68.89 ^{a}	359.9 ± 56.17 ^{b}
Ventilation	301.1 ± 25.85 ^{a}	118.9 ± 23.71 ^{b}	690.2 ± 64.68 ^{a}	332.9 ± 58.48 ^{b}
Floor	278.7 ± 22.74 ^{a}	13.0 ± 266.21 ^{b}	700.3± 55.48	164.0 ± 67.33
Walls	218.3 ± 30.30 ^{a}	31.9 ± 12.74 ^{b}	580.2 ± 88.11 ^{a}	69.9 ± 23.94 ^{b}
Drains	303.9 ± 25.89	201.7 ± 47.65	694.4 ± 65.14	727.7 ± 112.83
Fly-proofing	100.1 ± 27.91	203.1 ± 17.82	2372.1 ± 484.53^{a}	478.4 ± 43.60 ^{b}
Windows	305.8 ± 27.24	217.0 ± 40.97	696.2 ± 68.65	706.3 ± 98.07

Values of the same parameter (TBC and SCC) in the same row with different superscripts differ ($P < 0.05$).

5.3.6 Method of milk delivery and cleaning system

The effect of method of milk delivery and cleaning system on total bacteria count and somatic cell counts in milk is shown Table 5.8. The TBC in milk from farms that used pouring and gravity methods of milk delivery was higher than milk from farms that utilise the pump method ($P < 0.05$), however, there was no significant difference in SCC from the same farms. Farms that had the automatic systems like the Electobrain cleaning system in situ had much lower TBC and SCC in milk compared to farms that used hand washing or automatic or manual cleaning methods.

5.4 Discussion

The SCC is widely accepted and dependable predictor of milk quality and general herd management (Reneau, 2001). Most countries accept milk with somatic cell counts that are less than 400,000 cfu/ml for dairy product processing (Bytyqi *et al.*, 2010). Understanding the effect of farm conditions in milking parlours on the resultant TBC and SCC will assist regulatory agents on how best to assist farmers to improve their milking systems, as they conduct routine farm visits or regulatory visits.

The finding that most of the large -and small-scale farms had ceilings, fly-proofing, windows and doors in poor physical state and dirty hand washing basins could be the reason for the observed increased TBC and SCC in recent years. Bacteria usually come from the environment such as air, dirty equipment, vermin and dust (Pandey and Voskuil, 2011). Ceilings that are too low, difficult to clean and dark coloured can be sources of bacterial contamination. Door and windows made of rough material which is difficult to clean can also

Table 5.8: Effect of method of milk delivery and cleaning system on total bacteria counts and somatic cell counts in milk

Parameter	Total bacteria count (x 10^3cfu/ml)	Somatic cell counts (x 10^3)
Milking method delivery		
Pouring	333.5 ± 64.56 ^{a}	911.3 ± 159.42
Gravity	300.3 ± 87.77 ^{a}	752.3 ± 207.54
Pump	140.6 ± 59.12 $^{b\,c}$	911.2 ± 144.05
Machine cleaning system		
Electrobrain	154.3 ± 79.38 ^{a}	114.5 ± 39.08 ^{a}
Automatic circulation	494.3 ± 147.12 ^{b}	763.4 ± 99.87 ^{b}
Manual cleaning	328.4 ± 36.10 ^{c}	643.9 ± 92.76 ^{c}

Values in the same column for (TBC or SCC) with different superscripts differ (P<0.05).

be a hub of bacteria due to dust accumulation, vermin accumulation and holding moisture. Poor ventilation hinders clean air circulation and promotes condensation and, thus, bacterial contamination. Fly infestations in the milking area also increases bacterial counts in milk. The same finding also implies that the majority small-scale and largescale farmers have limited knowledge of good milking parlour hygiene practices. For farmers to be able to produce milk with low bacterial counts, they need advice and assistance on proper construction and maintenance of the milking parlour and hygiene practices. The finding that a considerable percentage of small-scale dairy farmers practiced hand milking, used pouring as a milk delivery method and cleaned their milking equipment manually shows that they are resource poor.

It is possible that the finding that the TBC and SCC in milk from dairy farms that had asbestos roofs was higher than dairy farms with iron roofs could be attributed to iron roofs being much easier to clean and harbouring less contaminants that can contaminate milk during the milking process or storage. The SCC in milk from farms that use machine milking is lower than dairy farms that hand milk (Dufour *et al.,* 2011). Contrarily, Hovinen and Pyörälä (2011) reported that the installation of automatic milking machines in some Danish dairies did not necessarily coincide with a reduction in bulk tank somatic cell counts. In the current study, the TBC and SCC from farms that use machine milking was lower than those farms that hand milked. Such observations concur with literature (Dufour *et al.,* 2011). It is possible that this could be as a result of increased risk of contamination from hand milking being much higher than machine milking and thus the bacterial counts would be expected to be higher (Olofsson, 2013). Hand milking, delivering milk by pouring and manual cleaning all predispose milk to dirty and, thus increases bacteria contamination.

The finding that TBC and SCC in milk from farms that had clean milking buckets and hand washing basins was lower than dairy farms that had dirty milking buckets and hand washing basins was expected. Bacteria counts and somatic cell counts in milk increased when there is dirt, manure or different forms of soiling on farm milk handling equipment (Kelly *et al.*, 2009; Sant'anna & Paranhos da Costa, 2011; Nagy *et al.*, 2013).

Reneau (2001) reported that those farms that visually appeared neat , tidy and sanitary did not consistently produce high quality low SCC milk and vice versa (Reneau, 2001). In agreement with this, the finding that total bacteria counts in milk from dairy farms with milking parlour that had good ceilings and door physical state was higher than those farms with milking parlour with poor physical state indicates that visual cleanliness of milking parlours do not equate to reduce bacterial loading in that facility. Similarly, we found that dairy farms with milking parlours that had poor ventilation physical state had unexpectedly much lower TBC and SCC in milk compared to those farms with milking parlour that were in good physical state. Therefore, visual cleanliness or good physical state of facilities did not always equate to lower microbial counts. In agreement to the finding that washrooms with good doors, floors, walls and ventilation had higher TBC and SCC than those farms with wash room with poorer physical state confirming that good physical state of facility did not always correlate to lower bacterial counts. It could be possible that workers may not clean properly these places as they may look visually clean, yet for those farms in poor physical state more efforts could be put in cleaning out the dirt. The observation that farms with poor ventilation, fly-proofing and drainage had a higher TBC and SCC could be because unwanted foreign matter or contaminants gained access into the milk causing the resultant counts to be high.

The finding that SCC in milk from farms with milking parlour that had poor physical state of doors was higher compared to farms that's had good doors confirms the observations by Chassagne *et al.* (2005) that, clean farms, milking parlours and houses were positively correlated with lower somatic cells counts. Failure to provide clean, dry housing increases the risk of environmental pathogens that results in increased SCC in milk (Wenz *et al.*, 2007). The finding that the SCC in milk from dairy farms with milking parlour that had good drainage, fly-proofing and windows was lower than those farms with milking parlour with poorer physical state tallies the study by Wenz *et al.* (2007) and this shows that minimisation of environmental pathogens in the milking facility lowers the SCC in milk.

The findings that TBC in milk from farms that used manual methods of milk delivery was higher than milk from farms that utilise the pump method could be explained by the fact that they are more chances of contaminants introduced during manual delivery compared with closed automatic milk delivery systems. With direct pumping of milk there is minimal handling and reduced risk of contamination from the environment. On the other hand, farms that had automatic cleanings system had much lower TBC and SCC in milk compared to farms that used hand washing cleaning methods. The automatic cleaning system is more efficient and effective at removing dirt compared to hand cleaning. Olosfsson (2013) reported lower SCC from machine milking and cleaning systems compared to manual cleaning systems.

5.5 Conclusions

Farm housing physical state, method of milking and farm equipment cleaning systems affects TBC and SCC in milk. Commercial dairy farms produce milk with lower TBC and SCC than small-scale dairy farms. Using automatic milking cleaning systems results in production of milk with low TBC and SCC. Milk from farms that have milking parlours with asbestos roofs have higher TBC and SCC than that from farms with milking parlours with iron roofs. The TBC and SCC in milk from dairy farms with wash room with doors, floors, walls and ventilation in a good physical state is high than those farms with wash rooms with poor physical state. Keeping farm houses in good physical state thus reduces bacterial contamination of milk during milking and handling. It is, however, essential to evaluate the effect of physical state of farm housing and milking practices on other determinants of milk quality such as butterfat, protein, lactose, solids non-fat and total solids before encouraging farmers and dairy regulatory agencies to include them into their intervention programmes.

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Chapter 6: Effect of physical state of farm housing and milking practices on the physico-chemical properties of raw milk

Abstract

The study investigated the effect of physical state of farm housing and milking practices on physico-chemical characteristics of raw milk. Milk records were collected by Dairy Services Unit (DSU) from randomly selected large-scale dairy farms (n =78) and small-scale farms (n =126) The effect of the physical state of ceilings, doors, ventilation, walls, drains, fly-proofs, windows, roof type, milking system, milk delivery methods and machine cleaning system on butterfat (BF), protein, lactose, solids non-fat (SNF) and total solids (TS) was determined using PROC GLM of SAS (2008). The butterfat (BF) in milk from dairy farms with milking parlour and washrooms that had doors and fly-proofing in good physical state was higher than those in poor physical state ($P < 0.05$). The protein content in milk from dairy farms with milking parlours that had ceilings, ventilation and floor physical state was lower than those in good physical state ($P < 0.05$). The butterfat, protein, lactose and solids non-fat (SNF) content in milk from farms that utilised hand milking was higher than dairy farms that machine milked ($P < 0.05$). Poor physical state of doors, floors and ventilation of the milking parlour resulted in production of milk with low protein content. The chemical compositions of milk protein, BF, lactose and SNF was lower when conditions and state of repair of doors, floors, walls, ventilation and fly-proofing in the milking facility was poor. Farm milking facilities should be maintained in good physical state to minimise reduction in milk protein, butterfat or solids non-fat contents.

Key words: butterfat, lactose, milk quality, physico-chemical, solids non-fat

6.1 Introduction

Raw milk is one of most complete foods available in the developing countries capable of addressing food and nutrition insecurity. Milk is a nutritionally complete source of food that contains protein, carbohydrate, fats, vitamins and minerals in right proportions. Due the its chemical composition and high degree of assimilation milk and dairy products continue to play an important role in human nutrition (Ostan, *et al.,* 2016). Whilst milk is a nutritionally balanced food that can be easily accessed by resource poor consumers, there are still huge safety challenges faced by producers and processors because of pre-and-post milking contamination. Contamination of milk from different sources can alter the chemical composition of milk (Dehinenet *et al.,* 2013; Aziz and Khan, 2014).

Consumption of milk that has balanced physico-chemical characteristics is important in preventing chronic illnesses, maintenance of health and promoting early childhood development (Erasmus and Webb, 2013). Whilst milk has more than 200 components that are important for dairy processing, the major components of unadulterated cows' milk that is produced under hygienic conditions are water (87.2%), protein (3.5%) fat (3.7%), lactose (4.9%) and dry matter (12.8%) and ash (Belay and Janssens, 2014; Ostan *et al.,* 2016). Good quality control measures at the farm or milk processing sites ensures production of milk and by-products that have acceptable levels of physico-chemical characteristics.

Several studies conducted on improving milk quality at farm level have focused on breed, feeds, milk hygiene, cow cleanliness, season and equipment (Kelly *et al.,* 2009; Elmoslemany *et al.,* 2010. Poor physico-chemical quality of milk has been mainly attributed to poor cow nutrition, breeds, age and hygiene among the many other factors that affect milk quality (Belay and Janssens, 2015). Mastitis has been reported to contribute to decrease in protein and butterfat in milk (Petlane *et al.*, 2016). Due to poor hygiene, bacteria predispose cows to infection from mastitis and, thus, elevate levels of somatic cell counts, which alter the protein quality, fat composition, and pH of raw milk (Ogola *et al.*, 2007; Petlane *et al.*, 2013; Murphy *et al.*, 2016). The effects of factors such as breed, nutrition, poor hygiene, stage of lactation, age, season, diet and diseases on milk quality have been well researched (Belay and Janssens, 2014; Azeze and Tera, 2015).

Despites efforts to address the issues that contribute to poor physico-chemical qualities, it appears there are still other unheeded sources of contamination or factors that cause of deterioration of milk at the farm level. A few, if any, studies have investigated the effects of farm housing physical state on the quality and safety of milk. Yet housing features such as floors, ceilings, doors, walls and windows can be possible sources of contamination if they are not constructed, repaired and maintained appropriately. As observed in Chapter 5, door, floors, walls and/or windows that are broken or made of rough material can be difficult to clean and, thus, can be a hub of bacteria due to dust accumulation, vermin accumulation and holding moisture. Poor ventilation hampers clean air flow and encourages condensation and, thus, bacterial contamination, which can affect the physico-chemical characteristics of milk. It is inevitable that farm housing physical state and milking environment have the potential to alter the physico-chemical characteristics of milk, which will affect milk quality and safety. Despite the potential risk of contamination of milk due to poor housings physical state, there is no data on the association between physico-chemical characteristics of milk and physical state of farm housing. Dairy service agents such as the Dairy Services Unit (DSU) gather massive amount of data yearly on the farm housing physical state, which is used to determine if the dairy farmers can be registered to produce milk or continue with milk production.

Understanding the effect of the physical state of farm housing features like walls, drainage, fly-proofing, ceilings, doors, ventilation in milking parlours or bulk tank rooms on milk quality will justify the rationale behind assessing physical state of farm housing. Examining the effects of farm housing and milking management practices on physico-chemical characteristics of milk also enables corrective actions to be put in place appropriately because farm milking practices have the potential to impact the physico-chemical characteristics of milk or by products. The physico-chemical characteristics of milk was determined by the butterfat, lactose, protein, total solids and lactose in milk. The objective of the study was, therefore, to determine the effects of physical state of farm housing and milking practices on physico-chemical characteristics of milk. It was hypothesised that physical state of farm housing features such as doors, floors, ventilation, drains or walls and milking practices affect physico-chemical characteristics of milk.

6.2 Materials and Methods

6.2.1 Study site

The study site was described in section 5.2.1.

6.2.2 Data collection

Data collection was described in Chapter 5.2.2

6.2.3 Data structure and preparation

Data structure and preparation is described in section 5.2.3.

6.2.4 Laboratory analyses

The content of butterfat, protein, lactose, total solids and solids non-fat in milk was analysed by Dairy Services Unit at Aglabs using the standard method of examination of dairy products by Wehr and Frank (2004), while bacterial counts and somatic cell counts were determined using a milk analyser (LACTOSCAN 8) by Milkotronic, Ltd, Bulgaria.

6.2.5 Statistical analyses

All data were analysed using Statistical Analysis System 9.2 (SAS, 2008). The PROC UNIVARIATE procedure (SAS, 2008), was used to examine the contents of BF, protein, lactose, TS and SNF in milk. The effect of the physical state of ceilings, doors, ventilation, walls, drains, fly-proofs, windows and roof type, farm classification, milking system, milk delivery methods and machine cleaning system on butterfat, protein, lactose, total solids and solids non-fat was examined using PROC GLM of SAS (2008). Data were pre-analysed and all first order interactions they were not significant were excluded from the final model. Means were separated using pdiff.

6.3 Results

6.3.1 Effect of bulk tank room physical state on butterfat and protein

Butterfat and protein content in fresh milk from farms with bulk tank rooms with ceilings, doors, ventilation, floor and walls in poor and good physical state are shown in Table 6.1. Farms which had bulk tank rooms with ceilings, ventilation, floors and walls in good physical state had higher protein percentage compared to those in poor physical state ($P < 0.05$).

Lactose, total solids (TS) and solids non-fat (SNF) content in milk from farms with bulk tank rooms features in poor and good housing physical state is shown in Table 6.2. Dairy farms that had bulk tank rooms with good ceilings, doors, ventilation, floors and walls did not differ in lactose and solids non-fat content when compared to those poor physical state ($P > 0.05$). Total solid content in milk from farms that had bulk tank rooms with walls, ventilation and floors in poor physical state was higher than those in good physical state ($P < 0.05$)

6.3.2 Effect of milking parlour physical state on butterfat and protein, lactose, SNF and TS

Butterfat and protein in fresh milk from farms with milking parlours features in poor and good housing physical state is shown in Table 6.3. Butterfat in milk from dairy farms with milking parlour with doors, ventilation and fly-proofing in good physical state was higher than those in poor physical state ($P < 0.05$). Protein content in milk from dairy farms with milking parlours that had ceilings, floor, doors and fly-proofing in poor physical state was lower than those in good physical state ($P < 0.05$). Lactose, total solids (TS) and solids non-fat (SNF) content in fresh milk from farms with milking parlours features in poor and good housing physical state is shown in Table 6.4. Dairy farms with milking parlours with doors, ventilation and fly-proofing in good physical state had higher lactose compared to those that had poor physical state ($P < 0.05$). The total solids and solid non-fat content in milk from farms with milking parlour doors, fly-proofing and ventilation in good physical state was much lower compared to those with poorer physical state ($P < 0.05$).

Table 6.1: Butterfat and protein content in fresh milk from farms with bulk tank rooms with ceilings, doors, ventilation, floor and walls in poor and good physical state

	Butterfat (%)		Protein (%)	
Bulk tank room area	Good	Poor	Good	Poor
Ceiling	5.4 ± 1.92	4.8 ± 1.32	4.4 ± 0.17 [a]	3.7 ± 0.19 [b]
Doors	4.6 ± 1.70	4.4 ± 1.61	3.3 ± 0.17	3.1 ± 0.26
Ventilation	3.7 ± 1.31	3.9 ± 0.98	4.6 ± 0.19 [a]	3.3 ± 0.28 [b]
Floor	3.5 ± 1.57	3.5± 1.18	4.3 ± 0.01 [a]	3.0 ± 0.03 [b]
Walls	3.5 ± 1.38	3.2 ± 0.95	3.3 ± 0.01 [a]	2.9 ± 0.03 [b]

Values of the same milk component (Butterfat and Protein) in the same row with different superscripts differ ($P < 0.05$).

Table 6.2: Lactose, total solids (TS)and solids non-fat (SNF) content in milk from farms with bulk tank rooms with ceilings, doors, ventilation, floor and walls in poor and good housing physical state

Feature	Lactose (%)		Total solids (%)		Solid non-fat (%)	
Bulk tank room area	Good	Poor	Good	Poor	Good	Poor
Ceiling	4.4 ± 0.19	4.5 ± 0.22	11.8 ± 0.84	12.2 ± 0.95	13.2 ± 2.15	13.3 ± 1.55
Doors	4.7 ± 0.20	4.8 ± 0.30	12.1 ± 0.85	12.2 ± 1.32	13.9 ± 3.98	14.1 ± 3.47
Ventilation	4.8 ± 0.22	4.8 ± 0.33	12.7 ± 0.01 ^{a}	14.9 ± 1.42 ^{b}	13.8 ± 3.56	13.9 ±2.66
Floor	4.7 ± 0.01	4.6 ± 0.14	12.8 ± 0.06 ^{a}	15.5 ± 0.17 ^{b}	13.6 ± 3.52	14.4 ± 2.92
Walls	4.6 ± 0.01	4.6 ± 0.26	12.7 ± 0.05 ^{a}	14.42 ± 0.17 ^{b}	13.7 ± 3.32	13.8 ± 2.01

Values of the same milk component (TS, SNF and lactose) in the same row with different superscripts differ ($P<0.05$).

