THE FOOD AND NUTRITION SECURITY POTENTIAL OF SMALLHOLDER DAIRY FARMING IN RURAL EASTERN CAPE, AND EVALUATION OF MILK HANDLING AND HYGIENE PRACTICES

BY

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ABSTRACT

Milk is a leading nutritive food source. Rural smallholder dairy farmers in South Africa have the potential to contribute significantly to milk supply for own consumption as well as to the lucrative formal urban markets, which would contribute to enhanced rural household livelihood options and improve food and nutrition security of the country. However, milk is highly susceptible to microbial contamination and as such strict hygiene and quality management are required to ensure that the product is of acceptable quality and safety. The formal urban markets particularly set high standards of milk quality and safety. On the other hand, rural smallholder dairy farmers are generally resource poor- they rely heavily on Indigenous Knowledge Systems (IKS) in their dairy practices. The IKS-based dairy practices would probably not be adequate to achieve quality and safety standards of milk demanded by the formal urban markets, which would severely restrict the rural smallholder farmers accessing these lucrative markets.

Whilst some studies have been conducted in other Sub-Saharan African countries on the dairy practices of rural smallholder farmers and the impact of the practices on milk quality and safety, it seems that similar studies have not been conducted in South Africa. The aim of the current study was to investigate milk utilisation patterns and assess dairy practices, including animal husbandry and milk handling and hygiene practices of rural smallholder dairy farmers of the Matatiele Local Municipality in the Eastern Cape Province of South Africa. The potential impact of these practices on milk quality and safety was also investigated.

A sample of 150 smallholder dairy farmers were selected from rural areas of Matatiele by simple random sampling and used to determine whether their dairy practices where informed by IKS. The perceptions of the farmers about the importance of milk quality and safety in relation to their dairy practices were also explored. The sampled farmers were interviewed using a pre-tested questionnaire on various aspects of dairy practices, namely the farm facilities; animal husbandry; milking practices; and the sources of the knowledge used to inform their practices. Focus group discussions (FGDs) were conducted to explore the perceptions of the farmers about milk quality and safety and transect walks were done to observe the dairy environment.

The study revealed that milk was an important protein source that was commonly consumed by 94% the farmers. The majority of the farmers predominantly used IKS in their dairy practices. The farmers housed their cows in kraals, milked by hand in the kraals, and the milk produced

was stored at room temperature. However, some of the IKS-based practices were in line with the recommended modern agricultural practices. The IKS-based practices were, however, limited with respect to cattle husbandry and hygiene standards. Milk storage was a major challenge due to lack of refrigerators. The majority of the farmers had the perception that milk quality and safety was important, whilst the perception of 17 % of the sampled farmers was that changes that occurred in milk were due to natural fermentation and as such would not impact negatively on milk safety. There is a need to interface IKS-based agricultural practices with the modern science-based agricultural practices in order to address the limitations of the IKS-based practices as well as facilitate the adoption of the recommended modern science-based practices by rural farmers.

The study further investigated farmers' knowledge and awareness of dairy hygiene and quality management through questionnaires, FGDs and direct observation of the milking process. The microbiological quality and safety of the milk was assessed by analysing total plate and coliform counts of milk samples collected from 19 farmers. The questionnaires revealed that the hygiene practices of the farmers were quite in line with the recommended modern science-based practices, although there were few exceptions. The farmers had good knowledge of personal and equipment hygiene, but had poor knowledge of environmental hygiene. The milk was consumed raw and the study participants reported that milk was often contaminated with foreign objects such as grass, dung, and soil. This would impact negatively on milk quality and safety and ultimately the food and nutrition security of the households. Results of microbiological analysis showed that 79% of the samples collected had a Total Plate Count of 8.8×10^5 to 3.3×10^{10} cfu/ml; the coliform counts (2.0×10^1 to 1.6×10^4) 84% of the milk samples exceeded the legal limit (1.0×10^1 cfu/ml); and 57.9% of the samples tested positive for faecal *E. coli*. These results indicate that the quality and safety of the milk samples was poor.

The study findings indicate that smallholder dairy farming is an essential source of rural household livelihoods- it produces milk for household consumption and income. The milk produced is well utilised by the rural communities of the Matatiele Local Municipality; it is used as the main source of protein, especially for children. The farmers aspire to access formal markets, however; they predominately use IKS-based dairy practices, which significantly reduces the ability to achieve the standards of milk quality and safety set by the formal markets. The farmers face serious challenges of limited resources, including finance, quality dairy facilities and refrigeration. This seriously limits their ability to achieve acceptable standards of quality and safety, especially the high standards set by the formal markets. There is a need to provide support to these farmers; one critical and essential support area is capacity building, through training of the rural dairy farmers to interphase IKS with modern science in their practices, to improve milk quality and safety. Provision of basic facilities such as taps to increase access to clean and safe water would be also helpful. The provision of cold storage facilities accessible to smallholder dairy farmers would also be helpful in assisting them to maintain microbiological safety.

DECLARATION

I, **ATLEHANG BRIDGET MAKAKOLE** hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication.

I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices.

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Signed Date:

As Research Supervisor, I agree to submission of this thesis for Examination.

Dr Muthulisi Siwela

Signed Date:

As Research Co-supervisor, I agree to submission of this thesis for Examination.

Professor Unathi Kolanisi

Signed Date:

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CHAPTER 1: THE PROBLEM AND ITS SETTING

1.1. INTRODUCTION

The global demand for milk and milk products has been increasing rapidly (Cusato et al. 2013). Milk consumption increased from 77.9 Kg/capita/year in 1987 to 84.9 Kg/capita/year in 2007 (FAO 2012). This increase has been more evident in developing countries, where the increase in milk consumption per capita was by 37.5 Kg/capita/year and 55.2 Kg/capita/year in 1987 and 2007 respectively (FAO 2012). This demand has resulted in developing countries creating opportunities for smallholder farmers to actively participate in the economy of the countries, which would contribute to improved food and nutrition security and poverty alleviation (Mapekula *et al.* 2009). Indeed, a number of sub-Saharan African countries have reported significant increases in the contribution of smallholder dairy farmers to milk supply, e.g. Zimbabwe and Kenya (Mhone *et al.* 2011). The increased milk demand, however, comes with a need for improved milk quality and safety (Mhone *et al.* 2011). Therefore, smallholder farmers are required to comply with the quality and safety standards prescribed, especially, by the formal markets. However, smallholder farmers are generally resource poor; their farming systems are commonly characterised by low inputs leading to low productivity and profitability (Mhone *et al.* 2011).

Because of limited resources, the smallholder farmers, especially those based in rural areas struggle to comply with strict, high standards of milk quality and safety set by the formal markets (Gran *et al.* 2002; Mhone *et al.* 2011; Mosalagae *et al.* 2011). Some of the resources required to achieve the quality and safety standards are milking sheds, access to clean, safe water, cleaning sundries, storage facilities, such as refrigerators, all of which are highly costly (Mhone *et al.* 2011). These resource constraints have been reported to contribute to poor milk handling and hygiene practices, which impact negatively on milk quality and safety (Klass de Vries 2012). Low standards of handling and hygiene increase the risk of contamination of milk with spoilage and pathogenic bacteria. Pathogenic bacteria in milk supplied by smallholder dairy farmers has been reported to cause serious health conditions, such as diarrheal diseases and stomach cramps, some of which have been fatal (WHO 2015).

Limited knowledge and awareness of acceptable standards for milk handling and hygiene practices have been identified to be amongst the major factors contributing to the widely reported failure of smallholder dairy farmers to achieve and maintain high standards of milk quality and safety (Leus *et al.* 2012). Limited knowledge of acceptable hygiene practices in dairy has been observed to be a leading factor contributing to high levels of milk contamination (Chepkoech 2010). When dairy farmers in Kenya were requested to assess their awareness of possible food-borne pathogens that could contaminate milk, they mostly ranked themselves as poorly to fairly aware (Chepkoech 2010). The study participants believed that increased knowledge and awareness of possible occurrence of food-borne pathogens would contribute to improved quality and safety of milk produced by smallholder dairy farmers especially those who are based in rural areas (Mosalagae *et al.* 2011). Awareness of the health and economic ramifications of milk contaminations is an important motivating factor for most of the famers to comply with the recommended handling and hygiene practices (Mosalagae *et al.* 2011). Although farmers were reported to have inadequate knowledge of handling and hygiene practices, it was observed that most of them did follow some practices, which were based on Indigenous Knowledge Systems (IKS) (Mhone *et al.* 2011; Brown 2004).

Few studies have been conducted in rural South Africa to determine the smallholder farmers milking practices and hygiene. Furthermore, the safety of the milk produced by the smallholder dairy farmers has not been studied in South Africa. The aim of this study is to assess the milk handling and hygiene practices of smallholder dairy farmers of the Matatiele Local Municipality in the Eastern Cape Province of South Africa and thereby determine the potential impact of these practices on milk quality and safety.

1.2. PROBLEM STATEMENT

Currently, smallholder farmers in South Africa, the majority of which are rural households, make an insignificant contribution to milk supply to the formal markets. However, smallholder dairy farming has been identified as a potential source of milk to meet the continually increasing demand for milk and milk products in both rural and urban areas (DAFF news 2013). The quality and safety of milk for human consumption is critical, yet, it is very resource-consuming to achieve, because the milk is highly susceptible to microbiological contamination and proliferation. In South Africa, formal dairy markets are largely urban- they are highly economically lucrative and competitive. These markets set and maintain strict, high standards of milk quality and safety. On the other hand, the majority of the rural smallholder dairy farmers are resource-poor and as such they are highly likely to apply affordable IKS-based practices of milk handling and hygiene. The supposed IKS-based practices would probably not be effective enough to limit microbial contamination of the milk to acceptable levels, especially as set by formal markets.

Currently, there is either very limited or no information about the dairy practices of rural smallholder farmers in South Africa. The impact of the dairy practices on milk quality and safety is not known. Knowledge, awareness and perceptions of these farmers about the importance of milk quality and safety are not known. Thus, there is a need to investigate the dairy practices of these farmers and determine whether they produce milk of acceptable quality and safety for own consumption and formal markets.

1.3. OVERALL AIM

To investigate the milk utilisations patterns; and assess milk handling and hygiene practices of smallholder dairy farmers of the Matatiele Local Municipality in the Eastern Cape Province of South Africa, and thereby determine the potential impact of these practices on milk quality and safety.

1.4. STUDY SPECIFIC OBJECTIVES

The study objectives were:

- 1.4.1 To assess the effect of Indigenous knowledge systems -based hygiene and safety practices on milk quality and safety in terms of exposure to risk for contamination and guidelines set to manage safety & quality of milk
- 1.4.2 To assess the handling practices of selected dairy products
- 1.4.3 To assess the smallholder farmer's knowledge and awareness of the hygiene and handling practices.
- 1.4.4 To determine the microbiological load and safety of selected dairy products.