Table 6.3: Butterfat and protein content in fresh milk from farms with milking parlours with ceilings, doors, ventilation, floor, walls drains, fly-proofing and windows in poor and good housing physical state

	Butterfat (%)		Protein (%)	
Milking Parlour Area	Good	Poor	Good	Poor
Ceiling	3.8± 1.51	3.9 ± 2.47	3.3 ± 0.01 [a]	2.96 ± 0.01 [b]
Doors	4.6 ± 0.99 [a]	3.2 ± 1.68 [b]	3.9± 0.02 [a]	3.1 ± 0.01 [b]
Ventilation	4.9 ± 0.21 [a]	2.9 ± 0.36 [b]	3.6 ± 0.19	3.2 ± 0.28
Floor	4.1 ± 3.04	3.9 ± 2.04	3.3 ± 0.01 [a]	2.9 ± 0.14 [b]
Walls	4.2 ± 0.06	4.0 ± 0.94	3.3 ± 0.01	3.18 ± 0.09
Drains	3.3 ± 1.07	3.2 ± 1.62	3.2 ± 0.01	3.25 ± 0.08
Fly-proofing	4.9 ± 1.54 [a]	3.2 ± 1.44 [b]	3.5 ± 0.03 [a]	3.0 ± 0.01 [b]
Windows	4.1 ± 1.34	4.0 ± 1.39	3.7 ± 0.17	3.7 ± 0.01

Values of the same milk component (BF and P) in the same row with different superscripts differ ($P < 0.05$).

Table 6.4: Lactose, total solids (TS)and solids non-fat (SNF) content in fresh milk from farms with milking parlours with ceilings, doors, ventilation, floor, walls, drains, fly-proofing and windows in poor and good housing physical state

	Lactose (%)		Total solids (%)		Solid non-fat (%)	
Milking Parlour Area	Good	Poor	Good	Poor	Good	Poor
Ceiling	4.7 ± 0.06	4.6 ± 0.01	13.1 ± 0.28	12.7± 0.06	13.4 ± 1.29	13.5 ± 1.41
Doors	4.5 ± 0.02 ^{a}	3.7 ± 0.02 ^{b}	11.7 ± 0.11 ^{a}	12.8 ± 0.07 ^{b}	13.2 ± 2.91 ^{a}	16.8 ± 2.63 ^{b}
Ventilation	4.7 ± 0.22 ^{a}	3.4 ± 0.33 ^{b}	10.8 ± 0.05 ^{a}	12.9 ± 0.15 ^{b}	12.7 ± 3.17 ^{a}	16.6 ± 3.24 ^{b}
Floor	4.6 ± 0.01	4.6 ± 0.04	12.4 ± 0.06	12.3 ± 0.72	14.9 ± 2.99	14.6 ± 3.45
Walls	4.7 ± 0.01	4.7 ± 011	12.9 ± 0.05	13.1 ± 0.48	13.7 ± 3.01	14.3 ± 2.24
Drains	4.6 ± 0.01	4.7 ± 0.11	12.6 ± 0.05	12.9 ± 0.47	14.8 ± 3.02	15.0 ± 2.25
Fly-proofing	4.8 ± 0.03 ^{a}	3.9± 0.01 ^{b}	11.36± 0.14 ^{a}	12.71 ± 0.06 ^{b}	13.7 ± 3.43 ^{a}	15.9 ± 3.39 ^{b}
Windows	4.7 ± 0.21	4.6 ± 0.01	12.25 ± 0.91	12.74 ± 0.06	14.8 ± 1.68	15.1 ± 2.33

Values of the same milk component (TS, SNF and lactose) in the same row with different superscripts differ ($P < 0.05$)

6.3.3 Effect of washroom physical state on butterfat and protein

Butterfat and protein content in fresh milk from farms with washroom with ceilings, doors, ventilation, floors, walls, drains, fly-proofing and windows in poor and good housing physical state is shown in Table 6.5. The butterfat content in milk from dairy farms with wash room that had good doors, ventilation and walls was higher than those farms with wash room with poor good doors, ventilation and walls ($P < 0.05$). Dairy farms with washrooms with ceilings, doors, ventilation, floors and walls in good physical state had higher protein content in milk than those in poor physical state ($P < 0.05$).

Lactose, Total solids (TS) and solids non-fat (SNF) content in fresh milk from farms with washrooms with ceilings, doors, ventilation, floors, walls, drains, fly-proofing and windows in poor and good housing physical state is shown in Table 6.6. Farms with wash room that had ceilings and walls in good physical state had lower lactose and total solid content in milk than those in poor physical state ($P < 0.05$). The SNF content in milk from dairy farms with washrooms that had good doors, ventilation, walls and fly-proofing physical state was much lower than those farms with washrooms in poorer physical state of doors, ventilation, walls and fly-proofing ($P < 0.05$).

6.3.4 Effect of milking system on BF, protein, TS, SNF and Lactose

The effects of farm classification, milking system and cleanliness of hand washing basins and milking buckets on butterfat, protein, lactose, TS and SNF content in fresh milk are shown in Table 6.7. The butterfat and protein content in milk from commercial dairy farms was higher that of milk from small scale dairy farms. However, there was no significant difference in lactose, total solids and solids non-fat content from commercial dairy farms and small -scale dairy farms.

Table 6. 5: Butterfat and protein content in milk from farms with washrooms with ceilings, doors, ventilation, floors, walls, drains, fly-proofing and windows in poor and good housing physical state

	Butterfat (%)		Protein (%)	
Washroom	Good	Poor	Good	Poor
Ceiling	3.28 ± 1.82	3.48 ± 1.47	4.1 ± 0.01 [a]	3.2 ± 0.04 [b]
Doors	4.8 ± 0.45 [a]	3.6 ± 0.68 [b]	5.3 ± 0.02 [a]	3.0 ± 0.02 [b]
Ventilation	5. 7 ± 1.44 [a]	3.4 ± 1.11 [b]	4.9 ± 0.02 [a]	3.1 ± 0.02 [b]
Floor	3.3 ± 1.79	3.62 ± 1.99	6.8 ± 0.01 [a]	2.9 ± 0.14 [b]
Walls	6.7± 2.06 [a]	3.5 ± 1.32 [b]	4.3 ± 0.14 [a]	3.0 ± 0.13 [b]
Drains	3.8 ± 1.01	3.70 ± 1.42	3.2 ± 0.03	3.2 ± 0.05
Fly-proofing	3.0 ± 0.06	3.1 ± 1.36	3.1 ± 0.28	3.2 ± 0.02
Windows	3.7 ± 1.49	3.6 ± 1.76	3.2 ± 0.03	3.2 ± 0.04

Values in the same column of the same milk component with different superscripts differ ($P < 0.05$).

Table 6.6: Lactose, Total solids (TS) and solids non-fat (SNF) content in milk from farms with washrooms with ceilings, doors, ventilation, floor and walls in poor and good housing physical state

	Lactose (%)		Total solids (%)		Solid non-fat (%)	
Washroom	Good	Poor	Good	Poor	Good	Poor
Ceiling	4.5 ± 0.02 [a]	6.8 ± 0.05 [b]	11.7 ± 0.11 [a]	12.8 ± 0.24 [b]	13.8 ± 2.73	14.6 ± 1.89
Doors	4.7 ± 0.03	4.6 ± 0.02	11.6 ± 0.15	11.9 ± 0.12	13.8 ± 1.32 [a]	15.9 ± 1.73 [b]
Ventilation	4.6 ± 0.03	4.5 ± 0.03	11.3 ± 0.14	11.6 ± 0.13	14.0 ± 1.83 [a]	16.3 ± 1.01 [b]
Floor	4.6 ± 0.02	4.7± 0.35	11.5 ± 0.11	11.7 ± 1.47	13.9 ± 1.99	12.9 ± 0.79
Walls	4.7 ± 0.17 [a]	5.6 ± 0.17 [b]	11.4 ± 0.71 [a]	13.1 ± 0.48 [b]	14.7± 1.25 [a]	17.7 ± 1.73 [b]
Drains	4.6 ± 0.03	4.7 ± 0.05	12.6 ± 0.15	12.5 ± 0.26	14.0 ± 1.89	13.7 ± 1.21
Fly-proofing	4.7 ± 0.36	4.5± 0.02	11.9± 1.54	11.8 ± 0.09	12.9 ± 2.16 [a]	14.3 ± 2.28 [b]
Windows	4.5 ± 0.03	4.6 ± 0.05	12.5 ± 0 16	12.6 ± 0.22	13.9 ± 1.35	14.0± 1.58

Values in the colum with same milk component (Lactose, TS and SNF) with different superscripts differ ($P < 0.05$).

Table 6.7: Effect of farm classification, milking system and cleanliness of hand washing basins and milk buckets on butterfat, protein, lactose, total solids and solids non-fat content in milk

Parameter	Butterfat (%)	Protein (%)	Lactose (%)	Total solids (%)	Solids non-fat (%)
Farm classification					
Commercial	4.6 ± 1.22 [a]	4.1 ± 0.02 [a]	4.6 ± 0.03	12.7 ± 0.11	16.1 ± 0.13
Small scale	3.2 ± 1.10 [b]	3.0 ± 0.02 [b]	4.5 ± 0.03	12.0 ± 0.11	17.0 ± 0.02
Milking System					
Hand milking	4.1 ± 0.23 [a]	3.3± 0.08 [a]	4.4 ± 0.09 [a]	12.3 ± 0.44	14.8 ± 2.62 [a]
Machine milking	3.6 ± 0.21 [b]	3.1 ± 0.08 [b]	4.6 ± 0.08 [b]	12.5 ± 0.42	17.6 ± 2.14 [b]
Handwashing basin cleanliness					
Clean	3.9 ± 0.07 [a]	3.2 ± 0.03 [a]	4.5 ± 0.03	10.8 ± 0.14 [a]	14.0 ± 0.24 [a]
Dirty	3.3 ± 0.08 [b]	2.9 ± 0.02 [b]	4.4 ± 0.03	12.5 ± 0.15 [b]	16.2 ± 0.45 [b]
Milking buckets Cleanliness					
Clean	4.8 ± 0.04 [a]	12.8 ± 0.16 [a]	3.9 ± 0.06	10.8 ± 0.14 [a]	14.0 ± 2.88 [a]
Dirty	4.2 ± 0.09 [b]	11.1 ± 0.37 [b]	3.7 ± 1.71	12.5 ± 0.15 [b]	19.7 ± 3.49 [b]

Values in the same row of the same milk component with different superscripts differ ($P<0.05$).

Butterfat, protein, lactose and solids non-fat content in milk from farms that utilised hand milking was higher than that in milk from dairy farms that utilised machines for milking ($P < 0.05$). The lactose content in milk from farms that used machines to milk cows was higher than those farms that hand milked ($P < 0.05$). The butterfat, protein, and solids non-fat in milk from farms that had dirty milking buckets and hand washing basins was lower than that in milk from dairy farms that had clean milking buckets and hand washing basins ($P < 0.05$).

6.3.5 Effects method of milk delivery and cleaning system butterfat, protein, solids non- fat and total solids

The effects of method of milk delivery and cleaning system on butterfat, protein, lactose, total solids and solids non-fat content are shown in Table 6.8. The solids non-fat content in milk from farms that used pouring methods of milk delivery was higher than milk from farms that utilised the gravity method ($P < 0.05$). Farms that had the automatic cleaning systems had higher total solids in milk compared to farms that used manual cleaning methods ($P < 0.05$)

. 6.4 Discussion

Dairy farmers are not only paid based the volume of milk produced but also on the quality of milk. In most countries farmers are paid a premium based on the content of the major physio-chemical components of milk such as protein and butterfat. Farm housing physical state and milking practices can influence the physico-chemical characteristics (water, protein, fat, lactose and solids-non-fat) of milk. Poorly constructed and maintained housings features such as doors, walls, ventilation, fly-proofing, and floors may contribute to contamination of milk.

Table 6.8: Effect of method of milk delivery and cleaning system on butterfat, protein, lactose, total solids and solids non-fat content in milk

	Butterfat (%)	Protein (%)	Lactose (%)	Total solids (%)	Solids Non-Fat (%)
Milking Method delivery					
Pouring	4.1 ± 0.18 [a]	3.2 ± 0.07 [a]	4.3 ± 0.09 [a]	11.9 ± 0.39 [a]	16.7 ± 0.09 [a]
Gravity	3.9 ± 0.23 [ab]	3.2 ± 0.09 [ab]	4.6 ± 0.10 [b]	13.3 ± 0.48 [b]	14.1 ± 0.15 [b]
Pump	3.5 ± 0.16 [c]	3.1 ± 0.07 [b c]	4.6 ± 0.08 [b c]	12.1 ± 0.36 [a]	15.0 ± 0.15 [b c]
Machine Cleaning System					
Electobrain	3.1 ± 0.45	3.0 ± 0.22	4.6 ± 0.23	11.9 ± 1.09 [a]	14.2 ± 2.05
Automatic circulation	4.4 ± 0.45	3.2 ± 0.17	4.5 ± 0.19	13.9 ± 0.89 [a]	16.6 ± 0.14
Manual Cleaning	3.9 ± 0.10	3.2 ± 0.04	4.4 ± 0.04	12.0 ± 0.21 [ab]	15.1 ± 1.05

Values in the same column with different superscripts differ (P<0.05).

Understanding the effect of farm physical state in milking parlours on the resultant physio-chemical characteristics will assist regulatory agents on how best to assist the farmers to improve their milking systems and to raise awareness on the importance of repair and maintenance of the farm housing features.

It is possible that the finding that fresh milk from farms that had bulk tank rooms with ceilings, ventilation, floors and walls in good physical state had higher protein content compared with farms that had poorer physical state could be attributed to easy of cleaning in such bulk tank rooms. As observed in Chapter 5, well maintained ceilings, ventilation, floors and walls possibly harbour less extraneous or foreign materials that can contaminate milk during milking. Contamination of milk from bacteria due to poor hygiene contributes to reduction of protein in milk (Petlane *et al.,* 2013). It is likely that those farms with poor physical state of ceilings, ventilation, floors and walls could have reduced protein content in milk. Similarly, as found in Chapter 5, ceilings that are low and doors that are cracked and made of rough or wooden material are difficult to clean can harbour dirt, dust and mould which can contaminate milk which may reduce the content of protein milk due to proteolytic enzyme activities.

It is possible that the elevated levels of TS in milk from bulk tank rooms in poor physical state of walls, ventilation and floors could be because unwanted foreign matter or contaminants gained access into the milk causing the resultant total solids in milk to be high. As seen in Chapter 5, milk could have been contaminated by physical contaminates tracked into the facility through air, people or equipment causing the total solids to be high. This suggests that maintaining milking facility housings in good physical state minimises the risk of contaminating milk with unwanted physical or biological contaminants.

The finding that butterfat and protein in milk from dairy farms with milking parlours and washrooms that had good door, ventilation, and fly-proofing physical state was higher than those in poorer physical state could attributed to housing features such as doors being easier to clean and harbour less physical and bacteria contaminates. In the previous chapter we observed that poor ventilation hinders clean air circulation and increases the risk of contaminating the milk with extraneous matter. It is likely that the physical and bacteria contaminants that arose from poorly maintained doors, ventilation and fly-proofing may have reduced the content of butterfat and protein in milk. Protein or butterfat being be altered in quality due by poor control of temperature in the milking facility, or physical and bacteria contaminates that cause increased activity of lipolytic and proteolytic enzymes in milk (Sakar, 2016).

The finding that washrooms and milking parlours with doors and ventilation in good physical state had lower TS and SNF in milk compared with farms that had milking parlours and washrooms with poorer physical state, indicated that less extraneous material entered milk when these features are well maintained. According to Holah (2014), building features such as doors and service provision elements such as ventilation can act as portals for entry of micro-organisms, chemical and physical contaminates and extraneous matter into milk. It is likely that, due to poor construction or failure to maintain milking facilities doors and ventilation, resulted in foreign matter contaminating the milk, causing the elevated levels of total solids.

The finding that the butterfat and protein content in milk from commercial dairy farms was much higher compared with milk from small scale dairy farms could be attributed to the use better and improved dairy breeds and feeds by the commercial farmers. It is likely that because of poor nutrition and lack of good quality feeds used by the small-scale dairy sector the resultant milk protein and butterfat in milk would be low. As supported by Masama *et al.* (2015) who observed that poor nutrition negatively affected quality of milk produced by small-scale farmers. Also, the commercial dairy farmers aggressively selected for milk protein and fat content when choosing breeds they use at the farms unlike some of the small -scale farmers that use mixed breeds

The finding that the butterfat, protein and lactose content in milk from farms that utilised hand milking was higher than dairy farms that used machine milking is supported by Sarkar (2016), who reported that milking technique, method of milking and milking machine disinfection and handling all decrease the physico- chemical quality of milk. This could imply that hand milking process is gentler than machine milking and therefore causes less disruption of milk components such as butterfat and protein (Sarkar 2016)

The finding that butterfat and protein was lower in fresh milk from farms that had dirty milking buckets and hand washing basins compared with farms that had clean milking buckets and hand washing basins agrees with previous research by Sant'anna and Paranhos da Costa (2011), which reported that dirty milking utensils and poor disinfection of milking equipment increases contamination of milk from bacteriological and physical contaminants that will decrease the butterfat and protein content of milk. The bacteria will come from dirt, manure or different forms of soiling on farm milk handling equipment (Kelly *et al.,* 2009; Sant'anna and Paranhos da Costa, 2011). Similarly, unhygienic conditions, poor cleaning and disinfection of milking utensils and equipment have been reported to decrease the content of butterfat and protein in milk due to increased activity of lipolytic and proteolytic enzymes (Yuen *et al.,* 2012; Sarkar, 2016).

6.5 Conclusions

Farm housing physical state, method of milking and farm equipment cleaning systems affects butterfat, protein, lactose, total solids and solids non-fat content in milk. Commercial dairy farms produced milk with higher protein and butterfat content than small-scale dairy farms. The butterfat, protein and lactose content in milk from dairy farms with wash room, bulk tank rooms and parlours with doors, floors, and ventilation in a good physical state was higher than those farms in poorer physical state. Maintaining good farm housing physical state of building features such doors, walls, floors, fly-proofing and ventilation possibly reduces the risk of contamination of milk from physical and bacterial contaminants, which may cause a reduction in physico-chemical characteristic of milk. Basing on the conclusion that farm housing and equipment can be a source of milk contamination during milking and, thus, affect milk quality, it can be inferred that the physical state of milk processing facilities can be a source of contamination during milk processing. In order to make recommendations on maintaining quality and safety throughout the milk value chain, it is important to ascertain the effect of milk processing housing physical state on safety of milk products.

6.6 References

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Chapter 7: Effect of physical state of milk processing house, biosecurity practices and quality assurance systems on *Escherichia coli* and coliforms presence in cultured buttermilk

Abstract

The study investigated the effect of physical state of milk processing house, biosecurity practices and quality assurance systems on *Escherichia Coli* (*E. coli)* and coliform presence in cultured buttermilk. Milk records collected by Dairy Services Unit (DSU) from large-scale dairy milk processors (n =12) and small-scale farms (n = 15) were analysed. Binomial logistic regression was used to estimate probability of E. coli or coliforms being present in buttermilk from large-and small-scale milk processors. A higher proportion (> 70%) of small-scale milk processors did not have disinfection, rodent control and access control for milk processing facilities as routine biosecurity practice. Butter milk from processors with poor disinfection practices were 2.5 times more likely to be contaminated by *E. coli* (P < 0.05). The likelihood of buttermilk from processors with buildings, processing and packaging areas that had drains, roofs, fly-proofing and windows in poor physical state having *E. coli and* coliforms was two times higher than those whose facilities were in good physical state (P < 0.05). Milk processors that used unfiltered water were 1.77 times more likely to produce buttermilk contaminated with *E. coli (*P < 0.05). Processors with quality assurances systems or food safety training were twice more likely to produce buttermilk contaminated by *E. coli* and coliforms (P < 0.05). Poor physical state of roofs, windows, fly-proofing and drainage in small-and large-scale processing facilities results in production of buttermilk that contaminated by *E. coli* and coliforms. buttermilk produced by large-and small-scale processors.

Key words: buttermilk, biosecurity coliforms, *E. coli*, housing physical state, processors

7.1 Introduction

Milk is a concentrated dietary source of macro- and micronutrients often consumed as fresh milk or processed milk products. Milk products commonly consumed include yoghurt, ghee, ice-cream, butter, cheese and cultured buttermilk (SNV, 2012; Moffat *et al.,* 2016). Findings in Chapter 3 showed that cultured buttermilk is one of the most commonly produced and consumed milk products because it does not require high levels of expertise or processing equipment as compared to the other dairy by-products (SNV, 2012; Chapter 3). Cultured buttermilk is fermented milk that has been produced through culturing milk with live beneficial bacteria (Parekh *et al.,* 2017). In most developing countries buttermilk is predominantly sold through the informal sectors (Chapter 3). While cultured buttermilk has been traditionally produced by registered large-scale processors, there has been increase in the number of small-scale processors who mainly supply the buttermilk to the informal sector (SNV, 2012). As discussed in Chapter 3, some of these informal milk processors may not necessarily have the food safety systems in place that can assure quality of buttermilk produced and sold (Chapter3). As a result, consumers are at risk of consuming potentially contaminated buttermilk.

As the informal milk processors continue to increase, milk products such as buttermilk are made under unsanitary conditions (Bereda *et al.,* 2012; Negash *et al.,* 2012). The informal milk processors may not always have the equipment, refrigeration, facilities and at times lack the expertise to manufacture buttermilk safely as reported in chapter 3.

Safe milk processing requires that processors follow strict biosecurity practices in order to minimise risk of contamination of processed products. Most processors may not have biosecurity and quality assurance systems within their operations. This could be because of lack of knowledge or understanding of why biosecurity measures should be implemented at the processing site. These practices include limiting and controlling access of people, equipment and vehicles into the processing plant. Biosecurity measures such as rodent control, disinfection and cleaning, fly-control, dust and air management, chemicals and waste disposal reduce the risk of introduction of *E. coli* and coliforms into processing facilities. Use of unclean processing equipment and lack of potable water in some facilities, may increases the risk of contamination of milk with coliforms and E. coli which will affect the quality of buttermilk (Yuen et al., 2012; Sakar, 2016). As reported in Chapter 5 and 6, doors, roofs, ventilation and floors in poor physical state can harbour extraneous or foreign materials that can contaminate milk or milk products.

Although most milk processors encourage workers to follow strict standards of hand hygiene, there are other often-overlooked sources of hygiene related contaminations of milk processing plants. As reported in chapter 5, doors, floors, walls and windows in bad physical state results in high TBC and SCC in raw milk. It is highly likely that such doors, floors, walls and windows can also result in increased bacterial contamination of buttermilk during processing. As observed in Chapter 5, door, floors, walls and/or windows that are broken or made of rough material can be difficult to clean and, thus, can be a hub of bacteria due to dust accumulation, vermin accumulation and holding moisture. *E. coli* and coliforms occur in dust, faecal matter, dirt and unsanitary conditions (Gran *et al.,* 2003). Bacteria harboured in accumulated dust and moisture can, thus, enter the buttermilk during processing through mist splashing that occurs during cleaning with pressure pipes. Poor ventilation may result in condensation in the rooms. Condensate on the equipment or building features may get in contact with buttermilk being processed, thus, transmiting pathogenic bacteria such as *E. coli*. It is possible that clean milk produced at the farm can be contaminated by the processor during production of milk products like buttermilk.

Implementation of food safety management systems such as hazard analysis critical control point (HACCP) during buttermilk processing has the potential to reduce contamination of milk from E. coli and coliforms. This study will act as tool of awareness that can assist dairy agents and regulators to continue enforcing the need for processor housing conditions to be maintained in excellent physical state to minimise risk of transmitting pathogenic organisms like *E. coli*. The microbial quality of processed milk is a major feature in determining quality. For processed milk products like buttermilk, the presence or absence of coliforms indicates safety of buttermilk for human consumption (Yuen *et al.,* 2012). The presence of pathogenic bacteria such as *E. coli* not only degrades milk quality but poses a serious health threat to consumers.

Whilst, the dairy sector has made significant efforts in promoting use of HACCP systems to eliminate pathogenic bacteria, *E. coli* continue to be enumerated from fresh and fermented milk products like buttermilk. *E. coli* poses a huge challenge to the dairy sector because of its ability to survive very low pH, yet pathogenic organisms like *S. aureus* can be destroyed at pH 5 (Gran *et al.,* 2003; Chimuti *et al.,* 2016). Poor hygiene and physical state of housing can be attributed to the presence of faecal coliforms in processed milk (Yuen *et al.,* 2012). Yet most studies conducted on reducing coliforms in manufacturing environments have focused more on the general milk processing environment and not specifically the contribution of housing conditions or state of repair and maintenance of building features. As reported in Chapters 4 and 5, elevated levels of bacteria and coliforms have been attributed to contamination of milk from the cows from dirty teats, udders and tails of cows, milking equipment and poor worker's hygiene (Chapter 4; Chapter 5 and Ellis *et al.,* 2007). The objective of the current study was to determine the effect of physical state of milk processor housing, biosecurity and quality assurance systems on presence of *Escherichia Coli* and coliforms in cultured buttermilk from large- and small-scale processors. It was hypothesised that physical state of milk processor housing, biosecurity and quality assurance systems have no effect on the presence of *E. coli* and coliforms in cultured buttermilk from large- and small-scale processors.

7.2 Materials and Methods

7.2.1 Study site

Data were obtained from records collected by trained technical officers at Dairy Services Unit from 12 large-scale dairy processors and selected 15 small-scale milk processors. Table 7.1 shows the identities of location, climatic conditions and the number of processors from each province.

7.2.2 Data collection

Records on presence or absence of *E. coli* and coliforms in buttermilk were collected from DSU in the Department of Veterinary Services Zimbabwe. Records were generated from buttermilk samples submitted to and analysed by DSU over a 10-year period from 2006 to 2016 for 12 small-scale and 15 large-scale farms milk processors in Manicaland and Mashonaland provinces. Processors submitted their buttermilk samples for testing to DSU once a month. Each processor provided four samples every month over the 10-year period. A total of 12 960 buttermilk samples were sent for laboratory analyses over the 10-year period. The physical state of housing at the milking processing factories was collected three times a year by trained DSU technical officers. These officers worked in close collaboration with senior lecturers and professors.

Table 7.1: Climatic conditions and the number of large scale or small-scale milk processors used in the study

Processing type	Location	N	Coordinates	Altitude	Mean Annual rainfall (mm)	Mean Annual Temperatures (ºC)
Large scale	Mashonaland Central	3	16.7644° S, 31.0794° E	1319	850	21.3
	Mashonaland East	6	18.5872° S, 31.2626° E	1026	789	19.4
	Mashonaland West	2	17.4851° S, 29.7889°E	1216	838	20.2
	Manicaland	1	18.9216° S, 32.1746° E	1756	1133	18.6
Small scale	Mashonaland Central	4	16°4554°S 31°34.30°E	1211	812	20.8
	Mashonaland East	5	19.0742° S, 31.1624° E	1037	789	19.4
	Mashonaland West	2	18.1380° S, 30.1474° E	1196	838	20.2
	Manicaland	3	20.0330° S, 32.8708° E	1648	1123	18.6

Source: Meteorological Services of Zimbabwe

Standardised checklists and recording sheets were used to assess biosecurity practises, presence of food safety management systems and physical state of floors, roof, drains, doors, ventilation and walls of the processing houses. To assess biosecurity practices used the technical officers assessed the presence of clear signage, dust proofing, disinfection and rodent control, site drainage, storage of chemicals and control of traffic, people and equipment into the milk processing facilities

The physical state of milk processing housing and facilities were classified as either good or poor by inspectors as described in Section 5.2.2 All milk processors were assessed on the availability of quality assurance and food safety system such as Hazard Analysis Critical Control Points (HACCP). The data recorded included presence or absence of a traceability systems for raw materials of inputs used in manufacturing buttermilk, product recall and withdrawal system for defective or non-conforming products, availability quality assurance and food safety training programmes, training documentation and manuals.

7.2.3 Data structure and preparation

Data obtained from DSU were a merger of data collected from routine dairy factory visits and laboratory data into a single database. Incomplete and mismatching records were excluded from the final analyses. Out of the 12 960 records on *E. coli* and coliforms from the buttermilk samples sent for laboratory analysis, 4 301 records had complete and matching entries with physical state of housing and management practices data.

7.2.4 Laboratory analyses

Buttermilk samples for coliform counts and *E. coli* determination were collected using sterile 50ml containers and stored in below 4^{0}C then analysed by DSU at Aglabs using the standard method of examination of dairy products (Wehr and Frank, 2004). Presence or absence of coliforms in buttermilk were determined using the plate count method (Wehr and Frank, 2004). One millilitre of milk was cultured directly on petrifilm dishes and incubated at 35-37° C for 24 hours. All bacterial cells were read using an automatic colony counter. The bacteria present in buttermilk were expressed as the number of colony forming units per millilitre (CFU/ml).

7.2.5 Statistical analyses

All data were analysed using Statistical Analysis System 9.2 (SAS, 2008). A chi-square test was used to determine the association between the processor and physical state of processing housing (SAS, 2008). The data were tested for normality. Binomial logistic regression (PROC LOGISTIC) was used to estimate the probability of *E. coli* or coliforms being present in buttermilk (SAS, 2008). The logit model fitted physical state of processing house features (poor vs good), type of processor (small-scale vs large scale), biosecurity measures (presence vs absence) and quality assurance systems (absence vs present) as the predictors. The logit model used was:

$\text{Ln}\,[P/(1-P)] = \beta_0 + \beta_1X_1 + \beta_2X_2\ldots + \beta_tX_t + \varepsilon$

Where:

P = probability of buttermilk having *E. coli* or coliforms;

$[P/(1-P)]$ = odds ratio (the odds of buttermilk having *E. coli* or coliforms);

β_0 = intercept;

β_1X_1 = regression coefficients of predictors;

ε = random residual error.

7.3 Results

7.3.1 Biosecurity practices

Majority (more than 60 %) of large-scale milk processors had clear biosecurity signage at their processing facility while less than 30% of small-scale producers had clear signage ($P < 0.01$). A large proportion (> 80 %) of large-scale processors had dust proof surroundings of their buildings as compared to % for small scale processors ($P < 0.05$). A larger proportion of small-scale milk processors (more than 70 %) did not have disinfection, rodent control and access control for milk processing facilities, whilst more 60 % of large-scale processors had disinfection, rodent control and good access control for processing sites ($P < 0.05$). About 60 % of large-scale milk processors had good drainage around milk processing sites, compared with 40% of small-scale processors who had good drainage ($P < 0.05$). More than 50 % of both small scale and large-scale processors had acceptable storage for hazardous chemicals ($P > 0.05$).

7.3.2 Physical state of milk small- and large-scale processing housing

Associations between physical state of milk processing housing physical state and processing type are shown in Table 7.2. Majority of large-scale processors (more than 75 %) had buildings with walls, gutters, drainage and windows in good physical state whilst about 45 % of small scale processors had milk processing building in good physical state ($P < 0.05$). Larger proportion (>90%) of small-scale processors had milk reception areas in poor physical state and not closed, compared to large-scale processors ($P < 0.01$). More than half of the small-scales processors had processing areas with poor physical state of walls, ventilation, drains, ceilings and windows. Less than half of large-scale processors had floors in packaging rooms that were in good physical state, whilst 50% of small-scale processors had floors in good physical state. More than double the number of small-scale processors had milking processing areas with poor physical state of walls ($P < 0.05$). The higher proportion (>70 %) of both small-scale and large-scale processors had poor temperature control in storage rooms. More than 65% of the small-scale processors had poor ventilation and walls in the storage room whilst less than half the number of large-scale processors has good ventilation in storage rooms.

7.3.3 Biosecurity practices and buttermilk contamination

The odds ratio estimates of buttermilk having E. coli or coliforms are shown in Table 7.3. Buttermilk from processors with poor disinfection practices was 2.5 times more likely to have *E. coli* compared with those with good disinfection practices ($P < 0.05$).

Milk processors with poor fly proofing were 1.3 times more likely to produce buttermilk that contained E. coli when compared with those with good fly-proofing systems ($P < 0.05$). The likelihood of buttermilk from processors with buildings that had good fly-proofing having coliforms was 1.8 times higher than those with poor fly-screening ($P < 0.01$). Buttermilk from processors with poor drainage was at least 1.25 times more likely to have E. coli and coliforms compared with those with good drainage facilities in their milk processing housing ($P < 0.05$)

7.3.4 Association between physical state of processor housing and E. coli *presence in buttermilk*

The odds ratio estimates of buttermilk from processors with different housing physical state (poor vs good) having *E. coli* is shown in Table 7.4. Milk processors with buildings and processing areas with windows in poor state were twice more likely to produce buttermilk

Table 7.2: Frequencies (%) of physical state of processing housing features of small scale and large-scale dairy processors

	Areas	**Large-scale processors**		**Small-scale processors**		Significance
		Good	Poor	Good	Poor	
Buildings	Outer Walls	82.1	17.9	47.2	52.8	**
	Gutters	71.4	28.6	58.3	41.7	NS
	Roofing	75.0	25.0	44.4	55.6	*
	Windows	78.6	21.4	41.7	58.3	**
Milk reception						
	Closed	57.4	42.6	5.6	94.4	**
	Water	53.7	46.3	22.2	77.8	*
	Drainage	50.0	50.0	22.2	77.8	*
	Foot bath	53.6	46.4	11.1	88.9	**
Processing						
	Walls	53.7	46.3	36.1	63.9	*
	Ventilation	50.0	50.0	41.7	58.3	NS
	Floors	50.0	50.0	33.3	66.7	NS
	Ceilings	42.8	57.2	50.0	50.0	NS
	Drains	50.0	50.0	44.4	56.6	NS
	Windows	46.4	53.6	41.7	58.3	NS
Packaging						
	Walls	42.8	57.2	33.3	66.7	NS
	Ventilation	64.3	35.7	31.6	69.4	**
	Floors	39.3	60.7	50.0	50.0	NS
	Ceilings	50.0	50.0	55.6	44.4	NS
	Drains	64.3	35.7	38.9	61.1	*
	Windows	53.6	46.4	33.3	66.7	NS
Storage						
	Temperature Control	28.6	71.4	27.8	72.2	NS
	Ventilation	46.4	53.6	30.6	69.4	NS
	Walls	42.9	57.1	27.8	72.2	NS

**P < 0.01; *P < 0.05; NS - P > 0.05

Table 7.3: Odds ratio estimate, lower (LCI) and upper confidence interval (UCI) of buttermilk from processors having E. coli or coliforms

Predictors	*Escherichia coli*			‡Sig.	Coliforms			Sig.
	Odds	LCI	UCI		Odds	LCI	UCI	
Type of processor	1.18	1.43	3.22	*	1.29	0.46	3.62	NS
Clear signage	0.98	0.31	3.08	NS	0.47	0.15	1.48	NS
Dust proofing	0.25	0.04	1.30	NS	2.17	0.50	9.45	NS
Disinfection	2.5	1.53	12.1	*	0.56	0.13	2.47	NS
Fly-proofing	1.33	1.37	5.2	*	0.56	1.14	2.33	**
Drainage	1.27	0.52	0.91	*	1.36	1.41	4.27	*
Access and traffic control	0.43	0.12	1.54	NS	1.08	0.302	3.83	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$.

Higher odds ratio estimates indicate greater difference in likelihood of presence of *E. coli* contaminated with *E. coli* (P < 0.05). The likelihood of buttermilk from processors with buildings with good roofs having *E. coli* was 1.01 times higher than those with poor roofs (P <0.05). Buttermilk from processors with enclosed milk reception areas was 2.04 times more likely to have *E. coli* compared with those facilities that had open milk reception areas (P < 0.05). The likelihood of buttermilk from processors with unfiltered water having *E. coli* was 1.77 times higher than those with clean filtered water for washing equipment and cleaning the processing facilities (P < 0.05). Milk processors with poor drainage systems were 1.11 times more likely to produce buttermilk contaminated with *E. coli* (P < 0.05).

7.3.5 Association between processor housing physical state and coliform presence in buttermilk

The odds ratio estimates of buttermilk from processors with different housing physical state (poor vs good) having coliforms are shown in Table 7.5. The likelihood of buttermilk from processors with buildings with poor roofs having coliforms was 1.25 times higher than those with good roofs (P < 0.05). Buttermilk from processors with buildings that had poor windows were 1.33 times more likely to have coliforms compared with those buildings with good windows (P < 0.05). The likelihood of buttermilk from processors with enclosed milk reception area having coliforms was 2 times higher than those with open milk reception areas (P < 0.05). Milk processors with poor ventilation in processing areas were 1.8 times more likely to produce buttermilk contaminated with coliforms. Buttermilk from processors with packaging rooms that had poor windows and ventilation in poor state were 1.7 times more likely to have coliforms compared to those packaging rooms with good ventilation and windows.