1.5. STUDY PARAMETERS

The study included smallholder dairy farmers that were actively producing milk. The limitations in the collection of milk samples prevented collection of the samples in both the hot and cold seasons. The cows were dried in the cold season and no milk was produced, and during the hot season there was drought in the area and this led to farmers preserving milk for the new-born calves.

1.6. ASSUMPTIONS

1.6.1. The smallholder dairy farmers are truthful and honest in answering the questions.

1.6.2. The hygiene and handling practices observed were representative of the usual practices.

1.7. DEFINITIONS

Contamination: The introduction or occurrence of a contaminant (chemical or biological) in a food or food environment (Codex).

Food Hygiene: All environmental factors, practices, processes and precautions involved in protecting food from contamination by any agent, and preventing any organism present from multiplying to an extent that would expose consumers to risk or result in premature spoilage or decomposition of food (http://www.foodsafetyinitiative.co.za/fsi.aspx).

Food Safety: The assurance that food will not cause harm to consumers when prepared and/eaten according to its intended purpose (http://www.foodsafetyinitiative.co.za/fsi.aspx).

Food Security: The state existing when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active lifestyle (Wallace et. al. 2011 citing WHO 2010).

Good Agricultural Practices: A set of principles, regulations, and technical recommendations applicable to production, addressing human health, environment protection and improvement of worker conditions and their families (FAO 2007).

Hazard: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard Analysis and Critical Control Point (HACCP): A preventative system of foods safety management based on product design, hazard analysis and process control (Wallace *et. al.* 2011).

Indigenous Knowledge Systems: Indigenous knowledge refers to traditional and local knowledge systems, involving social, economic and environmental variables, unique to a particular culture or society (Brown 2004).

Infection: An illness or condition caused by the growth of a microorganism in a host.

Microorganisms: An organism that can be seen only through a microscope (http://www.who.int/trade/glossary/story076/en/).

Microbial Load: Measurable quantity of bacteria in an object, organism, or organism compartment (http://www.reference.md/files/D058/mD058491.html).

Pasteurization: A process of heating the milk in an effort to minimize the bacteria in the milk and thereby increase the shelf life and microbiological safety of the milk.

Process flow diagram: A diagrammatic representation of the process, identifying all processing activities, which is used as the basis for hazard analysis.

Public Health: Public health refers to all organized measures (whether public or private) to prevent disease, promote health, and prolong life among the population as a whole (http://www.who.int/trade/glossary/story076/en/).

Rural areas: A low population dense area with loose network of infrastructure, service as well as below average manufacturing and office based employment; it is normally dominated by farmland and forestry (Hoggart 1988).

Smallholder Dairy Farmers: Run on individual household farms keeping low numbers of cattle (median herd size 14 cattle) and are characterized by low input and low productivity (Mhone et al. 2011).

Spoilage: Any perceivable change undergone by a food, through any cause, that renders it unwholesome or unacceptable for use (http://www.who.int/trade/glossary/story076/en/).

1.8. ABBREVIATIONS

cfu/ml	Colony Forming Units per millilitre
E. coli	*Escherichia Coli*
FAO	Food and Agriculture Organization of the United Nations
FDGs	Focus Group Discussions
HACCP	Hazard Analysis and Critical Control Point
HSRC	Human Sciences Research Council
IK	Indigenous knowledge
IKS	Indigenous Knowledge Systems
SA	South Africa
SPSS	Statistical Package for Social Sciences
TBC	Total Bacteria Count
TPC	Total Plate Count

WHO World Health Organisation

1.9. SUMMARY

Smallholder dairy farming is an important activity that improves the availability and accessibility of milk in rural households, thus improving household food security. However, smallholder dairy farmers are challenged because of the limited resources available to them, reducing the ability of the farmers in meeting the milk quality and safety standards required for the commercial formal markets.

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CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

Agriculture has always been the main source of livelihoods in Africa; 86% of the people in rural areas depend on agriculture as their main source of livelihoods (Baiphethi & Jacobs 2009). Although, there has been an observed decline in the agricultural production dependency due to the increase in market dependency, the majority of the rural poor still rely on agricultural production for food and income generation (Baiphethi & Jacobs 2009). However, agricultural productivity has been observed to be declining, for example, the number of cattle per household has decreased significantly in the last decades, which has resulted in the characterisation of the majority of African farmers as smallholder (Baiphethi & Jacobs 2009). Mhone *et al.* (2011) stated that the low numbers of cows owned by smallholder dairy farmers and low farm inputs indicate that these farmers are resource-poor, which largely contributes to their low productivity.

Dairy farming among the rural poor in Africa is a customary practice (Baiphethi & Jacobs 2009). Africans have historically owned cows for food production, traditional and monetary purposes (Baiphethi & Jacobs 2009). When farmers in the rural parts of Zimbabwe were asked to rank their reasons for keeping cattle, they ranked milk production third, after money from selling the cattle and traditional ceremonies (Mapekula, *et al.* 2009). Milk production ranked higher than meat production and this is highly significant because it illustrates that milk is the main source of protein in these households.

The resource-poor nature of smallholder dairy farming has presented a number of challenges with regard to food quality and safety (Mhone *et al.* 2011). Some of the main challenges are the limited capacity to follow the recommended modern science-based agricultural dairy practices, including recommended milk handling and hygiene practices. These farmers also have very limited or no access to effective milk storage facilities and transport infrastructure (Gran *et al.* 2002). These factors have a direct negative impact on the quantity, quality and safety of the milk produced. Milk of high quality and safety is important because it would increase the opportunity for smallholder farmers to access the formal commercial markets, which are economically lucrative due to the ever-increasing demand for dairy products and hence offer higher incomes and profits (Cusato *et al.* 2013). One of the critical determinants of milk quality and safety is the level of microbial contamination- therefore the ability of the farmer to keep microbial contamination of the milk at acceptable levels is key to the economic viability of the dairy enterprise. The reduction of microbial contamination of milk to an acceptable minimum requires sound knowledge and awareness of the importance of acceptable milk handling and hygiene practices and appreciable resources, including finance, which, as stated earlier, maybe significantly limited among rural smallholder farmers.

However, the significance and success of smallholder dairy farming has been reported by a number of developing countries including India, Kenya and Zimbabwe. India has grown to be one of the largest producers of milk due to smallholder dairy systems implemented in the country (Sraïri *et al.* 2011). Kenya has also successfully implemented their smallholder farming schemes to contribute about 75% of the national milk production, making Kenya the leading milk supplying country in East Africa (Chepkoech 2010). In Zimbabwe, the smallholder dairy scheme has increased the national milk production by 5%, and this has significantly increased the milk production base of the country (Mhone *et al.* 2011).

2.2. MILK CONSUMPTION TRENDS

There has been a shift in developing countries due to urbanization; people in developing countries are relying less on their household agricultural production and more on commercial markets (Cusato *et al.* 2013). The preference of commercially produced and processed food has been increasing rapidly (Cerva *et al.* 2014; Cusato *et al.* 2013). This increase has been reported to be a result of an increase in the education level of people, increased income as well as increased physical access to food (Cerva *et al.* 2014).

The people in rural areas have been reported to prefer home-made milk (Lues *et al*. 2012; Mapekula *et al.* 2010; Mhone *et al.* 2011). This preference is specific to raw milk. (Cusato *et al.* 2013) reported that people prefer raw milk due to their belief that raw milk is of higher quality. According to Mosalagae *et al* (2011), Zimbabwean communities commonly consume raw milk. Raw milk was argued to be the preferred over pasteurized milk because it required less work, especially in rural areas where electricity is not available (Neeta *et al.* 2015). Respondent from various studies however, stated that their main reason was their preferred taste of raw milk (Lues *et al*. 2012; Mapekula *et al.* 2009; Mhone *et al.* 2011; Neeta *et al.* 2015)

Pasteurization was not reported as a practice for any of the smallholder farmers and their family (Lues *et al*. 2012; Mapekula *et al.* 2010; Mhone *et al.* 2011). The smallholder farmers were reported to consume the milk raw. The preference of raw milk as reported by numerous authors is significant because this preference predisposes consumers to contamination and increases the risk of illnesses (Mdegela *et al.* 2004). There is however, very limited information on the milk preferences of South Africans living in the rural areas as well as their understanding of pasteurization and willingness to pasteurize their milk.

2.3. SMALLHOLDER DAIRY FARMING POTENTIAL IN ADDRESSING FOOD AND NUTRITION SECURITY

Globally, the food and nutrition security status has improved with a current status of 14% of the population undernourished (Benson 2008). However, the nutrition security status of Africa has worsened, with 27% of the African population undernourished and this has been specifically reported for sub-Saharan African countries (Benson 2008). South Africa like other sub-Saharan countries are burdened with protein-deficiency malnutrition and micronutrient deficiencies, with the most prevalent identified to be vitamin A, iron, zinc and iodine deficiencies. Vitamin A deficiency continues to be of great concern in South Africa, with 43.6% of the population identified to be deficient in vitamin A (Human Sciences Research Council 2013).

Milk is an essential food item that is rich in macronutrients as well as micronutrients. Milk is high in protein; access and consumption of milk could address the protein deficiency problem faced by African countries (Cerva *et al.* 2014). Milk is rich in micronutrients such as vitamin A, Thiamin (vitamin B1), Riboflavin (vitamin B2) as well as the minerals: calcium, iron, zinc, magnesium and phosphorus (Milk SA 2014). These micronutrients are very important because they could potentially address some of the nutrient deficiencies prevalent in South Africa, especially vitamin A deficiency in children. Smallholder dairy farming allow for milk and milk products to be an affordable source of protein which is often lacking in the diets of people living in the rural areas due to the costs of protein rich foods and their highly perishable nature (Milk SA, 2014).

The majority of the smallholder farmers have been reported to use the milk they produce for household consumption and sell to their neighbors (Mapekula *et al.* 2009). Some of the smallholder dairy farmers from countries with more established dairy cooperatives such as Kenya and Zimbabwe were reported to sell their milk to the dairy cooperatives (Chepkoech 2010). The use of the milk contributes significantly in improving food and nutrition security for the rural community (Baiphethi & Jacob 2009).

Food security is defined as the sustained ability of people to have enough food available and accessible to them, that is safe and contains the required nutrients for them to lead a healthy and productive life (Benson 2008). Food security involves a number of aspects but the primary pillars are food availability, food access, security of access and utilization of food (Benson 2008). Household food security focuses on the households' continuous access and availability of safe foods that are of good quality and quantity for every member of the family.

The department of Agriculture, Forestry and Fisheries in (2012) reported that South Africa is facing a difficult and complex situation of being a food secure country, while there are millions of South Africans starving due to lack of access to food. This was based on statistics that disclosed that 2.8 million households in South Africa have inadequate access to food, constituting 20% of the households in South Africa. Furthermore, they reported that an additional 14.4 million households in South Africa are vulnerable to food insecurity. The minister stressed the importance of smallholder farms contribution in addressing this household food insecurity situation, and the need for the smallholder farms support in producing food of good quality and quantity (DAFF news 2013).