7.3.6 Association between presence of quality assurance systems and presence of E. coli and coliforms in buttermilk

The odds ratio estimates of buttermilk from milk processors with different quality assurance systems (absent vs present) having E. coli or coliforms is shown in Table 7.6. Milk processors without quality assurance systems like HACCP in place were 2.6 times more likely to produce buttermilk contaminated with *E. coli* ($P < 0.05$). The likelihood of buttermilk from processors without product recall and withdrawal systems having *E. coli* and coliforms was 1.1 times higher than those processors with products recall and withdrawal procedures ($P < 0.05$). Buttermilk from processors without food safety training programmes were 2.08 times more likely to have coliforms compared with those processors with food safety training programmes ($P < 0.05$). Milk processors without food safety training programmes were 1.27 times more likely to produce buttermilk contaminated with *E. coli* ($P < 0.05$).

7.4 Discussion

Understanding the importance of housing physical state, biosecurity and quality assurance systems for milk processing factories and plants enables both dairy service agents and milk processors to put in place structures and systems that minimise contamination of the processed milk products such as buttermilk. It is possible that clean milk produced at the farm can be contaminated by the processor.

The finding that a higher proportion of small-scale milk processors did not have disinfection,

Table 7.4: Odds ratio estimate, lower (LCI) and upper confidence interval (UCI) of buttermilk from processors with different housing physical state (poor vs good) having *E. coli.*

Area	Predictor	Odds	LCI	UCI	Sig.
Buildings	Outer walls (poor vs good)	3.64	0.81	16.33	NS
	Gutters and pipes (poor vs good)	1.34	0.34	5.25	NS
	Ceiling (poor vs good)	0.99	1.21	4.61	*
	Windows (poor vs good)	2.02	1.44	9.28	*
Milk reception	isolation (enclosed vs open)	2.04	1.07	3.23	*
	Washing water (unfiltered vs filtered)	1.77	2.16	3.68	*
	Drainage (poor vs good)	1.11	0.84	0.57	*
	Footbath (absent vs present)	0.43	0.04	4.3	NS
Processing area	Walls (poor vs good)	3.03	0.93	9.96	NS
	Ventilation (poor vs good)	0.89	1.32	3.13	*
	Floors (poor vs goods)	0.72	0.21	2.49	NS
	Drains (poor vs good)	0.422	0.03	5.55	NS
	Windows (poor vs good)	2.32	2.04	5.01	*
Packaging	Walls (poor vs good)	1.04	0.28	3.8	NS
	Ventilation (poor vs good)	0.53	0.11	2.59	NS
	Floors (poor vs good)	1.14	0.36	3.63	NS
	Ceilings (poor vs good)	1.56	0.44	5.52	NS
	Drains (poor vs good)	3.03	0.87	11.1	NS
	Windows (poor vs good)	1.21	0.27	5.39	NS
Storage	Temperature (poor vs good)	1.08	0.25	4.73	NS
	Ventilation (poor vs good)	0.45	0.13	1.58	NS
	Walls (poor vs good)	2.65	0.69	10.21	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$. Higher odds ratio estimates indicate greater difference in likelihood of presence of *E. coli*.

Table 7.5: Odds ratio estimate, lower (LCI) and upper confidence interval (UCI) of buttermilk from processors with different housing physical state (poor vs. good) having Coliforms.

Area	Predictor	Odds	LCI	UCI	Sig.
Buildings	Outer Walls (poor vs good)	0.68	0.17	2.72	NS
	Gutters and pipes (poor vs good)	0.92	0.24	3.43	NS
	Ceiling (poor vs good)	1.25	1.18	3.59	*
	Windows (poor vs good)	1.33	3.31	5.75	*
Milk reception	Closed (enclosed vs open)	2.01	1.03	3.13	*
	Washing water (unfiltered vs filtered)	0.30	0.05	1.83	NS
	Drainage (poor vs good)	0.52	0.05	5.39	NS
	Footbath (absent vs present)	0.28	0.01	4.2	NS
Processing	Walls (poor vs good)	2.39	0.65	8.69	NS
	Ventilation (poor vs good)	1.82	1.24	2.70	*
	Floors (poor vs good)	2.09	0.66	2.49	NS
	Drains (poor vs good)	1.20	3.11	12.75	*
	Windows (poor vs good)	1.33	0.14	12.46	NS
Packaging	Walls (poor vs good)	2.61	0.69	9.9	NS
	Ventilation (poor vs good)	1.70	1.23	5.32	*
	Floors (poor vs good)	2.98	1.01	3.57	*
	Ceilings (poor vs good)	0.71	0.19	2.63	NS
	Drains (poor vs good)	0.46	0.11	1.78	NS
	Windows (poor vs good)	1.71	1.14	4.68	*
Storage	Temperature control (poor vs good)	2.46	0.59	10.34	NS
	Ventilation (poor vs good)	1.00	0.29	3.46	NS
	Walls (poor vs good)	2.09	0.53	8.1	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant ($P > 0.05$), *$P < 0.05$. Higher odds ratio estimates indicate greater difference in likelihood of presence of coliforms.

rodent control and access control for milk processing facilities as routine biosecurity measures was expected. It is likely that most small-scale processors lack knowledge and understanding of the importance of biosecurity practices in prevention of introduction and transmission of pathogenic organisms in dairy processing facilities (FAO, 2007).

The finding that buttermilk from processors with poor disinfection practices were more likely to have *E. coli* compared with those that had good disinfection practices may be a possible indication that these processors may have been utilising infective disinfectants following poor disinfection procedures for personnel and equipment. Yuen *et al. (*2012) reported that *E. coli* contamination of milk can occur when workers practice poor hygiene and sanitation procedures (Yuen *et al.,* 2012). Similarly, buttermilk manufactured under unsanitary conditions will be expected to be contaminated.

The finding that milk processors with buildings and processing areas with windows in poor state were more likely to produce buttermilk contaminated with *E. coli* could be a result of introduction of *E. coli* from dust through dust blown into the processing facilities through windows in poor state of repair or physical state. As observed in Chapters 5, poor maintenance and physical state of building features such as windows promote the introduction of contaminants into the facility. In agreement with this, several authors concur that *E. coli* can be transmitted through polluted air (Coorevits *et al.,* 2008; Pantoja et al., 2011; Sarkar, 2016).

The finding that buttermilk from processors with enclosed milk reception areas were twice more likely to have *E. coli* compared with those facilities that had open milk reception areas

Table 7.6: Odds ratio estimate, lower (LCI) and upper confidence interval (UCI) of buttermilk from milk processors with different quality assurance systems (absent vs present) having E. coli or coliforms

Predictors	E. coli			Sig.	Coliforms			Sig.
	Odds	LCI	UCI		Odds	LCI	UCI	
Quality system in place (HACCP)	1.98	2.24	3.88	*	1.97	0.41	8.89	NS
Traceability	0.95	0.04	1.30	NS	0.57	0.09	3.4	NS
Product withdrawal and recall system	1.10	1.01	1.62	*	1.14	1.02	2.39	*
Availability of food safety training programmes	1.27	1.02	2.52	*	2.08	1.41	7 .27	*
Availability of documentation and quality manuals	0.44	0.15	2.74	NS	1.79	0.302	2.58	NS

LCI- Lowest confidence interval, UCI-Upper confidence interval, Sig-Significance, NS- Not significant (P > 0.05), *P < 0.05.
Higher odds ratio estimates indicate greater difference in likelihood of presence of *E. coli* or coliforms.
Hazard Analysis Critical Control Point (HACCP).

was unexpected, because open milk reception areas tend to have higher traffic of people or equipment and the chances of bacteria contaminating is higher. Contrary to this finding, enclosed milk reception areas are better and enable restricted movement of equipment, people and air into the processing unit (FAO, 2007).

The finding that the likelihood of buttermilk from processors with unfiltered water having *E. coli* was higher than those with clean filtered water for washing equipment and cleaning the processing facilities maybe because unfiltered water is contaminated with *E. coli*. It is likely that installation of water treatment and filtration facilities reduces the contamination of water by *E. coli*, unlike unfiltered water that is most likely to harbour different pathogenic bacteria. In agreement to the finding, Chatterjee et al. (2006) reported that milk can be contaminated from polluted water sources.

The finding that milk processors with poor drainage systems were likely to produce buttermilk contaminated with *E. coli* could be because of introduction of pathogenic bacteria found in stagnated water around the processing facility that may be tracked into the factory or processing area through workers, air and/or equipment. The presence of coliforms in milk and processed products generally indicate that milk has been contaminated from faecal material, ineffective cleaning processes of machinery and equipment or milk originated from cows with subclinical mastitis (Gemechu, 2016). The finding that the likelihood of buttermilk from processors with buildings with poor physical state of roofs having coliforms was higher than those with good physical state of roofs, suggests that roofs that are in poor physical state are difficult to clean and thus harbour dust and bacteria which can contaminates buttermilk during processing. The same reason can be attributed to the observation that buttermilk from processors with buildings that had poor windows was more likely to have higher levels coliforms in buttermilk compared with those buildings with good windows (Chapter 5).

Buttermilk from processors with enclosed milk reception area was more likely to have coliforms than that from processors with open milk reception areas possibly because open milk reception areas are exposed to dust and debris. The debris and dust, thus, can be easily introduced into the processing area through the open reception area. Sakar (2016), reported that coliforms can be introduced into milk from unsanitary environments or processing conditions.

The finding that processors with windows in poor physical state and poor ventilation in processing areas and packaging rooms were more likely to have coliforms compared to those packaging rooms with good ventilation and windows reinforces our observation in chapter 5 and 6 that poor ventilation hampers the circulation of clean air, thereby increasing the risk of contaminating milk and its products with bacteria or undesirable physical contaminants during production (Holah, 2014).

The finding that milk processors without quality assurance systems like HACCP in place were twice more likely to produce buttermilk contaminated with *E. coli* could possibly be attributed to lack of knowledge or understanding of the importance HACCP by milk processor. In agreement with Garedew *et al. (*2012) and Sarkar (2016) implementation of HACCP systems during dairy milk processing results in improvement in the microbial quality of milk products. Milk processors that have no food safety systems can fail to identify or overlook some steps that have potential to introduce or increase the risk of milk contamination during processing (FAO, 2007; Meyerson, 2002).

The finding that buttermilk from processors without training programmes were more likely to have coliforms compared with those facilities without food safety training programmes could suggest that training provides processors with knowledge and information of food safety principles, which they can use to reduce transmission of bacteria such as *E. coli* in their dairy products. In a study by Mhone *et al.* (2011) milk and milk products from small-scale dairy enterprises with good access to training and monitoring programmes were reported to have lower counts of coliforms, *E. coli* and *S. aureus* (Mhone *et al.*, 2011). Training milk processors on food safety and the importance of management of housing physical state may be important in minimising the risk of contamination of buttermilk from pathogenic bacteria such as *E. coli*. Similarly, studies conducted on fermented milk by Gran et al. (2002) and Chimuti et al. (2016) confirmed that presence of E. coli in fermented milk products could be attributed to poor hygiene during processing and the lack of knowledge and training in food safety systems.

7.5 Conclusions

Buttermilk produced by both small-scale and large-scale milk processors contains coliforms and *E. coli*. Poor physical state of windows, doors, roofs and ventilation in processing facilities increased the risk of buttermilk contamination by coliforms and *E. coli*. Those milk processors without food safety systems such as HACCP and that lacked food safety training programmes were more likely to have coliforms and *E. coli* in buttermilk they produced compared with those that had food safety systems and food safety training programmes in place.

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Chapter 8: General discussion, conclusions and recommendations

8.1 General discussion

The study explored the importance of physical state of farm housing and milk processing facilities on milk quality and safety. The main hypothesis tested was that that physical state of farm housing and milk processing facilities influence the quality and safety of milk and its products. The hypothesis was formulated on scientific reports that building parts such as roof, doors, windows and floor harbours bacteria due to dust accumulation, vermin accumulation and holding moisture (Holah, 2014). Milk or by-products become contaminated when it comes into contact with condensate or dust arising from these features, as well as from equipment and people during handling and processing of milk. Bacterial counts in raw milk affects nutritional quality of processed dairy products (Murphy *et al.*, 2016).

The hypothesis tested in Chapter 3 was that perceptions of consumers located in urban and non-urban areas on quality and safety of cultured buttermilk and fresh milk purchased from different outlets did not differ. Choice of food is generally associated with place of residence due to differences in culture, beliefs and resource availability. Our results confirmed that households from non-urban locations preferred fresh milk from vendors. Our observation could be attributed to fact that the informal markets of milk are more pronounced in the non-urban locations. Households from urban settings may not always consume fresh milk frequently because they can easily access other substitutes to fresh milk available on the market such as soya milk and powdered milk. Buttermilk produced by the large scale commercial processors was often consumed by most households in urban settings may be as result of having easier access to these products in urban dwellings as compared to the non-urban settings. Dairy products such as yoghurt are mainly processed in urban areas and the products are perishable, transporting them to non-urban settings is a challenge and is costly for the consumers. Due to high number of dairy farms in non-urban settings, milk vendors tend to purchase milk directly from nearby farms and then go around on their bicycles or scotch carts selling to consumers in neighbouring towns. Milk is easily accessible to households that may not have transport to go to the local townships or bigger supermarkets in the urban areas. Consumers in both the urban and non-urban locations preferred to purchase milk from kiosks and vendors, because it was cheap and convenient to do so and, this route of accessing products cannot be completely disregarded since most people are resource poor and thus price of milk is an important consideration. Thus, consumers need to be informed and educated about milk safety and quality, especially when accessing such products from the informal milk marketing sector so that their decisions are not limited to price or convenience only.

In Chapter 4, the hypothesis tested was that perceptions of milk quality and safety of large- and small-scale farmers differ. Farmers' perceptions on factors affecting milk quality differed with milk production system. It was observed that the large-scale and older farmers who had more years of experience in dairy farming considered hygiene to be an important factor affecting milk quality. The production of high bacteriological quality of milk is positively correlated with maintenance of hygienic standards in the milking facilities during milking (Chassagne *et al.*, 2005; Wenz *et al.*, 2007). Farmers' perceptions might have been influenced by the facts that small-scale farmers' lack of access to good transportation modes and road network facilities. Most of the small-scale farmers transport their milk on foot, scotch carts, bicycles and public transport. It is possible that milk quality will deteriorate because of the distance and time it takes to reach the processor, due to lack of adequate cooling facilities. Yet for most large-scale farmers, milk is bulk transported in refrigerated trucks with good temperature control mechanisms. Large-scale farmers ranked udder diseases as the main cause of milk spoilage while the small-scale farmers ranked milking environment as the biggest source of contamination. Possibly, small-scale farmers did not have sufficient knowledge on the effects of udder diseases on milk quality. Both large-scale and small-scale farmers ranked personnel as the least cause of spoilage, indicating that personnel hygiene as a source of milk spoilage has been well researched and corrective measures have been implemented. Farmers, thus, are confident with their personnel's hygiene but did not necessarily have the same level of confidence with other players in the milk supply chain like transporters or processors. Small-scale farmers were more concerned about the milk quality in absence of the individualised milk quality testing as done in commercial farms because adulteration of milk by one small-scale farmer can easily affect others in the consortium. The large-scale farmers considered milk safety to be important, which demonstrated that they were not just interested in pushing milk volumes but safety of the milk they produce for human consumption.

Chapter 5 assessed the effects of farm housing and milking practices on bacteriological quality of cow milk. The hypothesis tested was that farm housing and milking practices do not affect somatic cell counts and total bacteria counts in milk from large- and small-scale farms. It was observed that most of both large-scale and small-scale farms had ceilings, fly-proofing, windows and doors in poor physical state and dirty hand washing basins could be the reason for the observed increased TBC and SCC in milk in recent years. Although farmers concentrate on ensuring hygiene of their milking personnel as indicated by their perceptions in Chapter 4, they overlooked the physical state of ceilings, fly-proofing, windows and doors of the milking houses. Bacteria usually come from the environment such as air, dirty equipment, vermin and dust. Ceilings, which are too low, difficult to clean and dark coloured, can be sources of bacterial contamination. Doors and windows made of rough material, which are difficult to clean can also be a hub of bacteria due to dust accumulation, vermin accumulation and holding moisture. Poor ventilation hinders clean air circulation and promotes condensation and, thus, bacterial contamination. Fly infestations in the milking area also increases bacterial counts in milk hence farms with no fly-proof had high TBC and SCC. It was observed that visual cleanliness or good physical state of the milking parlour did always correlate to lower bacterial counts. The TBC in milk from dairy farms with milking parlour that had ceilings and door in good physical state was higher than those farms with milking parlour in poor physical state while those farms with wash room with poorer physical state had much lower TBC and SCC. The reason could have been that, workers may not always clean the properly those doors, window and ceilings that are in good physical state yet for the farms with in poorer physical state they might have been putting more effort in cleaning out the dirt. The TBC in milk from farms that used manual methods of milk delivery was higher than milk from farms that utilized the pump method. It is possible that, they are more chances of contaminants being introduced into the milk during manual delivery when compared with closed and automatic milk pumping systems. With direct pumping of milk there is minimal handling and reduced risk of contamination from the environment. On the other hand, farms that had the automatic cleanings system had much lower TBC and SCC in milk compared to farms that used hand washing cleaning methods. The automatic cleaning system is more efficient and effective at removing dirt compared to hand cleaning.

In Chapter 6, the hypothesis tested was that farm housing and milking practices affect physico-chemical characteristics of milk. Farm housing physical state affected the physico-chemical characteristics (water, protein, fat, lactose and solids-non-fat) of milk. It was observed that farms that had bulk-tank rooms, milking parlours and washrooms with good physical state of windows, ventilations, doors and fly-proofing had higher protein and butterfat contents in milk compared to those in poorer physical state. As discussed in chapter 5, building features such a doors, windows, floors and ventilation are all excellent portals of bacteria and physical contaminants that can affect milk quality (Chapter 5). Those features made of rough material that is difficult to clean can also be a hub of bacteria due to dust accumulation, vermin accumulation and holding moisture as reported in Chapter 5. The TS and SNF were observed to be higher in farms that had poorer physical state of ventilation and windows. Butterfat and protein content in milk from large-scale dairy farms was much higher compared with milk from small-scale dairy farms possibly because most large-scale use better and improved dairy breeds and feeds compared to small-scale farmers. Contents of butterfat and protein were lower in farms that had dirty milking buckets, wash basins possibly because of the increased activity of lipolytic and proteolytic enzymes in milk which could have entered the milk through use of unsanitary utensils.

In Chapter 7, the hypothesis tested was that physical state of milk processor housing, biosecurity and quality assurance systems have no effect on the presence of *E. coli* and coliforms in cultured buttermilk from large- and small-scale processors. It was observed that a larger proportion of small-scale milk processors did not have basic biosecurity procedures that minimised transmission of pathogenic organisms into the processing facilities possibly because of lack knowledge and understanding of the importance of biosecurity in the prevention of the introduction and transmission of pathogenic organisms in dairy processing facilities (FAO, 2007). Like observation made in Chapter 5 and 6, housing physical state were associated with the presence of absence of *E. coli* in milk. In this chapter, processors with buildings, processing and packaging areas that had poor physical state of drains, roofs, fly-proofing, windows were more likely to be produce buttermilk contaminated by *E. coli* and coliforms compared with than those facilities in good physical state. Drains, roofs, wall and windows in poor physical state harbours microbes due to dust accumulation, vermin accumulation and holding moisture and these can easily be spread onto already cleaned milk contact areas during processing. Unfiltered water is most likely to be contaminated by pathogenic bacteria, therefore the use of unfiltered water by processors increased likelihood of buttermilk produced by those who did not use filtered water to be contaminated with E. coli and coliforms. Processors without quality assurances systems or food safety training were more likely to produce buttermilk contaminated by *E. coli* and coliforms because of lack of knowledge and poor compliance with food safety standards.

8.2 Conclusions

The households from urban settings preferred to milk from kiosks whilst non-urban dwellers preferred purchasing fresh milk from vendors and farms because it was cheap and convenient. Considering that consumers prefer buying milk and its products straight from the farm and informal milk marketing systems (kiosks and vendors), it is important to ensure that these outlets meet quality assurance standards for dairy products. Farmers perceptions to milk quality differed with milk production system. Small-scale dairy farmers perceived that contamination during milking was mainly due to the milking environment whilst large-scale farmers consider udder diseases to be the most important. Small-scale farmers were less concerned about milk safety. The management of farm housing physical state affected total bacterial counts and somatic cell counts in milk. The TBC and SCC in milk from dairy farms with wash room that had doors, floors, walls and ventilation in a good physical state were higher than those farms with wash room with poorer physical state. Farms that had the automatic milking cleanings system had much lower TBC and SCC in milk compared to farms that used hand washing cleaning methods. Poor physical state of windows, doors, roofs and ventilation in milk processing facilities increased the risk of buttermilk contamination by *E. coli*, coliforms and physical contaminants which compromised the quality of and safety of products produced. The physical state of processing facility housing, lack of food safety systems and training contributed to the presence of coliforms and E. coli in buttermilk produced by large-and small-scale processors

8.3 Recommendations and further research

Understanding the perceptions of consumers and farmers on milk quality and safety is critical in driving the future direction of the dairy industry. Policy makers and dairy service organisations need to put in place interventions and awareness programmes that educate people on the risks associated with producing and consuming contaminated dairy products. A policy brief can be developed from this study, which will highlight minimum food safety requirements for clean milk production and processing. Farm and processors housing physical state affect the bacteriological and physico-chemical characteristics of milk. It is important that farmers, processors implement procedures that ensure quality and safety of milk and by-products during handling, storage and process. Training of milk processors on food safety enables them to implement systems that reduce risk of contamination from *E. coli* and other pathogenic bacteria, thus improving the quality of milk products made.

Aspects that require further research include:

1. Determining the perceptions and willingness of consumers to pay extra for organic milk or other non-dairy milk products made from soyabean, almond, pea or rice milk which can be used as milk alternatives.
2. Determining the influence of hygiene on quality and safety of cheese, yoghurt and milk ice-cream.
3. Isolating, identifying and characterising micro-organisms present in fermented milk products produced in Zimbabwe.

4. Assessing the constraints that limit adoption of food safety systems in large-and small-scale dairy farms
5. Investigating farm and processing strategies that minimise recontamination of milk and/ by-products with pathogenic bacteria such as *Listeria monocytogenes* and *Staphylococcus aureus*.
6. To design or develop minimum infrastructural requirements for the processing of milk which can be adopted by regulators to improve food safety issues

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ORIGINAL ARTICLE

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Household consumption preferences of dairy products and their perceptions of milk safety

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Abstract

The study investigated consumer perceptions of milk safety and consumption preferences of dairy products. Households randomly selected from urban areas (n 5 135) and non-urban areas (n 5 135) were surveyed using semi-structured questionnaires. An ordinal logistic regression was used to estimate probability of households preferring to consume particular milk products and that of milk safety knowledge being important to households. Urban households were 2.8 times more likely to consume fresh milk ($p < .05$). Households from urban areas were two times more likely to purchase fresh milk from the kiosks, while households from non-urban areas were five times more likely to buy fresh milk from vendors. The likelihood of appearance, quality and nutritional value of milk products being important to households was higher in urban locations compared to non-urban locations. Consumers prioritized price and convenience over milk safety. Knowledge and awareness of milk safety issues was more important to urban households.

Practical applications

Understanding consumption preferences and consumer perceptions enables regulatory agencies, policy-makers, and the dairy industry to make informed decisions and to put in place awareness programs on the risks of purchasing potentially contaminated milk through informal markets.

1 | INTRODUCTION

World milk production has been growing at approximately 3% per year in recent years (Food and Agriculture Organization [FAO], 2015). Meanwhile, the demand for milk and dairy products has been growing at an average rate of 4% per year (FAO, 2015). As a result of the increase in population and per capita consumption, the demand for milk and dairy products worldwide is expected to continue rising (Coetzee, 2015). Slow growth in milk production has been attributed to economic hardships, frequent droughts, extreme temperatures, and cli-mate change. The effects of economic hardships on milk production are more pronounced in developing countries. For example, in Zimbabwe, overall milk production dropped from 260 to 50 million lit-ers per annum between 1980 and 2012 (Stichting Nederlandse Vriwilligers [SNV], 2012). The decline was associated with the herd depletion that was exacerbated by the land reform program.

The transformation of the Agrifood industry of developing coun-tries in the 1980s resulted in the formalization of a greater percentage of milk and milk product suppliers (Reardon, Barrett, Berdegue, & Swinnen, 2009).

Continuous increase in the demand of milk and milk products, coupled with slow increase in milk production has, however, resulted in vast changes in the dairy industry. The emergence and growth of the informal dairy sector is being witnessed in most develop-ing countries (Ndambi, Hemme, & Latacz-Lohmann, 2007). Small scale businesses, middlemen and milk vendors are taking advantage of the market gap to produce and process dairy products such as fresh milk, yoghurts, cheese, and buttermilk through the informal milk marketing channels. Unfortunately, most of these products are unregistered (SNV, 2012). The number of informal milk suppliers continue to rise in devel-oping countries (Kilelu et al., 2017).

The informal milk marketing system involves producers selling their milk products such as fresh milk, yoghurt, and cultured buttermilk directly to the consumers or indirectly through vendors (Ndambi et al., 2007). Predominant dairy products in the informal market are fresh milk and cultured buttermilk (SNV, 2012). Production and marketing of cheese and yogurt is low, probably due to the high expertise that is required in processing such products (Gebreselassie, Abrahamsen, Beyene, & Narvhus, 2012). Cultured buttermilk is fermented milk obtained through culturing milk with live beneficial bacteria (Parekh, Balakrishnan, Hati, & Aparnathi, 2017). In the informal sector in devel-oping countries, cultured buttermilk is usually made by churning natu-rally fermented sour milk in containers (Gebreselassie et al., 2012).

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Some of the milk and cultured buttermilk is transported in cans on foot, by donkeys, or using scotch-carts, on wheelbarrows or via public transport (Moffat, Khanal, Bennett, Thapa, & George, 2016). These modes of transportation are characterized by lack of hygiene standards and thus, subjecting the fresh milk and cultured buttermilk to physical contamination, adulterants, and bacterial contamination (Makoni, Mwai, Redda, Zijpp, & Van Der Lee, 2014). As a result, fresh milk and cultured buttermilk from the informal market puts the consumers at risk of infections.

Challenges faced by most of the informal, small, and medium scale dairy enterprises include lack of equipment and refrigeration facilities, insufficient knowledge, and skills in hygienic practices and lack of expe-rience in processing dairy products (Moffat et al., 2016). The informal and unregulated nature of the marketing structures in these dairy enter-prises may compromise quality of the dairy products. It is possible that milk from such channels may be adulterated or compromised in quality. In most cases, milk safety standards are not followed (Nada, Ilija, Igor, Jelena, & Ruzica, 2012). Despite these concerns, there is no information on the quality of dairy products produced in the ever-growing informal, small, and medium scale dairy enterprises. Since some of these pro-ducers may not be registered, it is difficult for government agencies and/or experts to advise and monitor the dairy producers. In some cases, farmers deliver their milk to Milk Collection Centres [MCCs] where their milk is pooled (Javaid et al., 2009). The pooling poses a chal-lenge as potentially clean milk can be mixed with contaminated milk.

Assessment of the safety of dairy products forms the basis of intervention programs to ensure production of safe milk that provide protection to the consumers. The existence of many informal and unregulated selling outlets such as kiosks (tuckshops and small corner shops) in both urban and non-urban residences poses yet another chal-lenge as these selling outlets may not meet quality assurance standards for dairy products. There is need to assess perceptions of consumers on safety of dairy products from informal and unregulated selling out-lets as a starting point the intervention programs.

Perceptions of consumers on food safety from different outlets in urban settings may differ from those in rural environments (Weatherell, Tregear, & Allinson, 2003). In developing countries, resource-limited households who rely on subsistence farming live in rural settlements and may have limited access to facilities such as electricity or refrigerators. Against this background, the objective of the study was to com-pare perceptions of urban and non-urban consumers on quality and safety of cultured buttermilk and fresh milk. It was hypothesized that perceptions of consumers located in urban and non-urban areas on sources of contamination, quality and safety of cultured buttermilk and fresh milk from different outlets are different.

2 | MATERIALS AND METHODS

2.1 | Study site

Data were collected from households residing in urban and non-urban areas of Bindura, Mazowe, and Harare districts in December 2016. The residential areas located around the central business district (CBD) were elected to represent urban settlements and non-urban settlements included households outside the city and those located in the rural areas. Bindura and Mazowe districts are situated at 17.30138 S, 31.31988 E. and 17.20048 S, 30.98768 E, respectively. Agricultural practices in the districts consist of field crops, vegetables, and extensive livestock production. Commercial, small-scale, and cooperative dairy production are pronounced in these districts. Harare district is situated at 17.82528 S, 31.03358 E. The main agricultural industries include live-stock production, peri-urban farming and horticulture with a few commercial dairy farms located near urban parts of Harare.

2.2 | Sampling procedure and data collection

Four focus group discussions with at least four key informants each and a trained interviewer were used to develop a structured questionnaire. Stratified random sampling was used to select respondents for the focus group discussions (agricultural extension officials, informal milk traders, small scale milk producers, and local farmer organizations). The information gathered from the focus group discussions was used to construct the structured questionnaire. Face validity of the questionnaire was established by comparing the questions with theoretical con-structs and expectations. The questionnaire was then pilot tested on 10 randomly selected households. Face-to-face interviews conducted by trained enumerators using the structured were then conducted on urban (n 5 135) and non-urban (n 5 135) randomly selected house-holds. One member (aged 18 years or above) of each of the households was randomly selected for the interview. Respondents aged 30 years and below were regarded as young (UNDESA, 2014).

The questions on the survey included socio-demographic and eco-nomic characteristics, milk consumption patterns, location where milk is purchased, perceptions on milk safety, knowledge, and awareness of food safety systems. Households were also asked to rank their pre-ferred outlets for purchasing dairy products. The study was granted the ethical clearance certificate AREC/080/016D by the University of KwaZulu-Natal's Research Ethics Committee.

2.3 | Statistical analyses

Data were analyzed using Statistical Analysis System 9.2 (SAS, 2008). Preliminary analysis of data showed that effect of city was not significant and thus classification was based on residency type urban versus non-urban. Chi-square tests were computed to determine the association between location and gender, age, household size, level of education, and household income.

Descriptive statistics and frequency distributions for categorical variables were used to describe the data. Ordinal logistic regression was used to model the determinants of dichotomous variables (preference of a particular milk product; purchasing of a particular milk product from a particular outlet; considering milk safety knowledge and awareness being important). The ordinal logistic regression (PROC LOGISTIC) model was used to estimate the probability of households preferring to consume particular milk products, the probability of a household purchasing a particular milk product from a particular outlet and the probability of milk safety knowledge and awareness being important to households. The logit model fitted predictors, gender, location (urban; non-urban), age and household size. The logit model used was;

Ln½P=12P&5b01b1X11b2X2 . . . 1btXt1E

Where;

P 5 probability of households (preferring to consumer particular milk product; purchasing a particular milk product from a particular out-let; considering milk safety knowledge and awareness being important)

[P/1 2 P] 5 odds of a household (preferring to consumer particular milk product; purchasing a particular milk product from a particular out-let; considering milk safety knowledge and awareness being important);

b0 5 intercept;

b1X1. . .btXt 5 regression coefficients of predictors; E

5 random residual error.

3 | RESULTS

3.1 | Socio-demographic characteristics

The socio-demographic characteristics of respondents in urban and non-urban areas are shown in Table 1. The majority of the participants were females. More than 70% of respondents in both urban and non-urban areas were adults aged over 30 years. Less than 20% of the respondents in both urban and non-urban areas had no formal education. More than 50% of urban households had high monthly income. The majority of non-urban dwellers had low monthly income.

3.2 | Consumption patterns of fresh milk and cultured buttermilk

The odds ratios of households preferring to consume fresh milk to cultured milk products are shown in Table 2. Households from the urban locations were 2.8 times more likely to consume fresh milk compared to their non-urban counterparts. Those aged over 30 years were three times more likely to consume fresh milk than the respondents below the age of 30.

The odds ratios of households purchasing fresh milk, buttermilk from straight from the farm, vendors, kiosks, and supermarkets are shown in Table 3. Households from urban areas were two times more likely to purchase fresh milk straight from the farms and kiosks, while households from the non-urban areas were five times more likely to purchase fresh milk from vendors. Males were two times more likely to purchase fresh milk straight from the farms. Young respondents were three times more likely to buy fresh milk from the supermarkets and females were two times more likely to purchase fresh milk from the supermarkets. Households from non-urban areas were two times more likely to buy buttermilk from vendors. Young respondents were two times more likely to buy buttermilk from the supermarkets.

3.3 | Importance of milk product characteristics

The odds ratio estimates of characteristics of milk products being important to households are shown in Table 4. The likelihood of

TABLE 1 Socio-demographic characteristics of the respondents

	Frequency (%)		
	Urban	Non-urban	Chi-square test (v^2)
Gender			ns
Males	48.2	47.1	
Female	51.8	52.9	
Age			ns
Young (30years)	17.3	27.4	
Old (30 years)	82.7	72.6	
Household size			ns
Small (4 people)	29.1	36.9	
Large (4 people)	70.9	63.1	
Level of education			ns
No formal education	8.2	17.9	
Primary school	21.8	30.8	
Secondary school	44.5	38.5	
Tertiary	25.5	12.8	
Household monthly income		*	
Low (< 250 USD)	41.2	56.9	
High (>500 USD)	58.8	43.1	

ns 5 not significant (p > .05); *p < .05.

appearance, freshness, quality, taste, nutritional value, and availability being important to households during selection of milk product was higher in urban areas compared to non-urban locations. The odds ratio estimates ranged from 2.83 to 6.75 for these attributes. The likelihood of packaging being considered important did not differ with location. For all the attributes, size of the household did not make significant difference to preference or purchase of milk products. Females were two times more likely to consider nutritional value as being important. Respondents aged over 30 years were five times more likely to con-sider the presence of labels as being an important characteristic when purchasing dairy products.

3.4 | Reasons for purchasing fresh milk and cultured buttermilk

Frequencies of reasons for purchasing fresh milk and cultured butter-milk from the various selling outlets are shown in Table 5. The majority

TABLE 2 Odds ratios estimates, lower (LCI) and upper confidence interval (UCI) of households preferring fresh milk to cultured buttermilk

Predictor	Odds	LCI	UCI	Significance
Location (urban vs. non-urban)	2.84	1.53	5.29	*
Gender (male vs. female)	1.02	0.57	1.82	NS
Age (old vs. young)	3.39	1.67	6.87	*
Household size (large vs. small)	1.39	0.72	2.68	NS

Note. Higher odds ratio estimates indicate greater difference in prefer-ence levels of predictors.
LCI 5 lowest confidence interval; UCI 5 upper confidence interval;
Sig 5 significance; NS 5 not significant (p > .05), *p < .05.

TABLE 3 Odds ratio estimates lower (LCI) and upper confidence interval (UCI) of households purchasing fresh milk and cultured buttermilk from different selling outlets

		Fresh milk				Buttermilk			
Outlet	Predictors	Odds	LCI	UCI	Sig	Odds	LCI	UCI	Sig
Straight from farm	Location (urban vs. non-urban)	2.64	1.40	5.00	*	0.92	0.36	2.36	*
	Gender (male vs. female)	1.75	1.00	3.20	*	1.59	0.59	4.32	NS
	Age (young vs. old)	0.62	0.29	1.34	NS	0.17	0.02	1.33	NS
	Household size (small vs. large)	0.90	0.46	1.78	NS	1.05	0.34	3.21	NS
Vendors	Location (urban vs. non-urban)	0.21	0.10	0.44	*	0.46	0.26	0.80	*
	Gender (male vs. female)	1.25	0.59	2.63	NS	1.20	0.67	2.15	NS
	Age (young vs. old)	0.62	0.24	1.59	NS	0.44	0.20	0.96	*
	Household size (small vs. large)	1.49	0.65	3.39	NS	1.37	0.71	2.65	NS
Kiosks	Location (urban vs. non-urban)	2.07	1.17	3.66	*	1.24	0.64	2.38	NS
	Gender (male vs. female)	0.95	0.55	1.64	NS	0.97	0.51	1.86	NS
	Age (young vs. old)	1.47	0.77	2.82	NS	1.11	0.51	2.41	NS
	Household size (small vs. large)	0.89	0.48	1.66	NS	0.89	0.43	1.86	NS
Supermarket	Location (urban vs. non-urban)	0.53	0.24	1.15	NS	0.63	0.29	1.39	NS
	Gender (male vs. female)	0.42	0.18	0.96	*	0.71	0.32	1.59	NS
	Age (young vs. old)	3.67	1.55	8.67	*	2.47	1.01	6.04	*
	Household size (small vs. large)	0.71	0.29	1.76	NS	0.59	0.23	1.53	NS

Note. Higher odds ratio estimates indicate greater difference in preference levels of predictors.
LCI 5 lowest confidence interval; UCI 5 upper confidence interval; Sig 5 significance; NS 5 not significant (p > .05), *p < .05.