The contribution of smallholder dairy farms on household level is particularly in subsistence farming in many rural areas (Baiphethi & Jacobs 2009). Leus *et al* (2012) stated that 40% of all the smallholder farmers in South Africa rely on their farm produce daily. In Kenya, smallholder dairy farms worked with dairy cooperatives and they were reported to have an enormous potential in improving the economy of the country, with smallholder dairy farming contributing 75% of the national milk base (Chepkoech 2010). This was also reported in other developing countries that had established dairy markets and dairy cooperatives to support the smallholder dairy farmers (Chepkoech 2010). The milk collected from the different smallholder farms in those countries was used to increase milk production base of the country (Chepkoech 2010).

Smallholder dairy farming is also an income generating activity for the farmers' households (Mapekula *et al.* 2009). Smallholder dairy farmers that are part of the dairy cooperatives gain income from selling the milk to the cooperatives, and this increases the households' food security status. The smallholder dairy farmers that mainly use the milk for household consumption were reported to also sell the milk to their neighbours, and this provided and supplemented the households' income (Mapekula *et al.* 2009; Mosalagae *et al.* 2011). Smallholder dairy farming is thus very important in improving the household financial access to food by providing opportunities for self-employment, especially for women, thus a more regular source of income (Mdegela *et al.* 2004).

The income generated from smallholder dairy farming, although often limited, provides the household with a more secure source of income and food (Baiphethi & Jacob 2009). Most of the poor people living in rural areas rely on wage employment. Wage employment is not a secure and sustainable source of income due to the presence of different opportunities at different times. The wages earned from such employment are often not sufficient to provide basic needs for all members of the household, and in this instance, smallholder dairy farming provides supplementary income (Benson 2008).

Smallholder dairy farming is also very important in improving physical access to food for the household (Baiphethi & Jacob 2009). People in the rural areas are not only challenged with affordability of food, they are additionally challenged with the limited access to markets for purchasing of food (Benson 2008). Rural areas are often remote and this restricts the people's physical access to food. Smallholder dairy farming then addresses this problem in the context of milk, because milk is then readily available to the household. Milk generally is produced daily in smallholder farms and this allows for milk to constantly be incorporated into the diet of the household (Leus *et al* 2012).

The ability of households to operate efficiently and significantly improving their food security situation is shown in Figure 1. The maintenance of good cattle management as well as good milking, milk handling and hygiene practices produces milk of high quality and quantity, thus significantly improving food security (Mapekula *et al.* 2009; Mhone *et al.* 2011; Mosalagae *et al.* 2011). The quality of the milk is highly reliant on cattle health and the handling and hygiene practices at the farm, and the ability of the farm to produce milk of high quality is very important because it determines the usability of the milk either for household consumption or for selling (Mhone *et al.* 2011; Mosalagae *et al.* 2011). This then directly impacts the financial and physical access to food, thus food security.

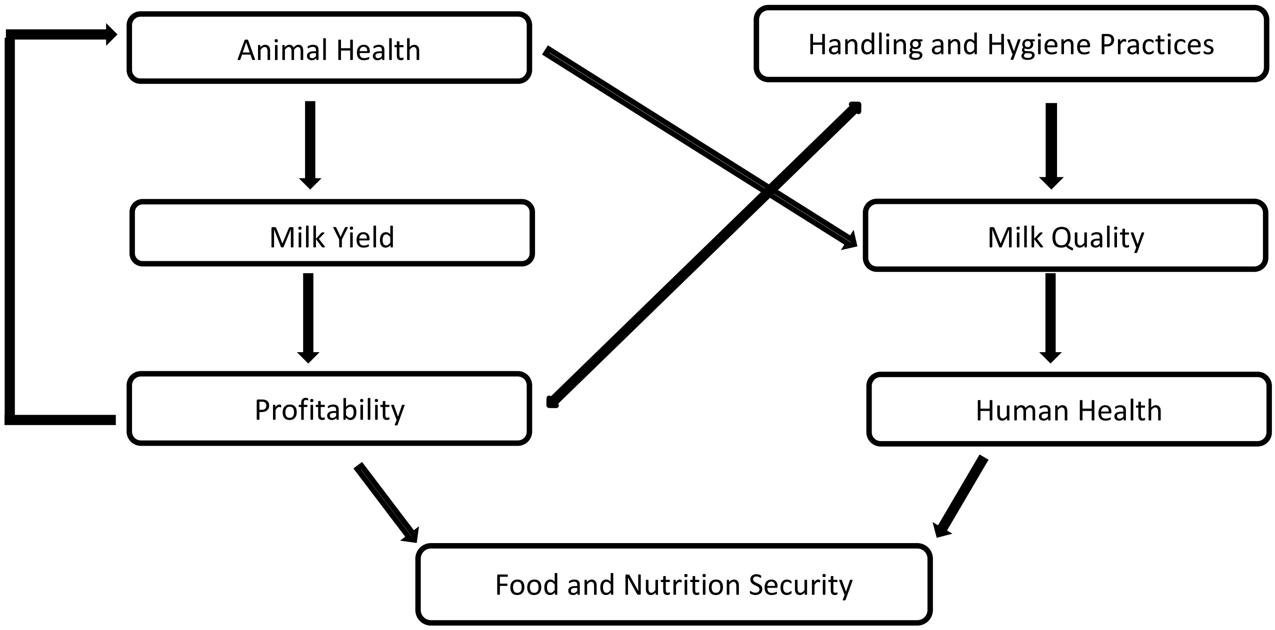

Figure 2.1: Conceptual framework of the different factors in smallholder dairy farms that affect food and nutrition security.

2.4. MICROBIOLOGICAL QUALITY OF MILK

Milk and milk products are of great importance in the context of food safety due to the composition of milk (Altalhi & Hassan 2009; Dermibaş *et al.* 2009). Milk is a food item in liquid form (high water activity), with significant levels of macronutrients namely; carbohydrates, proteins and fats, and micronutrients (Cerva *et al.* 2014). Milk is thus, very important because it adds variety to the diet and provides essential nutrients. However, the composition of milk; the high nutritional content, high water activity, and neutral pH makes it a great medium for microbial growth, making milk highly susceptible to contamination (Altalhi & Hassan 2009; Claeys *et al.* 2013). Contaminated milk could result in minor illnesses by spoilage bacteria and more severe illnesses by pathogenic bacteria. These illnesses have an impact on the national economy as well as the household economic situation, thus affecting national food security status and household food security (Mhone *et al.* 2011).

2.4.1. The prevalence of food-borne illnesses

Food safety has received increasing global attention in the previous years due to the increased incidents of food contamination. Public health concerns due to food safety have grown (Altalhi & Hassan 2009). In 2005, 1.8 million people died from diarrheal diseases globally, with most cases due to food and water contamination (WHO 2015). Millions of South Africans contract food poisoning and food-borne illnesses every year (DOH 2009).

The ingestion of food that is contaminated with microorganisms cause food-borne illnesses and this is a growing food and nutrition security concern (Cerva *et al.* 2014). The actual cases of foodborne illnesses are believed to be underreported in South Africa, due to the perception of diarrheal diseases as mild illnesses not worthy of reporting and seeking medical assistance from health facilities (DOH 2009). Moreover, when people do seek medical attention, health professionals are not likely to report diarrheal illnesses because they are thought to be mild illnesses (DOH 2009).

2.4.2. Microbial quality of milk and milk products

The total number of bacteria in milk has a direct relationship with the quality and safety of milk. High levels of bacteria signify poor quality and safety of milk (Mhone *et al.* 2011). Spoilage and pathogenic bacteria can both grow and proliferate in milk (Altalhi & Hassan 2009). Spoilage bacteria are not as harmful as pathogenic bacteria; however, in high levels they can alter the composition of milk and render milk undesirable to consumers (Cerva *et al.* 2014). Contamination by spoilage bacteria can alter the nutritive quality of milk, the pH of milk as well as the sensory attributes of milk, which is often unacceptable to consumers of milk and milk products (Mhone *et al.* 2011).

2.4.2.1. Types of bacteria commonly found in milk

Campylobacter jejuni, Escherichia coli, Listeria monocytogene, Samlonella spp., Bacillus aureus, mycobacterium bovis and Staphylococcus aureus, are some of the common pathogenic bacteria that have been identified in milk, from previous studies (Cerva *et al.* 2014; Mosalagae *et al.* 2011; Papademas & Bintsis 2010). These pathogenic bacteria cause illnesses and diseases when consumed by humans (Altalhi & Hassan 2009; Cerva *et al.* 2014). The consumption of milk contaminated with these pathogens is of great public health concern and economic impact, thus nutrition and food security (Mosalagae *et al.* 2011).

Bacteria pathogens are commonly found on dairy animals, in raw milk, milk products and the dairy farm environment (Mosalagae *et al.* 2011). The raw milk, cultured pasteurized milk and naturally fermented raw milk from some of the smallholder dairy farms in Zimbabwe were reported to be contaminated by large amounts of *E. coli*, *Staphylococcus aureus, Candida albicans* (Mosalagae *et al.* 2011).

Heat treatment destroys most of the bacteria in milk; therefore, pasteurised milk is expected to have low levels of microorganisms (Claeys *et al.* 2013). This was however, not the case in smallholder farms in Zimbabwe where high levels of coliforms, *E. coli* and *Staphylococcus aureus* were identified in both raw and pasteurized milk (Mosalagae *et al.* 2011). This indicated poor hygiene and post-pasteurization contamination of the milk (Mhone *et al.* 2011). Sraïri *et al.* (2009) reported that 75% of the milk samples collected from smallholder farms had very high levels of bacterial contamination, spoilage and pathogenic bacteria. The presence of *E. coli* specifically signifies fecal contamination post the pasteurization process, due to poor hygiene and handling practices of the milk (Mapekula *et al.* 2009). The minimum acceptable limits of some of the bacteria allowed in milk are shown in Table 3 below.4.2.2. Common methods used to assess microbial quality and safety.

There are various methods and tests that examine the quality and safety of milk by determining the microbial load (Harley 2014; Anderson *et al.* (2011). The different tests are used for the identification of certain bacteria through the use of different mediums (Harley 2014). The test that is commonly used for the Total Bacteria Count (TBC) is the standard plate count (SPC) method, using nutrient agar (Anderson *et al.* 2011). The TBC is calculated based on the colonies formed in a SPC and compared to the minimum legal standard of <50 000/ml, as seen in table 2 and 3 respectively.

The minimum legal standard of the above mentioned bacteria in South Africa, specifically in Cape Town is shown below in Table 2 and 3. The amounts of the bacterial load that exceeds the amounts in table 2 and 3 render the milk and milk products unsafe and unsuitable for human consumption and the markets (City of Cape Town 2008).

Table 2.1: Milk quality standards of pasteurized milk and milk products in Cape Town, South Africa

Test for Pasteurised Milk	Minimum legal standard
Total Count	<50 000 cfu/ml
Coliform Count	<10 cfu/ml
Presence of *E-coli*	Negative
Phosphatase test	Negative
Added water	0%
Coliform count (non-ripened products)	<50/ml or g
Coliform count (ripened products)	<1000/ml or g
E-coli	Negative

(City of Cape Town 2008).

Table 2.2: Milk quality standards of raw milk (unpasteurised) in Cape Town, South Africa

Test	Minimum legal standards
Total count	<50 000 cfu/ml
Coliform Count	10 cfu/ml
Antibiotics	Negative
Resazurin	2 – 6
E-coli	Negative
MRT (Milk Ring test)	Negative
Staphylococcus aureus	Negative
Streptococcus agalactiae	Negative

(City of Cape Town 2008).

Specific tests are performed for specific bacteria identification such as coliforms. The identification of coliforms in milk and milk products is very important because coliforms are an indicator of poor hygiene and handling of milk, thus sanitary quality (Harley 2014). High coliform counts indicate possible existence of pathogenic bacteria such as *Campylobacter jejuni, Escherichia coli O157:H7 (E. coli), Salmonella* and *Listeria monocytogene* (Harley

2014). The test commonly performed for coliform analysis is the coliform plate count (CPC) method using Red Violet Bile Agar (RVBA) (Anderson *et al.* 2011; Harley 2014). The methylene blue reductase test is used for the analysis of milk in determining the quality of milk. Furthermore, DNA sequencing can be performed for the identification of specific bacteria (Anderson *et al.* 2011).

2.4.2.2. Factors affecting microbial load in milk and milk products

Milk contamination can occur at the different stages of milking and milk handling. The causes of contamination may vary; the presence of bacteria in the milk could be due to dairy cattle diseases through an infected udder or the growth of bacteria on the teat canal, poor personal hygiene, environmental and cattle hygiene, as well as poor handling practices (Altalhi & Hassan 2009). Additionally, contamination can occur at different stages from the animal, the milker, and the environment; during milking, before pasteurization and post-pasteurization (Oliver *et al.* 2005). The levels and types of bacteria found in the milk is greatly correlated to hygiene and cattle health (Sraïri *et al.* 2009). Hand milked milk was reported to generally have higher levels of bacteria than machine milked milk (Mosalagae *et al.* 2011).

Mycobacterium bovis, Brucella species, *Streptococci* are some of the bacteria that are present in milk and their source of contamination is usually cattle disease through an infected udder and teats (Anderson *et al.* 2011). The bacteria that can be transmitted from humans and contaminate milk are *Salmonella* species and *Streptococcus* species (Harley 2014; Anderson *et al.* 2011). Milk contamination can also result from faecal contamination, which results from unsanitary handling; bacteria that indicate faecal contamination are *E. coli* and *Campylobacter jejuni* (Anderson *et al.* 2011).

2.5. KNOWLEDGE AND AWARENESS OF HYGIENE

Knowledge of hygiene and awareness of the implications of hygiene has a high impact on the practices of smallholder farmers and the safety of their milk and milk products. Mosalagae *et al* (2011), reported that 55.9% of the smallholder farmers in Zimbabwe were generally aware of the possibility of microorganisms affecting cattle, with 36 % of the farmers aware that the microorganisms could contaminate the milk. A higher percentage of 64.7% was reported from the study conducted in peri-urban Bloemfontein, with 52.8% of the farmers aware that consumption of contaminated milk and milk products could lead to illness and 45.3% of the farmers stating that consumption of any milk and milk products can never result in illness (Lues *et al*. 2012).

Lues *et al*. (2012) reported that the knowledge level of the farmers was high and they all had knowledge of the importance of personal and general hygiene. Lues *et al*. (2012) further indicated that all the farmers were aware not to consume milk from ill cattle and to dispose of the milk. This was contradicted by Chepkoech (2010) who reported that the level of contamination that resulted from the farmers' lack of knowledge and poor hygiene to be relatively high. Similarly, Mdegela *et al.* (2004) reasoned that the improper milking hygiene that was observed at the smallholder farms in Tanzania were due to lack of knowledge of the economic and animal ill-health implications of poor milking hygiene. There is limited information on the knowledge level of the smallholder farmers in South Africa, particularly in the rural areas and how that level of information affects their practices on their farms.

2.5.1. Handling practices of milk products

The milk products produced from cattle milk include fermented or soured milk, cheese, yoghurt and butter (Beukes *et al.* 2001). In rural South Africa, the main milk product that is produced is fermented milk, otherwise known as mafi and amasi/umvubo (Beukes *et al.* 2001). The Nguni and the Sotho of South Africa have been reported to indigenously consume milk in its sour, fermented form more than fresh milk (Beukes *et al.* 2001). This is due to the communities' common practice of converting the fresh milk into the less perishable food item for preservation (Kebede *et al.* 2007). Different fermentation methods and practices have been reported for the two tribes. The Sotho people use clay pots to make "mafi" and the Nguni people use calabashes to make "amasi" (Beukes *et al.* 2001).

The tribes indigenously used traditional containers such as milk sacks, calabashes, clay pots, stone jars and baskets (Beukes *et al.* 2001). The calabashes were seeded with microbial inoculum before fermentation (Beukes *et al.* 2001). The containers used as well as the practices, resulted in the traditional product that was rich and smooth, due to the elimination of undesired micro-organisms by gradual selection of specific micro-organisms (Beukes *et al.* 2001).

Some households and communities have lost the indigenous ways of producing fermented milk. Mapekula *et al.* (2010) reported that the souring of fresh milk was done in conventional milk churns at ambient temperatures for 24 to 48 hours. A perforated metallic plate was then used to carefully remove the curd formed was and the remaining whey was left in the churn. The curds removed were then mixed together, inspected visually and that was the ready product used for consumption and selling.

Modern socio-economic changes have resulted in the loss of some indigenous practices lost and with that, some of the associated micro-organisms are not easy to replicate using the modern methods with the introduction of some undesirable micro-organisms that have a negative effect on the fermented milk quality and safety (Beukes *et al.* 2001). The safety of these practices in producing fermented milk has not been established in South Africa. Furthermore, Oliver *et al.* 2005) reported that high levels of bacteria were found in cheese that was processed from raw milk and this resulted in disease outbreaks. There are a few studies available that have assessed the hygiene and milk handling practices in Africa, including South Africa.

2.5.2. Implications of milk and milk products contamination

The illnesses caused by consumption of contaminated milk are of great concern to food and nutrition security (Cerva *et al.* 2014). People burdened with food-borne illnesses have reduced capacities to work and this affects their livelihoods (Baiphethi & Jacob 2009). It is more so in the rural areas where farming is the main livelihood for many households (Baiphethi & Jacob 2009). Furthermore, some of these illnesses negatively affect the body's ability to absorb micronutrients thus hindering the progress in addressing micronutrient deficiencies.

Raw milk was reported to have higher levels of microbial contamination than pasteurised milk; this is due to the heat treatment applied to pasteurize the milk (Claeys *et al.* 2013). The United States Centre for Disease Control (CDC) reported that the milk related food-borne illnesses reported in the United States of America were only from states that allowed raw milk sales (Claeys *et al* 2013). Papademas & Bintsis (2010) reported that food-borne illness outbreaks caused by the consumption of raw milk, milk products made from raw milk, and milk that is inadequately pasteurized continue to be a burden. This is significant because people in rural areas were reported to predominately prefer raw milk to pasteurized milk (Mosalagae *et al.* 2011).

There are several diseases that can be caused by the consumption of contaminated milk, with varying effects and degrees. The most common illness resulting from milk consumption is diarrhoea, which is usually caused by *E. coli*, *Salmonella* and *Campylobacter jejuni* (Anderson *et al.* 2011). *Campylobacter jejuni* was reported to be the major cause of acute bacterial gastroenteritis in humans and *E. coli* was reported to be the cause of serious complications that could be fatal (Anderson *et al.* 2011). Some of the less common illnesses that can result from consuming milk are *listeriosis* and *streptococcal* infections caused by *Listeria monocytogene* and *streptococcus* species respectively (Harley 2014).

Milk contamination also has economic implications (Cerva *et al.* 2014). Milk contamination was reported to be the major cause of milk loss. Due to the decisive effect of microbial load to the quality of milk, milk significantly high in bacteria is not acceptable to the formal dairy market (Chepkoech 2010). Milk contamination thus negatively affects the farmers' ability to generate income from the sales of the milk in informal markets as well as in dairy cooperatives, thus limiting financial access to foods (Chepkoech 2010). The extent of milk and milk products contamination in rural South Africa and the actual implications are unknown. There is limited information in South Africa and the available information is not specific to rural areas.

2.6. SUMMARY

Smallholder dairy farming has the potential to produce milk of good quality, however, they is a need for support that addresses the challenges caused by the resource poor nature of the farms. The farmers' predominant practice of indigenous knowledge systems has to be further investigated and incorporated in commercial dairy market criterion to incorporated rural poor smallholder dairy farmers. The recommended agricultural practices, hygiene and handling practices are not well understood by farmers which further exacerbate the milk safety challenges because they have a direct impact on the safety of milk. There is a need for documentation and knowledge of smallholder dairy farmers practices in the rural parts of South Africa.

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CHAPTER 3: STUDY DESIGN AND METHODOLOGY

3.1. INTRODUCTION

This chapter describes and explains the study design and methodology used in the study. The study area, methods used in sampling, data collection, and data analysis are described and explained.

3.2. DESCRIPTION OF THE STUDY AREA

The study was conducted in the Matatiele Local Municipality. The municipality consists of three towns, namely, Matatiele, Cedarville and Maluti. The study was conducted in the Matatiele and Maluti towns only. The two towns are predominantly rural and the majority of the inhabitants are Sotho and Xhosa people. Thus, the main languages used in Matatiele and Maluti are Sotho and Xhosa, isiZulu is used to a limited extent.

Figure 3.1 shows the map of the study area, Matatiele Local Munipality. The Matatiele Local Municipality is situated in the Alfred Nzo District Municipality of the Eastern Cape Province. It borders with KwaZulu-Natal and Lesotho. The Matatiele Local municipality was transferred to Alfred Nzo District Municipality from the Sisonke District of KwaZulu-Natal province in 2006, where it only consisted of the two towns Matatiele and Cedarville (IDP 2013). The Matatiele Local Munipality covers an area of 4352 km^2, and consists of 26 wards. It has an estimated population of 258,758 people (Census 2007 and ANDM IDP 2013).