(> 40%) of households from urban areas who bought fresh milk from the farm did so because it was convenient. More than 50% of the urban households who bought fresh milk from the kiosks said it was because it was cheap. About 34% of households from urban locations who bought fresh milk from supermarkets did so because it was perceived to be safe for consumption. The majority (> 50%) of non-urban households who bought buttermilk from vendors and kiosks did so because it was cheap. Forty-five percent of households from non-urban areas who bought buttermilk from supermarkets did so because of the perception that it has a longer shelf life. The majority of the urban households who bought buttermilk straight from the farm did so to avoid paying extra for packaging, while more than 60% of those who bought buttermilk from vendors was because it was cheap.

The majority (> 50%) of the households in non-urban areas who purchased fresh milk from the vendors and kiosks did so because it was cheap. More than 60% of the non-urban households who bought butter milk straight from farms were because it was convenient to do so. Conversely, the households from the non-urban locations who

TABLE 4 Odds ratio estimates of characteristics of milk products being extremely important to households

Predictors	Location (urban vs. non-urban areas)				Gender (male vs. female)				Age (young vs. old)				Household size (small vs. large)			
Characteristics	Odds	LCI	UCI	Sig	Odds	LCI	UCI	Sig	Odds	LCI	UCI	Sig	Odds	LCI	UCI	Sig
Appearance	4.29	1.48	12.41	*	1.39	0.60	3.21	NS	0.96	0.40	2.30	NS	0.59	0.24	1.44	NS
Freshness	3.72	1.76	7.87	*	1.37	0.71	2.62	NS	0.59	0.28	1.23	NS	0.62	0.31	1.25	NS
Quality	4.49	2.22	9.52	*	1.23	0.65	2.32	NS	0.49	0.24	1.02	NS	0.65	0.32	1.31	NS
Taste	5.14	2.37	11.14	*	1.34	0.69	2.57	NS	0.72	0.33	1.61	NS	1.08	0.52	2.26	NS
Nutritional value	6.75	2.69	16.94	*	0.50	1.24	1.42	*	0.81	0.35	1.87	NS	0.66	0.28	1.50	NS
Brand name	2.08	0.96	4.51	NS	0.73	0.36	1.49	NS	0.59	0.26	1.36	NS	0.78	0.35	1.75	NS
Availability	2.83	1.26	6.37	*	1.26	0.61	2.63	NS	0.58	0.25	1.32	NS	0.72	0.32	1.64	NS
Packaging	2.89	0.94	8.84	NS	0.75	0.33	1.69	NS	0.71	0.29	1.73	NS	1.42	0.57	3.54	NS
Presence of labels	2.37	0.38	14.95	NS	0.73	0.28	1.92	NS	0.29	0.10	0.85	*	1.03	0.40	3.00	NS
Environmental friendliness	2.33	0.53	10.22	NS	0.49	0.19	1.24	NS	1.29	0.51	3.31	NS	1.01	0.37	2.77	NS

Note. Higher odds ratio estimates indicate greater difference in preference levels of predictors.
LCI 5 lowest confidence interval; UCI 5 upper confidence interval; Sig 5 significance; NS 5 not significant (p > .05), *p < .05.

TABLE 5 Frequencies (%) of reasons for purchasing fresh milk and cultured buttermilk from different outlets

		Urban				Non-urban			
Milk product	Reasons	Farm	Vendors	Kiosk	Super market	Farm	Vendors	Kiosk	Super market
Fresh milk	Convenient	43.5	20	28.9	21.1	57.9	29.0	30.2	16.7
	Cheap	17.4	40	57.8	0	26.3	51.1	55.8	0
	Avoid paying for extra packaging	15.2	20	6.7	0	0	0	2.3	0
	Variety	15.2	1	4.4	33.3	1.9	12.9	11.6	16.7
	Safe for consumption	0	0	0	34.4	6	3.2	0	16.7
	Long shelf life	6.5	0	2.2	2.5	5.2	0	0	45.8
	No reason	2.2	19	0	8.7	2.6	3.2	0	4.2
Buttermilk	Convenient	0	9.5	30.4	27.3	61.5	22.2	20.8	6.8
	Cheap	7.7	67.2	34.8	27.3	15.4	53.3	40.2	1.8
	Avoid paying for extra packaging	41.3	9	4.4	0	0	2.2	1.5	0
	Variety	46.1	0	17.4	9.1	7.7	8.9	8.3	12.6
	Safe for consumption	4.9	0	0	27.3	7.7	4.4	4.2	47.1
	Long shelf life	0	0	4.4	0	0	4.4	12.5	21.8
	No reason	0	14.3	8.7	9.1	7.7	4.4	12.5	9.9

purchased buttermilk from the supermarkets did so because it was considered to have a longer shelf life while others had no specific reason.

3.5 | Perceptions of consumers on sources of milk contamination

Mean rank scores of consumer perceptions on sources of milk contamination are shown in Figure 1. The ranking of sources of contamination differed with location. In non-urban areas, bacteria were ranked highest, followed by physical contaminants then chemicals ($p < .05$). In urban locations, physical contaminants were ranked highest ($p < .05$).

3.6 | Milk safety knowledge and awareness

The odds ratio estimates of milk safety knowledge and awareness being important to households are shown in Table 6. Households from urban locations were twice more likely to consider knowledge and awareness of milk safety issues being important. The likelihood of milk safety knowledge and awareness being important was 2.9 times higher for the large households compared to the smaller ones. The likelihood of safety of manufacturing environment being considered important did not differ with location. Respondents from the urban areas were two times more likely to consider traceability being important when buying milk products compared to the non-urban counterparts. Males

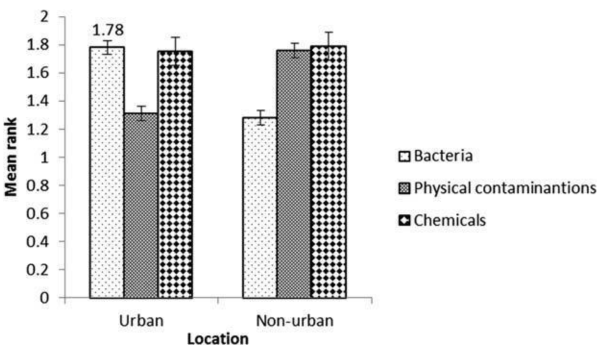

FIGURE 1 Mean rank score of consumer perceptions on sources of milk contamination from urban and non-urban locations

were twice more likely to consider the awareness and knowledge of ingredients in milk products being important when purchasing dairy products. The likelihood for knowledge and awareness of milk product ingredients being important was 3.9 times higher for the young compared to the old.

4 | DISCUSSION

Understanding the perceptions of consumers on milk quality and safety will assist policy makers and dairy service organizations to put in place interventions and awareness programs that educate consumers on the risk of buying potentially contaminated dairy products. Consumers need to be informed and educated about milk safety and quality, especially when accessing such products from the informal milk marketing sector so that their decisions are not limited to price or convenience alone. The participants in the study were almost equally distributed, in terms of gender, in both urban and non-urban locations.

The finding that households from the non-urban locations preferred consuming fresh milk to cultured buttermilk is in agreement with findings by Weatherell et al. (2003) who reported that choice of food is associated with place of residence. This could also be attributed to accessibility and differences in prices. Dairy products such as yoghurt are mainly processed in urban areas (SNV, 2012) and the products are perishable, transporting them to non-urban areas is a challenge. If transported to non-urban areas, the dairy products will be expensive due to transport costs and reduced supply. Some non-urban house-holds do not have refrigeration facilities to store dairy products for longer periods of time before these products go off. Moreover, in non-urban areas, consumption of products such as yoghurt and buttermilk is sometimes considered as a luxury. The finding that older people were more likely to consume fresh milk tallies with findings by Weatherell et al. (2003). This could be because old people think that fresh milk is healthy (Mitsostergios & Skiadas, 1994).

The findings that the households from non-urban locations more likely to buy fresh milk from the vendors indicates that informal mar-kets of milk are more pronounced in the non-urban locations. Because

Oddsratioestimatesofmilksafetyknowledgeand awareness being important to households TABLE6

Predictors Component / Location(urbanvs. non-urban areas) OddsLCI UCI Sig / Gender (male vs. female) Odds LCI UCI	Sig	Age (youngvs. old) Odds	LCI	UCI	Sig	Household size (small vs. large) Odds	LCI	UCI	Sig
0702 19 97 49 96Milksafetyknowledge2.1.4.*0.0.1.	NS	920.	430.	961.	NS	350.	170.	720.	*
Manufacturingenvironmentsafety1.0.1. NS 1. 0. 2.01670478653	NS	0.57	0.29	1.05	NS	0.74	0.41	1.34	NS
2107 59 08 51 2Traceability2.1.4.*1.0.2.	NS	741.	760.	014.	NS	591.	710.	593.	NS
Ingredientsinmilk0.0. 1. NS 2. 1. 5.8038360420938	*	3.89	1.72	8.79	*	0.91	0.38	2.19	NS
4519 01 47 21 03Labellinganddeclaration0.0.1.NS0.0.1.	NS	211.	510.	872.	NS	471.	640.	383.	NS

Note.Higheroddsratioestimatesindicategreaterdifferencein preference levels of predictors.5555 >*LCIlowestconfidenceinterval;UCIupperconfidenceinterval;Sigsignificance;NSnotsignificant(p .05). *p<.05.

of the high number of dairy farms in non-urban areas, Milk vendors tended to purchase milk directly from the nearby farms and then go around on their bicycles or ox drawn carts selling to the consumers or neighboring towns (SNV, 2012). This makes milk to be easily accessible to households who may not have transport to go to the local townships or bigger supermarkets. On the other hand, the majority of urban consumers also bought buttermilk from the vendors because it was cheap and these vendors come into the urban locations to retail their products. The findings that young females from urban locations were more likely to buy fresh milk and buttermilk from the supermarkets is consistent with results from studies by Weatherell et al. (2003) who reported that a majority of consumers prefer to purchase their food from supermarkets as their first choice. The adult males in this study were more likely to purchased fresh milk straight from the farms. Similarly, Van fleet and Van Fleet (2009), reported that older males purchase food from different selling outlets without necessarily confining their purchases to the local shops. However, it is important to remain conscious of the fact that there will always be difference in perceptions and attitudes towards safety of foods depending on the consumers' previous exposure, experience, location, or demographic characteristics (Worsley & Lea, 2008).

In agreement to the finding, Van Loo, Diem, Pieniak, and Verbeke (2013) also found attributes like taste, appearance, availability, and nutritional value are important to consumers when selecting food. Surprisingly, the male respondents in our study were more likely to con-sider nutritional value to be an extremely important attribute when selecting milk products. Our expectation was that females would be the one to be most commonly concerned about the nutritive value of foods because women tend to be involved more in dieting programs and are concerned about nutritive value of foods compared to males (Van Loo et al., 2013). The reasons for this unexpected result might have been as result of the numerous health campaigns being done in the developing world and possibly the males in our study were more informed or aware of the need to pay attention to the nutrition content of milk and by products.

The majority of households both in urban and non-urban locations who purchased buttermilk and fresh milk from kiosks did so because of convenience and products being cheap, without necessarily prioritizing milk safety. The milk and milk products handling practices and the ability to control temperature may differ for all the four outlets (farm, vendors, kiosks, and supermarkets) which would in turn affect micro-biological milk quality and thus, safety (SNV, 2012). Supermarkets with monitored cold chain processes and quality assurance systems in place tend to have better control of temperatures as compared to the kiosks or traditional markets. Households in both urban and non-urban areas, however, still preferred purchasing fresh milk, buttermilk from vendors and kiosks because it was both cheap and convenient suggesting that possibly bacterial or microbial safety is, thus, not a priority for house-holds in both urban and non-urban areas. For this reason, informal marketing of milk and milk products in developing countries is likely to continue because consumers will be inclined to buy from these places due to their perceptions.

Since the majority of the consumers in both the urban and non-urban locations preferred the kiosks and vendors, because it was cheap and convenient and this route of accessing products cannot be completely disregarded since most people are resource poor and thus price of milk is an important consideration. Similarly other researchers have reported that price is an important consideration to be made when making purchases (Grebitus, Yue, Bruhn, & Jensen, 2007; Soderlund, Williams, & Mulligan, 2008; Zanoli & Naspetti, 2002). Therefore, next best alternative could be educating the informal traders on proper pro-duction and storage methods and the importance of quality assurance. The consumers also need to be educated on the risks about buying potentially contaminated milk (Swai & Schoonman, 2011). Conversely, a sizable percentage of urban households who purchased buttermilk from the farm did so because they did not want to pay for extra in packaging and they also wanted variety. This is in agreement with Yayar (2012) who reported that some consumers prefer unpacked milk because it is cheaper and can be delivered at the doorstep without the additional costs incurred for packaging. The finding that urban house-holds who buy from supermarket prefer to do so because they believe such products have a guarantee of safety and long shelf life agrees with similar findings by Weatherell et al. (2003) and Yayar (2012).

The findings that mean ranking of bacteria and physical contamination as a source of contamination of milk differed is supported by other researchers who have found that dairy products contamination can occur via microbiological, chemical, and physical means (Ellis et al., 2007). Bacteria was ranked higher in non-urban areas possibly because the participants in this study thought most the milk contamination occurs from the disease causing agents from the cow or environment. This line of thinking is supported by research that confirm that hygienic profile of milk is characterized by the contamination levels and specific distribution of micro-organisms. These levels are highly correlated to udder health and pre-milking hygiene conditions (Ellis et al., 2007). The finding that physical contamination was ranked highest in urban areas as compared to non-urban areas was unexpected. One of the leading public health hazards from poor milk safety in non-urban areas is physical contamination (Girma, Tilahun, & Haimanot, 2014). The unexpected result is possibly because non-urban areas are not aware of the presence of physical contaminants in milk. Contrary to the finding that there was no difference in perception on chemicals as source of milk contamination in both urban and non-urban areas, Novoselova, Meuwissen, Van Der Lans, and Valeeva (2002) found that majority of the consumers in their study ranked chemical contamination high and considered chemicals to have a long term detrimental health effect (Novoselova et al., 2002).

The findings that consumers from urban areas are more likely con-sider awareness and knowledge of milk safety being important tallies with the finding that they are more likely to buy milk and milk products from reputable outlets such as supermarkets. Comprehensive aware-ness efforts should be made on milk safety in non-urban areas. It may be possible that households from urban areas in our study had better access to food safety information provided through media, food manufacturers and researchers compared to the non-urban counterparts. Perception on food safety vary depending on availability of information (Rohr,€ Luddecke,€ Drusch, Muller,€ & Alvensleben, 2005). The finding that traceability of milk products was more important for the urban households could be have been influenced by their awareness on milk safety. Traceability is a way of responding to potential risks and thus, knowing how quality has assured through the whole value chain is impor-tant to the consumers. While the male respondents in our study seemed to be interested in information about milk ingredients, other authors have reported that usually females are the ones are normally concerned about heath and healthy food (Aertsens, Verbeke, Mondelaers, & Van Huylenbroeck, 2009; Van Fleet & Van Fleet, 2009).

5 | CONCLUSIONS

The households from urban areas preferred buying fresh milk from kiosks while non-urban dwellers preferred purchasing fresh milk from vendors and farms. The reasons for households preferring to buy fresh milk from kiosks, farms, and vendors was because it was cheap and convenient. Knowledge and awareness of milk safety issues, traceability and declaration of milk ingredients was more important to urban households.

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Research Article

Perceptions of Factors Affecting Milk Quality and Safety among Large- and Small-Scale Dairy Farmers in Zimbabwe

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The study investigated the perceptions of milk producers on milk quality and safety. Randomly selected large-scale farmers (= 158) and small-scale farmers (= 186) were surveyed using semistructured questionnaires. An ordinal logistic regression was used to estimate the probability of farmers considering milk quality and safety important. Large-scale farmers were 3 times more likely to consider that breed affects milk quality compared to their small-scale counterparts. Farmers aged over 30 years were 3 times more likely to indicate that hygiene affected milk quality. The likelihood of milk transportation affecting its quality was 4 times higher in small-scale farmers compared to large-scale producers. Postmilking contamination of milk was perceived to occur during transportation by small-scale farmers, whilst commercial farmers ranked storage as the important source of contamination after milking. Udder diseases were ranked first by large-scale farmers while small-scale farmers ranked milking environment as the major cause of milk spoilage. The likelihood of milk safety being important was two times higher in large farms compared to small-scale farms. Intervention programmes on milk safety should mainly target small-scale dairy farmers since they are less concerned about milk quality and safety.

1. Introduction

Dairy production plays a vital role in numerous national economies through provision of employment, food security, and sustainable income [1]. For example, in Sub-Saharan Africa, the dairy industry is a major contributor to gross domestic product. Milk and dairy products play a crucial role through provision of healthy food and balanced diets. In Sub-Saharan Africa, dairy products are easy to access as a source of nutrients compared to meat. The industry, in general, is made of different sized farms and processors ranging from small-to large-scale operations. Smallholder dairy farming refers to the economic activity of keeping dairy cows with an average herd size of less than seven (7) milking cows on less than one hectare of land [2].

Both large- and small-scale dairy farmers operate under highly uncertain production and economic environments. One of the biggest concerns of dairy farmers is the quality and safety of milk production. Failure to meet quality assur-ance standards and regulatory requirement affects both the farmers and consumers. Penalties imposed for production of poor quality milk reduce income for farmers. Consumers are exposed to potential public health threats and diseases from consumption of potentially contaminated milk sources. At the same time, farmers also face other challenges such as increased production costs, low productivity, low milk prices, lack of liquidity or capitalization, and poor input support [3]. For example, in Zimbabwe, the drop in milk production over the last decade has been attributed to liquidity crunch, small herds, and lack of cheap lines of credit [4]. The dairy industry has not been spared from the adverse effects of drought and extreme temperatures. Despite these challenges the farmers are still expected by all stakeholders to produce good quality milk that is free from microbial, physical, and chemical contamination [5].

Milk and its products are rich in nutrients and contain high moisture and neutral pH. Milk, thus, easily favours the growth and multiplication of bacteria and other disease-causing agents. Contaminated milk may cause tuberculo-sis, brucellosis, listeriosis, gastrointestinal disorders, and salmonellosis. Milk contamination can originate from differ-ent sources such as the milking environment, wind, milking equipment, feeds, soil, faeces, farm personnel, and housing [6]. Although contamination of milk can occur at various stages including during handling, during transportation or storage at farm, and during processing or at the market, most of the contamination is usually associated with the farm. Therefore, it is important to put in place sound quality control measures at the farm level.

Poor hygiene practices at the farm level have been reported to be the main cause for poor productivity and income losses for the smallholder sector [4]. Research shows that high total bacteria count (TBC) is positively correlated with unsanitary conditions associated with dirty udders before milking, inadequate or poor teat sanitation, poor cleaning and sanitation of milking equipment, and inadequate cooling of milk [5, 7]. Other elements that influence TBC include health and hygiene of the cow, housing and management, cleaning and sanitizing procedures, farm milking environment, and quality of cleaning water [8].