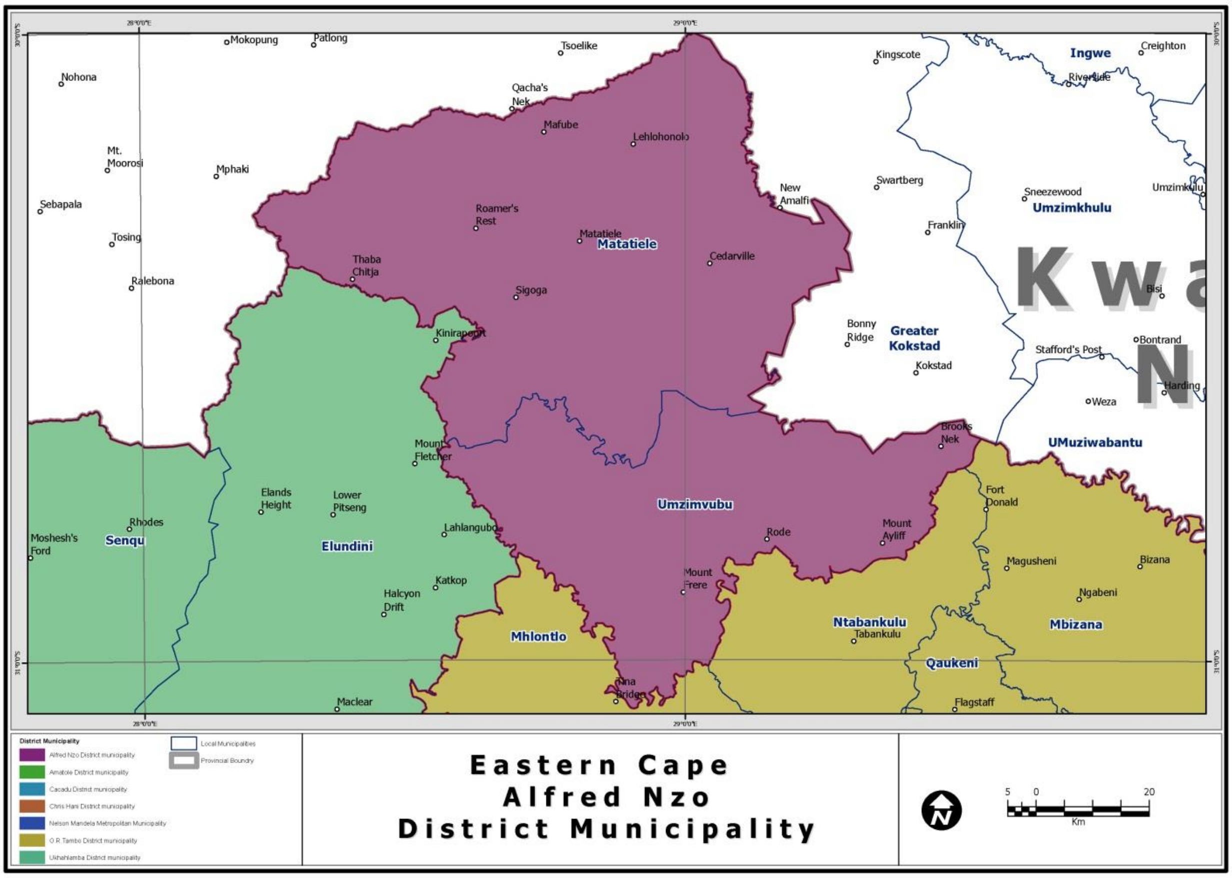

Figure 3.1: A map of the Alfred Nzo District Municipality, showing the Matatiele Local Municipality.

Dairy farming is the main activity in Matatiele and Maluti; there is a considerable number of smallholder farmers who are producing milk. This was enhanced by the Heifer project that donated pregnant Heifers to residents of the two towns (IDP 2013).

3.3. STUDY DESIGN

A cross-sectional descriptive survey was conducted for this project. The cross-sectional study design was chosen because it is cost and time effective. The study applied a combination of quantitative and qualitative methods. The qualitative methods included focus group discussions and transect walks, whilst the quantitative methods were in the form of a quantitative survey, including laboratory analysis of milk samples.

3.4. STUDY POPULATION AND SAMPLE SELECTION

The study population was 150 smallholder farmers from the Matatiele Local Municipality. Purposive sampling was used to select the participants. The main inclusion criterion was willingness of smallholder and/or emerging farmers to participate in the study and that they were actively producing milk. Within the purposive sample of farmers, simple random sampling was used to select 150 smallholder farmers who participated in the study. The milk samples used in the study were selected by stratified random sampling.

3.5. FIELDWORKER RECRUITMENT AND TRAINING

Three enumerators from Matatiele were employed to assist with conducting the interviews and completing the questionnaires. The researcher used the first day of data collection to train the enumerators on administering the questionnaires.

3.6. DATA COLLECTION

A pre-tested questionnaire with close-ended questions was administered to dairy smallholder farmers. The questionnaire was written in English and translated to Sotho (Appendix A). Focus group discussions (FGDs) with the sampled farmers and their household members were conducted. Five FGDs were conducted; the average size of each focus group was seven persons. A focus group discussion guide was developed in English and then translated to the local languages of the study area. Appendix B is the focus group discussion guide in English. The FGDs were facilitated by a trained facilitator who spoke the local languages. The discussions were recorded and transcribed after the discussions.

Transect walks were conducted at farms from which milk samples were to be collected. The transect walks included an observation of the milking process- milk handling and hygiene practices were documented using a pre-constructed checklist (Appendix C). Samples of the raw fresh milk were collected aseptically from the farms of the sampled farmers, transported, in cool conditions ($\leq 4^{O}$ C), to the University of KwaZulu-Natal where microbial analysis was done. Milk sampling, collection, and analysis are described with detail in Section 5.3.2.

3.7. DATA CAPTURING, PROCESSING AND STATISTICAL ANALYSIS

Data from the questionnaires was captured at the end of the data collection period. The data was captured into the SPSS system and the system was used for analysis. One questionnaire was rejected due to incompletion. The data was found to be acceptable and required no cleaning. Tables 3.1 below illustrated how the data was analysed.

Table 3.1: Analysis of Data.

Objective	Data To Be Collected	Data Collection Tool	Data Analysis
To assess the effect of indigenous knowledge systems -based hygiene and safety practices on milk quality and safety in terms of exposure to risk for contamination and guidelines set to manage safety & quality of milk.	Cow management, Cow husbandry, Use of Indigenous knowledge Systems	Questionnaire Focus group discussions	Descriptive statistics SPSS Content analysis
To assess the handling practices of selected dairy products (raw milk, & fermented milk).	Handling practices of the raw milk and fermented milk	Descriptive Observation Questionnaire	Descriptive statistics SPSS
To assess the smallholder farmer's knowledge and awareness of the hygiene and handling practices.	The smallholder farmer's knowledge and awareness of hygiene and handling practices	Questionnaire	Descriptive statistics SPSS
To assess the microbiological load and safety of selected dairy products.	Microbial load of the samples of raw milk, boiled milk, and fermented milk	Total Bacterial Count (TBC) test	South African Legal standards

3.8. RELIABILITY AND VALIDITY OF DATA

The questionnaire was pre-tested to assess whether the farmers understood its questions and to eliminate ambiguity of the questions. The researcher (author of the current report) ensured that the samples were kept at 4˚C during transportation.

3.9. REDUCTION OF BIAS

Bias was reduced in the study by not informing the participants on the exact day on which transect walks would be conducted at their farms to increase the probability of the events observed being similar to the daily practices. The research assistants were trained on administering the interviews to avoid the research assistants wording the questions such that they solicited for certain answers.

3.10. ETHICAL CONSIDERATIONS

Permission was granted by the department of agriculture through a meeting and ethical clearance was given by the Humanities & Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (Ethical clearance reference number HSS/1242/015M). Please refer to Appendix D for the ethical clearance letter.

SUMMARY

This chapter described and explained the study design and outlined the methodology applied in the current study. The data collection tools were described. The chapter also described the approaches used in sample selection, questionnaire formulation, data collection procedures, data capturing, analysis, and interpretation for each study objective. The study was divided into two investigations, which are reported in two separate research chapters, Chapter 4 and Chapter 5.

CHAPTER 4: MILK UTILISATION PATTERNS AND INDIGENOUS KNOWLEDGE SYSTEMS (IKS)-BASED PRACTICES IN SMALLHOLDER DAIRY FARMING: A CASE STUDY OF MATATIELE, SOUTH AFRICA.

4.1. ABSTRACT

Self-reliance in milk and effective utilisation of the milk is vital to the food and nutrition security of population groups, including resource poor rural communities, because milk is almost a complete source of essential nutrients for the human body. However, milk is highly susceptible to microbial contamination and proliferation and hence strict hygiene is critical in dairy farming for the achievement of milk quality and safety, especially if modern markets are targeted. Unfortunately, rural dairy farmers are generally resource-poor. Consequently, their dairy farming practices are likely based on affordable indigenous knowledge systems (IKS), which could have hygiene shortcomings, but this seems not to have been subjected to a rigorous study in South Africa. A case study with a sample of 150 rural smallholder dairy farmers from Matatiele in the Eastern Cape province of South Africa was conducted using questionnaires and focus group discussions to explore their milk utilisation patterns and evaluate the potential impact of the supposed IKS-based dairy practices on milk quality and safety. Findings of the investigation indicated that milk was well utilised as a household food source by the majority of the farmers (94%), and most of the farmers preferred consuming raw milk (79.3%). It was found that 58% of the farmers exclusively used IKS-based practices, whilst 42% of them applied modern science due to having received formal training. However, there were few significant differences in the dairy farming practices of the trained and non-trained farmers. The majority of the trained farmers preferred to continue using IKS concurrently with the science knowledge gained from formal training- this highlights the need to document the IKS used and develop methods of interfacing with modern science to enhance milk quality and safety for increased access to modern markets and thereby enhancing household livelihoods.

4.2. INTRODUCTION AND BACKGROUND

Dairy farming has historically been a major agricultural activity in Africa (Baiphethi & Jacobs 2009). Smallholder dairy farming has always been a major contributor in maintaining and improving the food and nutrition security situation (Mhone *et al.* 2011). Smallholder dairy farming contribute in providing sustainable availability and accessibility to milk and milk products and this is particularly so for subsistence farmers; while the farmers that sell their produce locally have additional benefits of providing a source of income for their households (Baiphethi & Jacobs 2009).

The increasing demand for milk and milk products reported globally has resulted in a number of African countries, including South Africa, putting emphasis on smallholder dairy farming as an additional source of milk for the formal commercial markets (Cusato *et al.* 2013). This has successfully occurred in some African countries, such as Kenya and Zimbabwe (Chepkoech 2010; Mhone *et al.* 2011). Milk is highly susceptible to microbiological contamination and proliferation (Cerva *et al.* 2014) and high risk of loss of product quality and safety (Claeys *et al.* 2013). Thus, strict standards for milk quality and safety are set by the formal commercial dairy markets. Unfortunately, rural smallholder dairy farmers are generally resource-poor, which results in the majority of them failing to achieve the quality and safety standards of the formal commercial dairy markets (Mhone *et al.* 2011; de Vries 2012). This deprives the farmers of a significant and sustainable source of income (Mapekula *et al.* 2009; Mosalagae *et al.* 2011), which would contribute to their food and nutrition security.

Dairy cow husbandry, milk handling and hygiene practices have a direct impact on the quality and safety of milk (Lues *et al*. 2012). Dairy cow husbandry can affect the health of the cow, including the susceptibility of its udders to microbial infection (Lues *et al.* 2012). Poor milk handling and hygiene practices increase the probability of contamination of the milk by microorganisms (Cerva *et al.* 2014; Mdegela *et al.* 2006; Lues *et al*. 2012; Mhone *et al.* 2011; Papademas & Bintsis 2010). Unfortunately, it is often reported that the low profitability of rural smallholder dairy farming results in the farmers being so resource-poor that they can barely afford to achieve and maintain minimum standards of cattle husbandry and hygiene practices for milk handling and processing, as set by the formal commercial dairy markets (Mhone *et al.* 2011; Papademas & Bintsis 2010). Figure 4.1. provides a conceptual framework for the relationship between farming operations and possible hurdles encountered by smallholder farmers in their efforts to utilise dairy farming as a significant contributor of food and nutrition security.

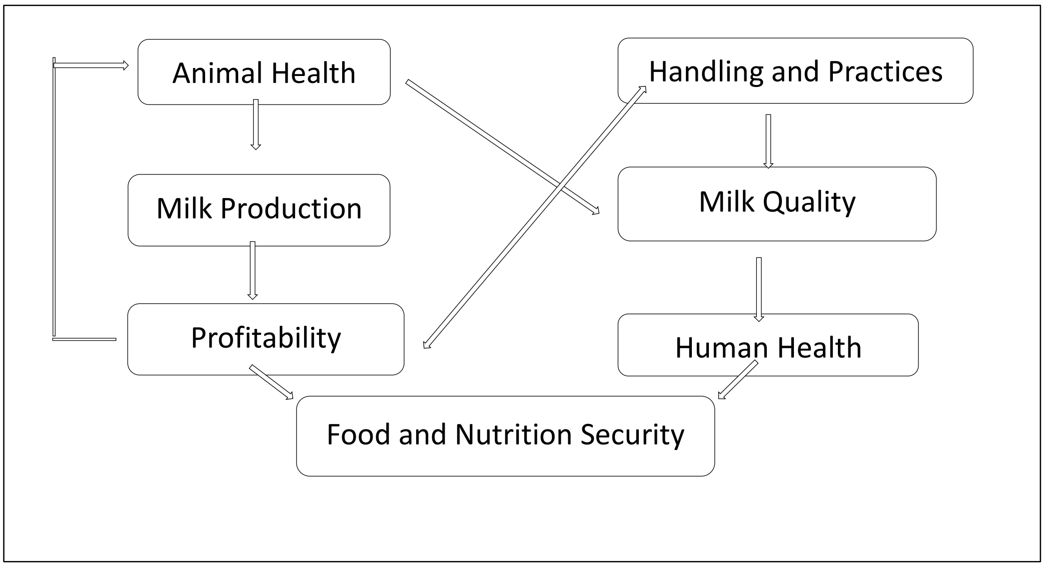

Figure 4.1: The conceptual framework of the dairy farming activities that affect the food and nutrition security potential of smallholder dairy farming.

The animal husbandry, milk handling and processing practices of rural smallholder dairy farmers in South Africa most probably rely predominantly on indigenous knowledge systems (IKS) as has been found to be the case in other African countries (Brown 2004; Njuki & Sanginga 2013). In other African countries, though subjected to limited studies, it has been found that the IKS-based practices have sustained dairy farming in these rural and remote areas where people have no formal training. Use of the IKS-based dairy farming practices have not only been reported to be an important contributor to the livelihoods of people living in the rural areas, but also to have a positive impact on the environment (Brown 2004; Njuki & Sanginga 2013). While dairy farming practices that are based on modern science are effective at achieving the milk quality and safety standards set by the formal commercial market, they may have negative effects on the environment and are generally not economically feasible and sustainable for the rural small holder dairy farmer (Brown 2004). Documenting and evaluating the IKS-based practices of smallholder dairy farmers could be useful for their preservation, promotion and enhancement of their effectiveness, for example by interfacing them with modern science where possible and necessary. It seems that in South Africa, the use of IKS in dairy practices by rural smallholder farmers has not been subjected to a rigorous study. The purpose of this study was to explore the milk utilisation patterns among rural smallholder farmers in the Eastern Cape province of South Africa and evaluate the potential impact of the supposed IKS-based dairy practices on milk quality and safety. The animal husbandry, milk handling and hygiene practices of smallholder dairy farmers were studied to identify IKS-based dairy practices. An additional objective was to investigate the perceptions of the farmers on milk quality and safety, and their perceived constraints and benefits of using IKS in dairy farming.

4.3. METHODOLOGY

4.3.1. Study area

The study was conducted in the Matatiele Local Municipality, Eastern Cape Province of South Africa. The municipality consists of three towns namely Matatiele, Cedarville and Maluti. The study was conducted in the Matatiele and Maluti towns only. The two towns are predominantly considered to be rural areas, with townships and areas with dispersed rural settlement patterns; populated by Sotho and Xhosa people. Sotho and Xhosa are the main spoken languages.

4.3.2. Study design and data collection

A cross-sectional descriptive survey was conducted. A randomly selected sample size of 150 smallholder dairy farmers was selected over a period of 2 weeks. Data collected included milk utilisation patterns; observations of the milking practices, cattle management, milk handling and storage (refer to Appendix A).

Milk utilisation patterns were explored using questionnaires, and the questions were further discussed during FGDs. Information on milking practices, cattle husbandry and milk storage was collected using questionnaires, and transect walks were conducted using a pre-constructed checklist to assess the farmers' actual practices.

Focus group discussions were conducted to assess perceptions of the smallholder dairy farmers and their household about milking hygiene and practices. Five focus groups, each containing 7 to 10 people were conducted. A pre-tested questionnaire was administered to the 150 participants to determine their knowledge and awareness of the acceptable milk handling and hygiene practices as well as establish whether IKS was used in these practices.

4.3.3. Data analysis

Descriptive statistics were calculated for the quantitative data; questionnaires were coded and data the captured onto spread sheets of the IBM Statistical Package for Social Sciences (SPSS) 23. The data was then analysed using descriptive statistics and the Chi-square tests. Frequencies and percentages were used to describe trends and patterns emerging from the data, and the Chi-square test was used to determine if there was any association between agricultural and milking practices, and the farmer's source of knowledge. The recordings from the focus group discussions were transcribed and the information was subjected to content analyses.

4.4. RESULTS AND DISCUSSION

4.4.1. Demographic data

The mean (SD) number of milking cows per farm was 6.45 ± 10.17 cows. The majority of the farmer owned ≤10 cows as seen in Table 4.1 below. Sixty-five percent of the cows were Nguni (Indigenous) breed cows, 34% were crossbreed and exotic breed cows. Males were predominately named the owners of the cows, even by the wives who were married in community of property to the farmers. Previous studies conducted in Kenya, Tanzania and Mozambique (Kristjanson *et al.* 2010; Njuki & Sanginga 2013) reported a shift on the ownership of cows inclining towards women. The focus group discussions of the current study revealed that women were increasingly becoming aware of their ownership rights, although they were reluctant to admit to having equal ownership of the cows. Traditionally, women largely own and manage the small animals, such as chickens and goats, and are often limited to only managing the larger animals such as cows, while they are not involved in decision making (Njuki & Sanginga 2013).

Table 4.1: Demographic data (n=150)

VARIABLES	N	%
Age Range:		
20 to 35	9	6.1%
36 to 44	11	7.3%
45 to 54	29	19.3%
55 to 64	48	32%
>= to 65	53	35.3%
Gender:		
Female	53	35.3%
Male	97	64.7%
Level of education:		
No formal education	8	5.3%
Primary	52	34.7%
Secondary	68	45.3%
Tertiary	22	14.7%
Employment status:		
Employed full-time	8	5.3%
Employment part-time	13	8.7%
Unemployed	102	68.0%
Self-employed	27	18%
Household income:		
R 0-1000	23	15.3%
R 1001-R2000	43	28.7%
R 2001-R3000	41	27.3%
>R3000	43	28.7%
Owner of the cows:		
Female	50	33.3%
Male	87	58%
Both (married couple)	13	8.7%
Number of cows owned:		
1-10	138	88%
11-30	12	8%
>31	6	4%

The mean (SD) of the participants age was 58 ± 14.3, and 86% were above 45 years (as seen in table 1 above). Although the younger generation was in the minority, it was interesting to see that there was an emerging recognition of equal ownership amongst the younger generation. The highest level of education for the majority of the participants was High School (45.3%) and Primary School (34.7%) respectively; these participants did not complete their High School. The low education level of the respondents posed constraint to attaining sustainable jobs. Consequently, the majority of the respondents were unemployed (68%) and solely depended on agriculture for livelihood. The high unemployment rate was reflected in the total household income levels, where a majority of the participants' household had a monthly income of

<R3000 as seen in table 1 above. Therefore, dairy farming poses to be an opportunity to enhance household food security and to maximise livelihood options.

4.4.2. Milk Utilisation

The majority of the participants consumed the milk that they produced as seen in Table 4.2 below. Only 6% of the participants sold all the milk they produced; while 27% sold and consumed the milk, and 67% exclusively used the milk for their household consumption. Milk was predominately consumed raw by the participants. The focus group discussions revealed that the prevalence of raw milk was due to sensory attributes such as taste, as well as the belief that some beneficial nutrients in milk are lost during pasteurisation. Consumption of fermented milk was common among the participants.

Table 4.2.: Use of milk in the household.

	Yes		**No**	
	N	%	N	%
Milk used in the household	141	94.0	9	6.0
Consume milk raw	110	79.3	31	20.7
Consume the milk fermented	106	70.7	44	29.3

Consumption of raw milk was very high in this study, and this was similar to various studies in the Eastern Cape, Free State, Zimbabwe and India that reported that the majority of the participants preferred raw milk to pasteurised milk (Leus *et al.* 2010; Mapekula *et al.* 2009; Mhone *et al.* 2011; Neeta *et al.* 2015). Raw milk was also believed by some participants to produce fermented milk of better quality than pasteurised milk. The preference of raw milk stresses the importance of good hygiene and handling practices because there is no processing of the milk that destroys the pathogenic and most spoilage bacteria in milk. Most of the participants' preference of raw milk was based on taste, and convenience, which is similar to a study conducted in a rural area in India, where 62.4% of the surveyed were reported to consume raw milk due to the convenience (Neeta *et al.* 2015). The high preference of raw milk is of great concern because raw milk has been identified as a major dairy based communicator of pathogenic bacteria, resulting in morbidity and mortality (Oliver *et al.* 2009).