In most countries, there are regulatory agencies that monitor the quality of milk delivered to and processed by var-ious processors. Milk is routinely checked for TBC, somatic cell counts (SCC), fat content, protein, lactose, and solids nonfat (SNF). For example, in Zimbabwe farmers are paid a premium based on the quality of milk. Most of the small-scale dairy farmers do not have facilities for bulk milk collection due to low milk volumes produced. They deliver their milk to nearby Milk Collection Centres (MCCs) where their milk is pooled. Farmers in such cases have their premium based on the group milk quality. This means that farmers with good production systems may be disadvantaged by the poor performers. These resource poor small-scale farmers' milk quality issues are further compounded by transportation time and mode and distance to milk processors.

As the demand for safe milk and dairy products increases, the importance of an integrated approach for ensuring safety throughout the whole supply chain becomes important. To ensure production of quality milk, it is necessary to under-stand the various causes and sources of milk contamination at the farm level. T he use of food safety and quality assurance systems at the farms is important to reduce contaminants in milk and dairy products. Policy makers and regulators should be in touch with the sources of contamination of milk products so as to implement long-term planning for clean and safe milk production.

Understanding farmer perceptions and attitudes towards clean and safe milk production contributes to clean milk production practised on farms. Factors affecting consumer perceptions on general food safety are fairly well-understood [9–11]. There is limited information on dairy farmers in Sub-Saharan Africa. Given that many dynamic and complex factors affect quality of milk, it is crucial to determine those elements which the farmers are likely to consider to be important. Understanding this will not only form the basis of intervention programmes for clean milk production but also assist farmers in putting in place mechanisms that ensure safe and profitable milk production. The current study was conducted to compare perceptions of large- and small-scale farmers on milk quality and safety. It was hypothesized that perceptions of milk quality and safety of large- and small-scale farmers differ.

2. Materials and Methods

2.1. Study Site. Data were collected from dairy farmers from Mashonaland and Manicaland provinces of Zimbabwe in December 2016. Data were collected from dairy farmers from Mashonaland and Manicaland provinces of Zimbabwe in December 2016. These two provinces are in agricultural regions 1 to 3. Average rainfall in both provinces is between 600 and 1200 mm per annum. The provinces also have the largest concentration of small-scale and large-scale dairy farmers and Milk Collection Centres (MCC). Manicaland province is situated at 18.9216˚S and 32.1746˚E. Mashonaland is subdivided into three regions, namely, Mashonaland Cen-tral East and West provinces that are situated at 16.7644˚S, 31.0794˚E, 18.5872˚S, 31.2626˚E, 17.4851˚S, and 29.7889˚E, respectively. Large-scale farmers deliver the bulk of their milk to the dairy processors. The milk from small-scale farmers that is not sold directly to the public is supplied to MCCs and various processors that manufacture long life milk, pasteurised milk, cheese, cream, butter, fermented milk, buttermilk, and fruit blends. The other agricultural practices in these two provinces include intensive and extensive live-stock production, periurban farming, horticulture, and field crop production. Small-scale dairy farming involves keeping a small herd of dairy animals usually less than seven milking cows on less than a hectare of land [2].

2.2. Sampling Procedure and Data Collection. Data were generated using a survey conducted by interviewing farm-ers selected from two production systems, large-scale and small-scale farmers. A database containing all registered large- and small-scale dairy farmers, their contact details, and addresses was obtained from Dairy Services Unit Limited. A total of 156 small-scale farmers and 186 large-scale farmers were randomly selected from the database. Table 1 shows sociodemographic characteristics, mean herd size, and the number of respondents from each production system. The selected farmers were visited and interviewed by trained enumerators at their homesteads using a pretested questionnaire. The questionnaire had been pilot-tested on 14 randomly selected farmers. The survey captured aspects on sociodemographic and economic characteristics, milk production patterns, perceptions on milk safety, concerns on milk safety, and factors affecting milk quality. Sociode-mographic characteristics captured included household size, age, gender, and educational level of farmer. A farmer was considered educated if he or she had received education above primary school level. Farmers who had primary school level education or less were considered uneducated. Each farmer was asked to rank the causes of milk spoilage during milking and sources of contamination of milk postmilking. The farmers were also asked whether they are concerned or not concerned about milk safety and whether they considered milk quality important or not important. The farmers were also asked whether they thought factors such as milking

Table 1: Sociodemographic characteristics, mean herd size (±SD), and the number of respondents from each production system.

Class	Large-scale	Small-scale
	158	186
Age (%)		
Young (<30 years)	35.5	13.5
Old (>30 years)	64.5	86.5
Household size (%)		
Small (<4 people)	40.8	37.3
Large (>4 people)	59.2	67.1
Marital status (%)		
Married	8.2	50.0
Single	21.8	42.9
Divorced	44.5	6.4
Widowed	25.5	0.8
Highest education level (%)		
No formal education	16.9	19.8
Primary	33.8	17.5
Secondary	35.1	41.3
Tertiary	14.3	21.4
Cow herd size		
	184±18.7[a]	10±6.3[b]

[ab]Values with different superscripts, within a row, are different (< 0.05).

method, breed of cows, hygiene, and mode of transport affected milk quality. The study was granted the ethical clearance certificate AREC/080/016D by the University of KwaZulu-Natal's Research Ethics Committee.

2.3. Statistical Analyses. Data were analysed using Statistical Analysis System 9.2[12]. Descriptive statistics and frequency distributions for categorical variables were used to describe the data. Mean rank scores for the causes of milk contamina-tion and spoilage were determined using PROC MEANS of SAS [12]. An ordinal logistic regression (PROC LOGISTIC) model was used to estimate the probability of farmers per-ceiving specific milk quality attributes being important. The logit model tested effects of production system (large- and small-scaled), household size, age, gender, and educational level of farmer.

The logit model used was

$$\ln [\ \frac{}{1-J} = {}_{0} + {}_{11} + + {}_{22} + \quad + , \qquad (1)$$

where is probability of farmers (considering a particular factor affecting milk quality); [/1 −]are odds of farmers' households (considering milk quality important; concerned about the milk safety); 0 is intercept; 1 1 ⋯ are regression coefficients of predictors; is random residual error.

3. Results

3.1. Factors Affecting Milk Quality. The odds ratio estimates of factors affecting milk quality are shown in Table 2. Large-scale farmers were 3 times more likely to consider breed to affect milk quality, when compared with small-scale farmers. Farmers aged over 30 years were 3 times more likely to indicate that hygiene affected milk quality. Small-scale farmers were 4 times more likely to consider transport a main contributor to poor milk quality when compared to the commercial farmers.

3.2. Causes of Milk Spoilage and Source of Contamination. Table 3 shows the farmers' rankings of reasons for causes of milk spoilage during milking for large-scale and small-scale dairy farms. Whilst the large-scale farmers ranked udder diseases highest as the major cause of milk spoilage, small-scale farmers ranked milking environment as the highest contributor to milk spoilage during milking. Udder diseases were ranked second by small-scale farmers. For both, production systems personnel were considered the least cause for milk spoilage. The mean rank scores of sources of contamination postmilking are shown in Table 4. Mean rank scores of transportation and processing as sources of postmilking contamination differed with production system (< 0.01). While small-scale farmers ranked transportation as the most important source of postmilking contamination, large-scale farmers ranked it least. Storage was ranked as the most important source of postmilking contamination by large-scale farmers. The small-scale farmers considered milking machinery as the least contributor to postmilking contamination.

3.3. Milk Quality and Safety. The odds ratio estimates of farmers being concerned about milk quality are shown in Table 5. The small-scale farmers were 4.5 times more likely to be concerned about milk quality than the large-scale

Table 2: Odds ratio estimate and lower (LCI) and upper confidence interval (UCI) of farmers indicating that different factors affect milk quality.

Factor	Predictor	Odds	LCI	UCI	Sig.
	Production system (large- versus small-scale)	0.70	0.38	1.27	NS
	Gender (female versus male)	1.29	0.77	2.17	NS
Milking method	Age (young versus old)	1.56	0.83	2.96	NS
	Household size (small versus large)	1.00	0.98	1.02	NS
	Education (uneducated versus educated)	0.87	0.53	1.43	NS
	Production system (large- versus small-scale)	3.05	1.66	5.62	*
	Gender (male versus female)	0.73	0.44	1.23	NS
Breed	Age (young versus old)	1.08	0.57	2.04	NS
	Household size (small versus large)	0.99	0.97	1.07	NS
	Education (uneducated versus educated)	1.43	0.87	2.36	NS
	Production system (large- versus small-scale)	1.04	1.57	1.91	*
	Gender (male versus female)	0.83	0.49	1.41	NS
Hygiene	Age (young versus old)	0.54	0.34	0.98	*
	Household size (small versus large)	1.17	0.69	1.97	NS
	Education (uneducated versus educated)	0.74	0.45	1.23	NS
	Production system (large- versus small-scale)	0.46	0.25	0.84	*
	Gender (female versus male)	1.29	0.76	2.18	NS
Transport	Age (young versus old)	0.83	0.43	1.58	NS
	Household size (small versus large)	0.95	0.74	1.21	NS
	Education (uneducated versus educated)	0.69	0.42	1.13	NS

LCI: lowest confidence interval, UCI: upper confidence interval, Sig.: significance, NS: not significant (> 0.05), * < 0.05; higher odds ratio estimates indicate greater difference in preference levels of predictors.

Table 3: Mean rank score (ranks) for causes of milk spoilage during milking in commercial and small-scale dairy farms.

Source	Large-scale	Small-scale	Significance
Personnel	3.21 (4)	3.08(4)	NS
Containers	3.04 (3)	2.93(3)	NS
Milking environment	2.14 (2)	1.97(1)	NS
Udder diseases	1.70 (1)	2.17 (2)	**

The lower the mean rank score (rank), the more important the cause of spoilage; ** < 0.01; NS: not significant (> 0.05).

Table 4: Mean rank score (ranks) for sources of contamination postmilking in commercial and small-scale dairy farms.

When contamination occurs	Large-scale	Small-scale	Significance
Milking machinery	2.72(3)	2.79(4)	NS
Storage	2.14(1)	2.32(2)	NS
Transportation	2.79(4)	2.16(1)	**
Processing	2.29(2)	2.75(3)	*

The lower the mean rank score (rank), the more important the source of contamination; * < 0.05; ** < 0.01; NS: not significant (> 0.05).

Table 5: Odds ratios estimates and lower (LCI) and upper confidence interval (UCI) of farmers being concerned about milk quality.

Predictor	Odds	LCI	UCI	Significance
Production system (large- versus small-scale)	0.22	0.09	0.51	*
Gender (male versus female)	0.83	0.43	1.63	NS
Age (young versus old)	0.99	0.41	2.43	NS
Household size (small versus large)	0.93	0.47	1.82	NS
Education (uneducated versus educated)	1.13	0.60	2.13	NS

LCI: lowest confidence interval, UCI: upper confidence interval, Sig.: significance, NS: not significant (> 0.05), * < 0.05; higher odds ratio estimates indicate greater difference in preference levels of predictors.

Table 6: Odds ratios estimates and lower (LCI) and upper confidence interval (UCI) of farmers considering milk safety to be important.

Predictor	Odds	LCI	UCI	Significance
Production system (large- versus small-scale)	2.19	1.17	4.08	*
Gender (male versus female)	1.29	0.71	2.37	NS
Age (young versus old)	0.99	0.48	2.07	NS
Household size (small versus large)	1.12	0.61	2.05	NS
Education (uneducated versus educated)	13.61	6.79	28.80	*

LCI: lowest confidence interval, UCI: upper confidence interval, Sig.: significance, NS: not significant (> 0.05), * < 0.05; higher odds ratio estimates indicate greater difference in preference levels of predictors.

farmers. Table 6 shows the odds ratios of farmers considering the importance of milk safety. The likelihood of milk safety being important was two times higher for large-scale farmers compared to the small-scale farmers (< 0.05). Educated dairy farmers were more likely to consider milk safety important than their uneducated counterparts (< 0.05).

4. Discussion

The study was designed to explore the factors affecting milk quality and perceptions of farmers on causes of poor milk quality in large- and small-scale farms. Understanding the perceptions of farmers on milk quality and safety assists policy makers and stakeholders in the dairy industry to put in place interventions for clean, safe, and profitable milk production.

The majority of farmers in the study were adults above 30 years of age. It could be possible that fewer younger farmers are engaged in dairy farming, especially in Southern Africa. Dairy enterprises require huge capital investments for purchasing heifers, equipment, or feeds, which may not be easily available to younger farmers [5]. It is also likely that, owing to the prevailing economic hardships in most developing countries, there are few financial institutions that offer credit facilities that can be easily accessed by resource poor youth [4, 13]. Therefore, challenges hindering the youths in participating in dairying farming need to be explored.

The finding that the large-scale farmers were more likely to consider breed of cows an important factor affecting milk quality when compared to the small-scale farmers agrees with Huijps et al. [14] who reported that breed type can affect milk quality. A lot of work has gone into the selection of dairy breeds based on milk production potential and disease resistance [15]. The majority of large-scale farmers consider the breeds to use on their farms based on the resistance to diseases such as mastitis, plus other milk production characteristics. Mastitis is the most common and costly disease which can contribute to economic losses due to penalties for dairy farmers [14, 15]. The large-scale farmers preferred Jersey and Holstein, while the small-scale farmers had mixed breeds. The finding that large-scale and older farmers who had more years of experience in dairy farming considered hygiene an important factor affecting milk quality agreed with findings by several authors [5, 7, 16]. These authors reported that the production of high quality milk is positively correlated with maintenance of hygienic standards in the milking facilities and cow cleanliness during milking. Following strict hygienic standards prevents intra-mammary infections during milking and ensures lower total bacteria counts in milk [17]. The finding that the older farmers, aged over 30 years, were more likely to indicate that hygiene affected milk quality could also have been influenced by those farmers' exposure, knowledge, and experience in dairying. It is possible that over the years of being involved in dairy farming, older farmers could have seen the impact that poor hygiene has on productivity and profitability. Therefore, they could be more likely to consider hygiene as an important factor compared to the younger farmers with less dairy farming experience.

The finding that small-scale farmers considered transportation as the main contributor to poor milk quality when compared to the commercial farms could have been influenced by the fact that small-scale farmers lack access to good transportation modes and road network facilities. Most of the small-scale farmers transport their milk on foot, scotch-carts, bicycles, and public transport. [1, 4]. It is possible that milk quality will deteriorate because of the distances and time it takes to reach the processor, due to lack of adequate cooling facilities. Yet for most large-scale farmers, milk is transported in bulk in refrigerated trucks with good temperature control mechanisms. The finding that transportation was ranked highest as the major source of milk contamination by the small-scale farmers was, therefore, expected. Most small-scale farmers in this study transported their milk via public transport, commuter omnibuses, owned vehicles, and animal drawn scotch-carts.

The finding that large-scale farmers ranked udder dis-eases as the main cause of milk spoilage is supported by another researcher's finding which confirms that the presence of udder diseases such as mastitis in cows is the main con-tributor to poor milk quality as evidenced by the high level of somatic cell counts [16]. For this reason, it would be expected that farmers would rank udder diseases high. The finding that the small-scale farmers ranked milking environment as the biggest source of contamination is consistent with findings by Swai and Schoonman [6] who reported that milk spoilage will occur due to microorganisms from different sources including the animal itself and its surrounds. These microorganisms may be found in the environment arising from animal faeces, air, milking equipment, grass, soil, or the animal feed [6]. Although both large-scale and small-scale farmers ranked personnel as the least cause of spoilage, other findings indicate that that personnel cleanliness during milking and handling affects milk quality. The reason why both large-scale and small-scale farmers ranked personnel hygiene as the least source of milk contamination could be that the farmers in our study were reasonably confident with their personnel's hygiene and milking practises on farm but did not necessarily have the same level of confidence with other players in the milk supply chain like the transporters or processors. Thus, they would attribute deterioration of milk quality to handling by others in the supply chain. Contamination was therefore perceived to occur during storage or transportation. The major cause of poor milk quality for MCCs is expected to come from the use of unhygienic storage containers and during transportation [1]. Overall, the farmers' perception in this study indicates that there are many sources and causes of milk contamination.

The finding that the small-scale farmers were three times more concerned about milk quality could be attributed to the existence of penalty and premiums-based milk payment systems in developing countries. Milk quality would be a major concern as it affects profitability and the small-scale farmers are affected by milk pooling at the MCCs. In such cases farmers with good quality milk are affected by those with poor quality milk. For this reason, it was expected that the small-scale farmer would be more concerned about the milk quality in the absence of individualised milk quality testing as done in commercial farms. The adulteration of milk by one small-scale farmer can easily affect others in the consortium.

The finding that large-scale farmers considered milk safety to be important shows that the large-scale dairy farmers are not just interested in pushing milk volumes but also in the safety of the milk they produce for human consumption. The small-scale farmer may, on the other hand, prioritize the quantity of milk produced to safety. The high odds ratio estimate for the effect of education level on perceptions of milk safety can be attributed to differences in understanding of the importance and determinants of milk quality. Dairy producers who attain some level of formal education are more likely to have a better understanding on the importance and determinants of milk quality compared to the less educated. Education increases farmer's ability to obtain, analyse, and interpret milk quality issues. The lack of differences in the likelihood that small-scale and large-scale farmers consider milk quality to be important shows that although small-scale farmers are less likely to consider milk quality important, they are particular about its safety. Raw milk has been implicated for causing foodborne diseases and as a source of zoonotic bacteria such as *Campylobacter*, *Escherichia coli*, and *Listeria* [8, 18, 19].

5. Conclusions

Farmers' perceptions of milk quality differed with milk production system, though differently ranked factors, such as production system, hygiene, breed, and age of farmers, affected perceptions on milk quality. Small-scale dairy farmers perceived that contamination during milking was mainly due to milking environment, whilst commercial farmers said it was mainly due to udder diseases. Small-scale farmers were less concerned about milk safety.

Additional Points

Practical Implications. One of the biggest concerns in the dairy industry is the quality and safety of milk. Although contamination of milk can occur at various stages in the value chain, most of the contamination is usually associated with the farm. Understanding farmer perceptions on factors affecting the quality and safety of milk will not only form the basis of intervention programmes for clean milk production but also assist farmers in putting in place mechanisms that ensure safe and profitable milk production.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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Appendix 3: Ethical Approval for Research Project

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

12 January 2017

Ms Asnah Paraffin (214584755)
School of Agricultural, Earth & Environmental Sciences
Pietermaritzburg Campus

Dear Ms Paraffin,

Protocol reference number: HSS/1949/016D
Project title: The influence of farm managment practices on milk quality and safety

Full Approval – Expedited Application

In response to your application received on 08 November 2016, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and **FULL APPROVAL** was granted for the protocol.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study

Yours faithfully

Dr Shenuka Singh (Chair)

/ms

Cc Supervisor: Professor M Chimonyo
Cc Academic Leader Research: Professor O Mutanga
Cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building

Appendix 4: Consumer perception on milk quality and safety of processed milk and milk products

Questionnaire No.…

Discipline of Animal and Poultry Science

College of Agriculture, Engineering and Science

School of Agricultural, Earth and Environmental Science

University of KwaZulu-Natal, Pietermaritzburg

2016

SURVEY ON CONSUMER PERCEPTION OF PROCESSED MILK AND MILK PRODUCTS

This study aims to evaluate the perception of consumers on milk quality and safety. It is a research project under the Discipline of Animal and Poultry Science, University of KwaZulu-Natal, Pietermaritzburg. We would like to obtain some personal, milk consumption you're your milk purchasing data. Your input is highly valued and the information that you provide will help to improve safe milk handling practices and general consumer awareness.