4.4.3. Animal husbandry and milking practices

The majority of the farmers (58%) exclusively used indigenous knowledge to inform their practices. Although 42% of the farmers claimed to have received formal dairy farming training, only 1% of the trained farmers strictly used the information received from the training. The farmers who attended the formal training were of the opinion that the information shared at the training was similar to the indigenous knowledge that they were using. The only difference perceived was that the trainings were more structured, conducted in formal settings and offered details on how the practices were beneficial. These farmers also argued that their experience and prior knowledge should be valued and integrated into formal training programmes. The farmers strongly believed that they carried valuable traditional, indigenous wisdom from their elders and they were custodians of IKS, and that presented a responsibility to transfer it to future generations.

As reported in various studies, IKS is usually undervalued and not recognised as an effective method to inform and educate farmers (Brown 2004). This is due to a lack of documentation and inclusion of IKS in policies and educational systems. As noted by Brown (2004), training based on modern science and modern technologies have costly demands that farmers are unable to adhere to and afford. The findings of this study concurred with opinions and concerns of Brown (2004) and Leus *et al*. (2012) that the modern dairy farming practices recommended to the rural smallholder farmers was not available and accessible to them. Brown (2004) further observed that the modern dairy farming practices recommended to achieve the standards of the formal commercial markets generally did not take into consideration the resources and culture of the community.

The majority of the smallholder farmers (96%) did not have milking sheds; they milked the cows in kraals that had no sheltering structures. The farmers who had received formal training in dairy farming reported to have put sheltering materials/roofing on the kraals (35.3%); with only 7% of the farmers reporting not to have put sheltering materials, and none of the farmers managed to cement the floors of the kraals due to financial constraints. Focus group discussions revealed that the training that the farmers received had a mandatory instruction to construct sheltered and cement floors on the kraals.

The formal training which was based on modern science proved to be costly for the poor-resource farmers as none of them had cemented floors in the sheds, more so; only 18 % of them had a draining system. There was a statistical difference (where p=0.00) illustrating that more of the trained smallholder farmers had draining systems, as compared to the farmers that use indigenous knowledge. The indigenous farmers reasoned that it was because they did not use water to clean kraals so there was no need for draining systems. Leus *et al*. (2012) and Chepkoech (2010) caution that poor hygiene quality of the milking sheds increases the probability of environmental contamination of the milk. Moreover, Abera et al. (2012) reported that 45.8% of the cattle kept in kraals with soil floors had mastitis compared to 19% of the cattle kept in concrete sheds, thus illustrating a higher prevalence of mastitis in cattle not kept in the recommended concrete or cement floors. However, in this study there was no significant relationship between the shed floor type and the prevalence of mastitis and udder infections.

As opposed to the farmers who attended training, the farmers who exclusively used indigenous knowledge predominantly had open kraals. This was similar to a study conducted in a peri-urban area in Bloemfontein by Leus *et al*. (2012), reporting that 62.3% of the farmers milked their cattle in kraals with no roofing, 15% in milking sheds that they constructed by themselves and 13% in open fields. It is important for the smallholder dairy farmers to have sheltered sheds even if they are simplified structures, to reduce the risk of contamination during milking. There was a significant difference (p=0.00) between the farmers with and without training on the availability and use of a sheltered living area.

4.4.4. Cleaning of the milking environment

Twenty-five percent of the farmers that exclusively used indigenous knowledge cleaned the sheds yearly; 8% of them cleaned once or twice a day; and 9% reported to never clean. Conversely, the trained farmers reported to clean the cow sheds twice a day (10%) and once a day (14.7%) predominantly, with only a few reporting to clean yearly (6%) and to never clean (2%). There was a significant difference (p=0.00) illustrating that the trained farmers cleaned the cow shelter more frequently than the farmers that use indigenous knowledge to inform their agricultural practices.

The focus group discussions (FGDs) revealed the informed reason behind the indigenous practice of cleaning the sheds yearly; as a system using the cow dung as bedding to protect the cows from the cold. The practice was also appreciated for manure production which significantly contributed to the well-being of the household. The manure was traditionally used as a fertiliser for crop production. There was a system in place where the cows would be taken to the harvested fields to facilitate the nutrient fixation cycle, fertilising the soil for the next season of seeding. The chief or community leaders informed the members of the fields that were harvested and all the cows in the community were sent to those fields. The cow dung was also used for housing; the dung is used in the flooring of the hut and walls. As stated by Kunene *et al.* (2014) the use of cow dung on flooring and walls of the hut contributes to regulation of ambient temperature. In this study, these huts were used as milk storage systems especially during winter seasons.

Although cleaning is necessary for the cows to promote environmental hygiene, the use of the dung is essential in maintaining and improving the wellbeing of the households. There is a need to interphase the indigenous knowledge systems with the recommended agricultural practices.

4.4.5. Cow hygiene

Sixty-nine percent of the farmers trimmed the hairs of the cow tail and 31% did not. There was no significant difference (p=0.12) between the farmers that attended training and those who were exclusively using IKS on their practice of trimming the tail. It was mentioned through the FGDs that the tail was left untrimmed to allow the cow to fight off flies. Secondly, the farmers used the tail to wipe their hands during milking, and this was practised by both the trained farmers and the indigenous farmers.

There was no statistically significant difference between farmers that had received training and those that use indigenous knowledge in their practices of washing the udder and teats of the cows before milking, and in using water to wash the udder and the teats. There was however, a statistical difference (p=0.02) observed in the farmer's practice of using a clean cloth to wash the udder and the teats of the cows. The majority of the farmers (70.7%) used a clean cloth to wash the udder and teats before milking whilst 29% did not; the majority of the farmers that reported not to use a clean cloth were indigenous farmers who preferred to use the tail. This is a bad practice as it increases the risk for faecal contamination which could cause diarrhoea and udder and teats infections.

Strips cups are highly recommended by Milk SA (2014), nonetheless, in this study all the farmers did not have strip cups, but they used IKS and methods to test the milk beforehand by milking small amount onto the floor or the feet of the cow (57.3%). This was a good practice reflecting IK intelligence even though milking onto the floor is not recommended. IKS shows wisdom, intelligence and scientific knowledge in maintaining the health of the udder and teats. This was illustrated in the IKS practice used by 92% of the farmers in which the calf was allowed to suckle on the cows after milking as a disinfecting technique; this was done in place of the chemical disinfectants with which they had limited access to smallholder farmer's perceptions on milk hygiene and safety.

Ninety-three percent (93%) of the smallholder dairy farmers had knowledge of the importance of personal hygiene and the effect of personal hygiene on milk quality and safety. However, there was a minority who did not believe that personal hygiene had an effect on quality and safety of milk. This practice of personal hygiene was embedded on to the cultural norms and expectations; the focus group discussions revealed that culturally, a person who is not neat was shunned and given negative names such as *'Yinuku' in isiZulu, 'Ixelegu' in Xhosa* and *'Mabohlaswa'* in Sotho. The giving of names was done to encourage community members to maintain personal hygiene.

It was also pleasing to notice that the majority of the famers were aware of the effects of consuming contaminated milk on human health. However, 14% of the famers still lacked the knowledge as they assumed that contamination was equivalent to fermentation. This was due to the lack of knowledge of the difference between the beneficial microorganisms that are responsible for the fermentation process and pathogenic microorganism that can cause illness. Experience has shown that farmers are mainly reliant on the physical quality attribute to assess the quality and safety of milk such as visual, smell and taste with no capacity to assess using other scientific methods (Vijayan & Prabhat 2015).

The discussion held with the farmers emphasised that the suspected contaminated milk was strictly given to animals that are not used for human consumption, such as dogs and cats. Although, not much explanation and justification was provided for this practice, it showed that there was awareness of the adverse effects of directly and in directly consuming contaminated milk on human health and livelihoods. Many studies conducted on IKS argue that there is too much trust in science alone and insufficient recognition of IK, there is a need to acknowledge that IKS has successfully maintained agricultural production for rural households for decades. There is however, a need to enhance and record IKS, and recognition of the significant IKS knowledge gaps that still need to be further investigated and documented, to address the limitations observed.

4.4.6. Influence of modernisation on IKS

Urbanisation and modernisation has resulted in a generation that is losing indigenous knowledge (Wahab *et al.* 2012). People are moving into urban environments that limit the ability to utilise indigenous knowledge systems and incorporate them in their daily practices. Although some of the study population lived in rural areas, some of their dairy practices were influenced by modern systems.

4.4.6.1. Preservation methods

In this study, the smallholder dairy farmers stated that fermented milk was still a fundamental part of their diet. However, the method of preserving the milk had changed due to the lack of elements used to produce the traditional containers, and the loss of knowledge on how to make the containers. In the modern time, the farmers ferment their milk by keeping the milk in a plastic container and exposing it to the sun for a few hours, and once it has curdled they separate the casein from the whey milk. The fermentation of milk was reported to occur in the summer seasons only; the farmers stated that the temperatures in winter were too low for fermentation. They then use the casein or curd as *amasi* or *mafi* (fermented milk) and used the whey milk in meal preparations, particularly for the children. The farmers all had knowledge of the importance of the nutrients in whey milk and this knowledge rooted from generational wisdom.

The Sotho and Xhosa people indigenously used traditional containers such as milk sacks, calabashes, clay pots and stone jars to produce fermented milk (Beukes *et al.* 2001). The calabashes were seeded with microbial inoculum before fermentation and this resulted in mafi or amasi (fermented milk) that was rich and smooth due to the elimination of undesirable microorganisms by a gradual selection facilitated by the fermentation process (Beukes *et al.* 2001). The traditional fermentation method required long periods of time to process and the community had adopted the current method because it required less effort and minimal time. However, the participants reported that the modern preservation method compromised the quality attributes such as taste, texture and colour.

4.4.6.2. Storage methods

Traditionally the milk was stored in clay pots and kept in the huts. These storage methods were believed to improve the shelf-life of the milk and to enhance it taste. The farmers believed that there was a system of managing the utilisation of the milk within an acceptable period of time that would not expose the milk to contamination and spoilage. In the modern time refrigerators are mainly used; and in this study area they still used the huts for storage.

4.4.6.3. Traditional indigenous wisdom

The farmers also stated that their indigenous ways are continuing to be lost due to the disinterest of the younger generation. Majority of the farmers were older people, with only 13.6% of the smallholder dairy farmers below the age of 45. Some of the farmers stated that the younger generation lacked interest of dairy farming due to the manual input required at the farms. Wahab *et al.* (2012) stated that the pressures of modernisation have led to the loss of indigenous knowledge systems. The disinterest of the younger generation in the indigenous knowledge system is a major contributor to the loss of the traditional systems. Additionally, there is an increasing need for a short turnover of products and this has led communities that adopt new, more time efficient methods, even at the expense of quality.