We request that as the **principal** decision-maker in your household please answer the questions in the survey. All information provided by you in this questionnaire will be treated **as strictly confidential**, and no individual household will be identified in the study results. Your **participation is voluntary** and you may **withdraw from the survey at any time without consequence**. Your participation in this survey is highly appreciated. Thank you!

Enumerator Number …………………… Province ………………….. Ward………………..

PERSONAL DATA AND DEMOGRAPHICS

1. **What is your gender** Male ☐ Female ☐
2. **Marital status** Married☐ Single ☐ Divorced☐ Widowed☐
3. **Age** 20- 30☐ 31-45☐ 45-50☐ 50-55☐ 55-60 ☐>60 ☐
4. **Highest level of education** No formal education ☐Primary education☐Secondary ☐ Tertiary☐
5. **What is your principal occupation?** ....
6. **What is your level of your monthly income. Tick one box**
7. <100 USD ☐ 100-250 USD ☐ 250-500USD☐ 500-1000 USD ☐ 1000-1500USD☐>1500 USD ☐
8. **What is your religion?** Christianity ☐ Traditional☐ Moslem☐ other (specify)…………
9. **What is the size of your household?Adults**: Male……Female……**Children**: Male…… Female..……

MILK CONSUMPTION PATTERNS

1. **Do you purchase milk for your own consumption Yes** ☐ **No**☐
2. **Which of these products do you purchase for your household consumption? Tick where applicable.** (where frequency is 1=never, 2=rarely, 3=sometimes, 4=often and 5=always)

	Place tick	frequency	Rank
Fresh Milk			
Cultured butter milk			
Yoghurt			
Others (specify)			

3. **How often do you eat these milk products? Tick where appropriate**

	DAILY =always	2-3 TIMES PER WEEK=often	WEEKLY =sometimes	FORTNIGHTLY =rarely	NEVER
Fresh Milk					
Cultured butter milk					
Yoghurt					
Other (specify)					

4. **Where do you normally buy these milk products. Tick where applicable.** (where frequency is 1=never, 2=rarely, 3=sometimes, 4=often and 5=always)
5.

	Straight from farm	frequency	'Off the road' from vendors	frequency	Kiosk	frequency	The market 'musika'	frequency	Supermarket	freque
Fresh Milk										
Cultured butter milk										
Yoghurt										
Others										

6. **Indicate to which degree you find the following selling locations as appropriate for selling milk products. Rank appropriateness on using the following scale** *where (1= absolutely inappropriate, 2= inappropriate, 3= slightly in appropriate, 4=neutral, 5= slightly appropriate, 6=appropriate and 7= absolutely appropriate)*

	Fresh Milk	**Cultured butter milk**	**Yoghurt**	Other (specify)
Straight from farm				
Off the road from venders				
Kiosk				
The Market 'musika'				
Supermarket				
Other (specify)				

7. **Indicate why you purchase milk from this location** *(1= its convenient for me, 2 = its cheap to buy from there, 3= I do not want to pay for extra like packaging 4= I like the variety there 5= the milk of better quality 6= its stores well and safe for me 7= its does not really bother me I just buy there).*

	Fresh Milk	**Cultured butter milk**	**Yoghurt**	Other (specify)
Straight from farm				
Off the road from venders				
Kiosk				
The Market 'musika'				
Supermarket				
Other (specify)				

ATTITUDES ON FURTHER PROCESSED MILK

1. **How important are the following product characteristics for you when making choices concerning cultured buttermilk? Tick where applicable. RANK in order of importance** *where 1= is not important, 2=slightly important, 3=moderately important, 4=very important and 5= extremely important.*

	Tick where appropriate	**Rank**
Appearance		
Freshness		
Quality		
Taste		
Nutritional value		
Brand name		
Availability		
Packaging		
Presence of labels		
Environmental friendliness		

A. PERCEPTION ON MILK SAFETY

Do you consider milk from these locations to be safe?

1. **Is Milk purchased and consumed from the following outlets safe? Tick and rank**

	Safe	**Rank**	**Not safe**	**Rank**
Straight from farm				
Off the road from vendors				
Kiosk				
The market 'musika'				
Supermarket				

2. **Where do you think contaminations in cultured buttermilk comes from?**

	Tick	**rank**
From bacteria or diseases causing agents		
Physical contaminants like grass or animal hair		
Chemicals or pesticides		
Other (specify)		

3. **Are there any health effects from these sources of contamination of milk? Rank in order of Severity** *where 1= mild, 2=strong, 3=severe*

	Sickness (headaches, vomiting)	**Indigestion**	**Long last effect (specify)**	**Death**	Other (specify)
Bacteria or diseases causing agents					
Severity					
Physical contaminants like grass or animal hair					
Severity					
Chemicals or pesticides					
Severity					
Other (specify)					
Severity					

4. **Are you concerned about how the milk you buy has been processed Yes ☐ No ☐**
5. **If you answered YES to the question above, SPECIFY Why?..**

FOOD SAFETY AND MANAGEMENT SYSTEMS

1. **My knowledge and awareness of food safety is**
Very good ☐ Good☐ Satisfactory☐ Poor☐ Very poor☐

2. **My knowledge and awareness of milk safety is**
   Very good☐Good☐Satisfactory☐Poor☐Very poor☐

3. **It is important for my milk to be manufactured in a safe environment?**
   Very Important☐ Neutral☐ Not important ☐

4. **Is product traceability important to you when you buy milk products?**
   Very Important ☐ Neutral ☐ Not important ☐

5. **Would you want to know the ingredients in the products you are purchasing?**
   Very Important ☐ Neutral ☐ Not important ☐

6. **Labelling and declaration of contents of my milk is important to me**

   Very Important ☐ Neutral ☐ Not important ☐

THANK YOU

Note: Consent should be sought from the participants and at any time the participants are free to withdraw from the survey as they wish.

Appendix 5: Farmer perception on factors affecting milk quality and safety

Questionnaire No.…

Discipline of Animal and Poultry Science

College of Agriculture, Engineering and Science

School of Agricultural, Earth and Environmental Science

University of KwaZulu-Natal, Pietermaritzburg

2016

SURVEY ON FARMER PERCEPTION ON FACTORS AFFECTING MILK QUALITY

This study aims to evaluate the perception of farmers on milk quality and safety. It is a research project under the Discipline of Animal and Poultry Science, University of KwaZulu-Natal, Pietermaritzburg. We would like to obtain some personal, milk production and farm management data. Your input is highly valued and the information that you provide will help to improve safe milk production practices.

We request that as the principal decision-maker in your household please answer the questions in the survey. All information provided by you in this questionnaire will be treated as strictly confidential, and no individual household will be identified in the study results. Your participation is voluntary and you may withdraw from the survey at any time without consequence. Your participation in this survey is highly appreciated. Thank you!

Enumerator Number …………………… … Province ……………………… ………..
Ward Name ……………………………….. Farm Name …………………………………..

PERSONAL DATA AND DEMOGRAPHICS

1. **What is your gender** Male ☐ Female ☐
2. **Marital status** Married☐ Single ☐ Divorced☐ Widowed☐
3. **Age** < 30☐ 31-40☐ 41-50☐ 51-60☐ 61-70☐ >70
4. **Highest level of education** No formal education ☐Primary education☐Secondary☐ Tertiary☐
5. **What is your religion?** Christianity ☐ Traditional☐ Moslem☐ other (specify)…………
6. **What is the size of your household?** Adults: M……. F………. Children: M…… F……
7. **What is the size of your farm (hectares)?** …………

8. **Do you own this farm? and if so how did you acquire it?**

	Tick	
Own purchase		
Resettled		
Lease agreement		
Renting		

What is the composition of your cattle herd?

	Lactating	**Dry**	**Heifers**	**Calves** (less than 7 months)
Number				

9. **What breeds do you have?**

Breed	**Holstein**	Jersey	Mixed Breed	Other……….
Number				

10. **What are the reasons for using the breed you named above?** (Tick one or more) (Rank 1 as the most important)

Reason	
High milk yield	
High protein content	
High butterfat content	
Resistance to mastitis	
Resistance to internal parasites	
Tolerance to extreme temperatures	
Other (specify)	

11. **What type of housing do you use for the milking cows. Tick where applicable**

	Tick
Free Stall	
Tie- stall	
Manure/straw	
Other specify	

12. **What type of milking system do you use? Tick where applicable**

Tie- stall with bucket milkers	
Tie- stall with pipeline	
Flat parlor	
Herringbone parlor	
Parallel parlor	
Tandem parlor	

Hand milking	
Other specify	

a. How often do you check the **milking house** for bacterial contamination**?**
Monthly ☐ Yearly ☐2 yearly ☐Never☐Does not apply☐
b. How often do you check the milking water supply for bacterial contamination**?**
Monthly ☐ Yearly ☐2 yearly ☐Never☐Does not apply☐
c. How often do you check the water supply system for hardness**?**
Monthly ☐ Yearly ☐2 yearly ☐Never☐Does not apply☐
d. Do you have a water purification system (UV or similar) for your water? **Yes** ☐ **No** ☐
e. Do you use water softeners in your water? **Yes** ☐ **No** ☐
f. Do you have a plate cooler or other device for pre-cooling milk prior to entry into the bulk tank? **Yes** ☐ **No**

MILK QUALITY AND SAFETY AND PERCEPTION

1. How important is milk quality to you? Tick
Not Important ☐Important☐ Extremely Important ☐

What are the determinants of milk quality

	Rank
PH	
SCC	
Fat (%)	
Protein %	
SNF %	
Other (Specify)	

What are the major factors affecting milk quality

Factor	**Rank**
Milking method	
Production system	
breed	
Hygiene	
Transportation	
Other (specify)	

Do you have concerns about your milk quality? Yes □… No □

If yes, what are they?

……
……
………………………………………………………………

How much milk do you produce per day………..
< 15 L □… 15-30L □… 30-40L □… 40 – 50L□> 50L □

How much milk is lost due to spoilage per day
< 5 L □… 5-10L □… 11-15L □… 16 – 20L□>20L □

What causes milk spoilage?

Personnel	
Milk containers	
Animal environment	
Udder diseases	
Other (Specify)	

What milk quality assurance measures do you use?

Mastitis testing	
Washing hands before milking	
Pre-dip	
Wash udder	
Dry teats	
Post dip	
Fly traps	
Milk health animals only	
Healthy and clean personnel	
Other (specify)	

2. How important is milk safety to you? Tick
   Not Important ☐ Important☐ Extremely Important☐

3. Are you concerned about how milk is processed? Tick
   Not Concerned☐Concerned☐ Extremely Concerned

4. Are you concerned about the consumer safety of the milk you produce?
   Not Concerned☐Concerned☐ Extremely Concerned

5. Where do you normally sale your milk?

___

6. Where do you think contamination of milk occurs?

	Tick	**rank**
During Milking		
In storage tanks		
During transportation During processing		
Other (specify)		

___

7. Do you transport your milk to the processor? If so what is the distance to the nearest processor?

___

A. FOOD SAFETY AND MANAGEMENT SYSTEMS

1. Does your farm have a food safety management system in place? **Yes** ☐ **No** ☐
2. What food safety system does your farm use? Tick where appropriate

HACCP ☐ ISO-CERTIFIED☐ FSSM☐DOES NOT HAVE ONE☐DO NOT KNOW☐

3. Does your farm have a quality assurance policy in place? **Yes** ☐ **No** ☐
4. Does your farm have a quality manual or task breakdown procedures? **Yes** ☐ **No**☐
5. Do you keep milk quality records? **Yes** ☐ **No** ☐ Specify

THANK YOU

Appendix 6: Farm Inspection recording sheet

NAME OF OWNER:.. **FARM NAME**:..

NAME OF DAIRY OFFICER:... **COLLECTION**:...

DATE OF VISIT:... **DHI**: YES [ ] NO [ ]

PURPOSE OF VISIT: RI[ ] ADVISORY[ ] BTA[ ] CHECK NOTICE[ ] PROSPECTIVE OTHER[ ]

ROOF: IRON[ ] ASBSTOS[ ] GOOD[ ] FAIR[ ] POOR[ ]

	BULK TANK ROOM/DAIRY	WASH-UP ROOM	PARLOUR
FLOOR			
WALLS			
CEILING			
FLY-PROOF			
DOOR			
WINDOWS			
VENTILATION			
DRAIN			

	TYPE	NO	PHYSICAL STATE	HOT/COLD
WASH TROUGHS (BUCKETS)				
WASH TROUGHS (CIRCULATION)				
WASH TROUGHS (BULK TANK)				
HAND BASIN				

BULK TANK SIZE(S):.................................... **PRE-COOLING**: YES[ ] NO[ ] PLATE[ ] SURFACE[ ]

METHOD OF GETTING MILK INTO TANK: POURING[ ] RECEIVED BY GRAVITY[ ] RECEIVED BY PUMP[ ]

MILK COOLING: IMMERSION COOLER [ ] ICE BANK[ ] COLD ROOM[ ]

CANS PHYSICAL STATE: GOOD[ ] FAIR[ ] POOR[ ] **RACKS**: YES[ ] NO[ ]

MILKING SYSTEM: HAND[ ] BUCKET[ ] PIPEPLINE[ ]

MAKE OF MACHINE:..

JARS/METERS/BUCKETS: NO:............. GOOD[ ] FAIR[ ] POOR[ ] CLEAN[ ] DIRTY[ ]

PHYSICAL STATE OF MACHINE RUBBERS: GOOD[ ] FAIR[ ] POOR[ ]

WHO INSTALLED MACHINE: STAKOLD[ ] LAKAS[ ] FARMER[ ] UNKNOWN[ ]

AGE OF MACHINE:....................**LAST SERVICE**:...................................**BY WHO**:......................................

MACHINE CLEANING SYTEM: ELECTROB BRAIN[ ] AUTOMATIC CIRCULATION[ ]

MANUAL CLEANING[ ]

DETERGENT:...**SANITISER**:................................**ACID**:..

MAIN DRAIN LENGTH................OPEN[ ] COVERED[ ] CLEAN[ ] DIRTY[ ] BROKEN[ ]

SUMP: PUMPED[ ] BAILED[ ] OPEN[ ] COVERED[ ] **MANURE CIRCULATION**:YES[ ] NO[ ]

AREA SURRONDS: CLEAN[ ] DIRTY[ ] **DIPS (No.)**: PLUNGE[ ] SPRAY[ ]

YARDS: EARTH[ ] BRICK[ ] CONCRETE[ ] GOOD[ ] CLEAN[ ] DIRTY[ ]

WATER: BOREHOLE[ ] RETIC[ ] DAM[ ] RIVER[ ] **HEADER TANK**: YES[ ] NO[ ]

NUMBER: BOREHOLES[ ] DAMS[ ] **WHEN WATER LAST TESTED**:..................................

WASH ROOM: S[ ] US[ ] DOOR WATER[ ] HOOKS[ ] DRAIN[ ] DOOR[ ]

TOILET: S[ ] US[ ] DOOR[ ] ROOF[ ] **DISTANCE FROM DAIRY**:.............................

WORKERS OVERALLS: YES[ ] NO[ ] CLEAN[ ] DIRTY[ ] TORN[ ] SEEN[ ] NOT SEEN[ ]

REGISTRATION CERTIFICATE DISPLAYED: YES[ ] NO[ ]

GENERAL COMMENTS:...

....

....

....

....

Appendix 7: Factory Inspection recording sheet

Factory Name:... **Date**:..

Name of Dairy Officer:.. Signature:...

Factory Representative:... Signature:...

Physical state of factory building

Areas to be inspected	**Poor**	**Good**	**Comment**
a) State of outer walls acceptance			
b) Availability of gutters and down pipes			
c) State of roofing acceptable			
d) State of windows acceptable (clean, not broken, no risk of contamination when open and fitted with fly-screens)			

Biosecurity

a) Clear signage	**Poor**	**Good**	**Comment**
b) Dust proof surroundings			
c) Disinfection control			
d) Rodent and fly control			
e) Hazardous chemical storage			
f) State of drainage acceptable			
g) Access and traffic control into premises and processing planting			

Milk and Input Reception Area

a) Closed from the rest of the area	**Poor**	**Good**	**Comment**
b) Water used (filtered or unfiltered)			
c) Drainage – Floors sloping to a drainage			
d) Foot bath at entrance (absent or present)			
e) Can racks (must not be rusty)			
f) General physical state of reception area hygiene			

Processing area

a) State of walls acceptable (impermeable material, easily cleaned and resistant to wear and corrosion)	**Poor**	**Good**	**Comment**
b) Availability of adequate ventilation			
c) State of floors acceptable (impermeable material easily cleaned and resistant to wear and corrosion)			
d) Floors sufficiently slopped to permit liquids to drain to trapped outlets and clean			
e) Drainage – Floors sloping to a drainage			
f) State of windows acceptable (clean, not broken, no risk of contamination when open)			

Packaging area

a) State of walls acceptable (impermeable material, easily cleaned and resistant to wear and corrosion)	**Poor**	**Good**	**Comment**
b) Availability of adequate ventilation			
c) State of floors acceptable (impermeable material easily cleaned and resistant to wear and corrosion)			
d) Floors sufficiently slopped to permit liquids to drain to trapped outlets and clean			
e) Drainage – Floors sloping to a drainage			
f) State of windows acceptable (clean, not broken, no risk of contamination when open)			
g) Product traceability (production date, batch number, BBD language, plant ID, physical location, contact details and ingredients))			

Finished product storage area

a) Temperature control. Storage does not promote product deterioration	**Poor**	**Good**	**Comment**
b) Adequate ventilation			
c) Walls clean and well maintained			
d) Handling prevents deterioration and damage			

Quality system and food safety systems

a) Availability of quality system which incorporates HACCP	**Present**	**Absent**	**Comment**
b) Type of quality system			
c) Does the QS incorporate HACCP			
d) Does the QS incorporate traceability			
e) Does the QS incorporate recall system			
f) Does the QS incorporate withdraw procedure			
g) Evidence of QS implementation			
h) Availability of personnel food safety training program			
i) Availability of training documents/manuals/package			
j) Availability of training results/certificates			
TOTAL MARKS SCORED			

General Comments and recommendations ....
....
....
....
....

Date of next visit:..