The influence of modernisation on IKS is undeniable. While indigenous knowledge is still used in the community, the adoption and respect for IKS is declining. Different details and aspects of IKS are being lost from generation to generation. There is thus an urgent need to further investigate and document IKS, as well as support IKS to encourage and illustrate the importance of IKS to the younger generation.

4.4.7. Recognising Indigenous Knowledge Systems into development and policies.

The farmers in this study raised several concerns through the focus group discussion about development projects that are usually targeted to improve their wellbeing. The farmers were of the opinion that in their situation as dairy farmers, their experience evoked concerns and emotions presented in Table 4.3.

Table 4.3: Focus group discussion findings

Theme/s	Concepts	Verbatim quote/s
Concerns	• Underestimation of IK wisdom and intelligence • Top down approach • Indirect encouragement of dependency syndrome • Unrealistic	• *'The development projects should first investigate and assess the community before implementation, so they can realize that certain cow breeds cannot survive in these harsh environments.'* • *'No one cared about our opinions, they just treated as us children, giving instructions'* • *'We can never sacrifice household money for animals, we have grazing land…we have experience of looking after our animals…but do they care?'*
Emotions	• Mistrust • Overpower	• *'The project has repeatedly promised to support us and this has not happened.'* • *'Limited resources are provided and the community members fight to get access to the resources and this is negatively affecting relations in the community.'* • *'They make decisions but it is us who have to look after our own animals.'*

In this instance the farmers referred to a dairy related development project that was within their community. Some of the farmers were the beneficiaries, although the intentions were of the project were appreciated, the project was viewed as imposing costs instead of improving their well-being. For example, the instructions of the projects required a great deal of resources such as the procurement of feed to comply with the zero grazing feeding system; building a sheltered living area with roofing and cemented floors for the cows; as well as limiting the cow to the yard to prevent crossbreeding and spread of diseases. The project provided the households with seeds of crops to produce for feed. The feed production took about 3 months while farmers were waiting for the feed to be ready, the cows did not have any feed. The farmers had to steal money for cow feed from the household money for food. This had a negative impact on the household food and nutrition security. The farmers argued that their IKS was disregarded. Subsequently, the project failed because it was costly and impractical for the dairy farmers who were the beneficiaries. Most of the beneficiaries sold their cows because they were more of a financial liability than an asset. On the contrary, the dairy farmers who were independent of the project still to date have their cows and the cows are productive to a certain degree.

These study findings confirm the various reports reporting that the experience of the community and recognition of indigenous knowledge systems enhances the ownership and sustainability of the development projects (FAO 2000). The understanding of the indigenous knowledge systems could allow for interventions to complement and enhance the development project.

Interventions aimed at community improvement and assistance are often unsuccessful due to the lack on guidance and support for indigenous knowledge systems. As stated by Tripathi & Bhattarya (2004), needs assessment and incorporation of the indigenous knowledge systems in developing projects would be highly valuable through the use of policies supporting IKS. Projects for people should reflect on the needs of the intended beneficiaries, what is available and accessible to them. As observed in the study, people in the community still base their agricultural practices on indigenous knowledge. The IKS have sustained their access to milk and milk products and this has a vital impact on food and nutrition security.

4.5. CONCLUSION

Milk was well utilised as a basic food item by a majority of the farmers and their households. Milk was consumed raw, both as fresh and fermented milk. The indigenous knowledge systems are utilised in the Matatiele community. The use of these systems is a part of the lifestyles and belief systems of the people. The handling and hygiene practices of the smallholder dairy farmers using indigenous knowledge to inform their practices were mostly similar to those of the people who had received formal training. This however could be attributed to a majority of the trained farmers using that knowledge concurrently with indigenous knowledge. Additionally, some of the practices were in line with the recommended agricultural practices.

IKS was however limited in regard to acceptable cattle husbandry and hygiene; the limitations could be a result of knowledge gaps on indigenous knowledge in the community. There is a need to further investigate indigenous knowledge system to address the knowledge gaps observed in this community. IKS are a basis for livestock production and future development; interventions should thus be inclusive of the local practices, beliefs and traditions. The interventions and projects intended for rural communities should additionally use technologies that are socially accepted, economically feasible, with low risks for the farmers.

IKS are beneficial and there is a need to build onto the systems, and not negate the use of the systems. People were more inclined to use the indigenous knowledge systems than in adopting the modern systems and disregarding IKS. It is thus evident that interventions designed for communities need to be local based interventions in order to significantly improve food and nutrition security.

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CHAPTER 5: ASSESSING THE MILK HANDLING AND HYGIENE PRACTICES OF RURAL SMALLHOLDER DAIRY FARMERS IN MATATIELE, EASTERN CAPE, SOUTH AFRICA AND THEIR IMPACT ON THE MICROBIAL QUALITY AND SAFETY OF MILK

5.1. ABSTRACT

Milk can be contaminated before, during and after milking. The person milking the cow, the environment, the animal and the utensils used for milking are agents of contamination. Neglect of the recommended hygienic practices could result in contamination which negatively affects consumer health. The purpose of this study was to investigate the milk handling and hygiene practices and the microbial quality and safety of the milk, of rural smallholder dairy farmers in the Matatiele Local Municipality of the Eastern Cape, South Africa. A cross-sectional study was conducted, using integrated research methods. A sample of 150 participants was randomly selected to participate in a series of five focus group discussions, which were complemented by transect walks in which the milk handling and hygiene practices of the farmers were observed directly. Milk samples were collected from 19 smallholder farmers randomly and assessed for microbial quality and safety by determining total plate and coliform counts. Some 69% of the sampled farmers (n= 150) had good knowledge of the recommended hygiene practices in dairy, transect walks revealed low compliance to the recommended practices. Foreign substances such as grass, soil and glass were not regarded as contaminants; they were just sifted out, although the milk was generally consumed raw. Only 21% of the milk samples did not exceed the South African legal limit for total plate count in raw milk (5 x 10^4 cfu/ml), these samples had total plate counts ranging from 8.8 x 10^5 to 3.3 x 10^{10} cfu/ml. About 84% of the milk samples exceeded the legal limit for coliform counts (10 cfu/ml), and about 58% of the milk samples tested positive for *E. coli*. Although a fairly high percentage of the farmers had knowledge of the recommended dairy practices, resource constraints impeded them from applying the recommended practices. Consequently, the majority of the farmers produced milk of poor quality and safety, which compromised the health of the household members and limited their access to the lucrative formal dairy markets. Interventions targeted at improving the quality and safety of milk produced by smallholder dairy farmers should take into consideration the resources available and accessible to the farmers.

5.2. INTRODUCTION

Milk is a highly nutritious food item that forms an essential part of the human diet (FDA 2012). It is a very important source of protein and it is rich in micronutrients such as vitamin A, Thiamin (Vitamin B1), Biboflavin (Vitamin B2), calcium, zinc and magnesium, which significantly contribute to promoting and maintaining human health (FDA 2012). The high nutritional content of milk makes it highly susceptible to microbial contamination and proliferation (Neeta *et al.* 2015; Swai & Schoonman 2011).

Milk can be contaminated with microorganisms before, during and after milking. The contamination can occur through agents such as the person milking the cow, the environment, the animal, and the utensils used for milking (Swai & Schoonman 2011). Both spoilage and pathogenic bacteria are known to contaminate and proliferate in milk (Cerva et al. 2014). Spoilage bacteria change the sensory attribute of milk such as the colour of milk, the taste of milk as well as the smell of milk, which could result in milk that is unacceptable to consumers (Mhone et al. 2011). Contamination by spoilage bacteria thus results in undesirable food product for consumers, while pathogenic bacteria can pose a health hazard. *Escherichia coli*, *Staphylococcus aureas*, *Salmonella sp.* and *Campylobacter sp*. are pathogenic bacteria that have been identified as the main causes of milk borne disease outbreaks in humans (Mhone et al. 2011). *E. coli* has been found in numerous milk samples from smallholder farms in developing countries such as Zimbabwe, Tanzania and India (Mhone et al. 2011; Neeta et al. 2015; Swai & Schoonman 2011). *E. coli* is an indicator of prevailing poor hygiene conditions and faecal contamination (Mhone et al. 2011).

The milk is likely to be contaminated when the recommended milk handling and hygienic practices are not adhered to. According to Millogo *et al.* (2010), milk hygiene is neglected in most dairy activities thereby compromising consumer health. Maintaining good hygienic environments in dairy farms; sanitation and to promote hygiene among farmers is fundamental, especially in rural communities where consumers are reported to prefer raw milk to pasteurised milk (Swai & Schoonman 2011). Furthermore, microbial contamination of milk reduces the opportunities of the dairy farmer to participate in lucrative formal dairy markets, which set strict, high standards for milk quality and safety (Mosalagae et al. 2011).

Recommended milk handling and hygiene practices reduce costs of loss through spoilage of the milk produce, which in turn reduces the country's economic burden and increases the households' access to safe foods and nutrition security (Gran et al. 2002). Unfortunately, microbial contamination of milk produced by rural smallholder farmers in sub-Saharan African countries is of great concern. Several studies indicate that the milk produced by the rural smallholder farmers is largely used for own household consumption while some is sold locally (Gran et al. 2002).

Unfortunately, due to resource constraints, basic quality and safety management processes, such as pasteurisation are often not performed (Gran et al. 2002). Although the situation is likely the same as that of the rural smallholder dairy farmers in other sub-Saharan African countries, there is limited knowledge of the quality and safety of milk produced by smallholder farmers in the rural parts of South Africa. Little is known about whether they adhere to recommended milk handling and hygienic practices. Knowledge of the milk handling and hygiene practices could be useful in assisting the farmers to improve milk quality and safety and thereby increase their access to the formal commercial dairy markets. This study assessed the hygiene knowledge, awareness of safety, and milk handling and practices of rural small smallholder dairy farmers in South Africa. The microbiological load and safety of selected milk samples and consumer perceptions towards the quality and safety of raw milk were also assessed.

5.3. METHODOLOGY

5.3.1. Study area

The study was conducted in the Matatiele Local Municipality (coordinates 30.3422° S, 28.8061° E). The local municipality is part of the Alfred Nzo District Municipality, as seen in figure 1 below. The study was conducted in two wards within the Municipality, namely, Matatiele and Maluti. Sotho and Xhosa are the main languages used in the area. The study area is categorised as a rural area where 78% of the population do not have access to safe water (IDP 2013). Agricultural production is the main economic activity in the area, with a majority of the population unemployed (75.3%) (IDP 2013). The majority of the population in Matatiele live below the poverty line (82.7%) and HIV/AIDS is a great challenge in this area (IDP 2013).

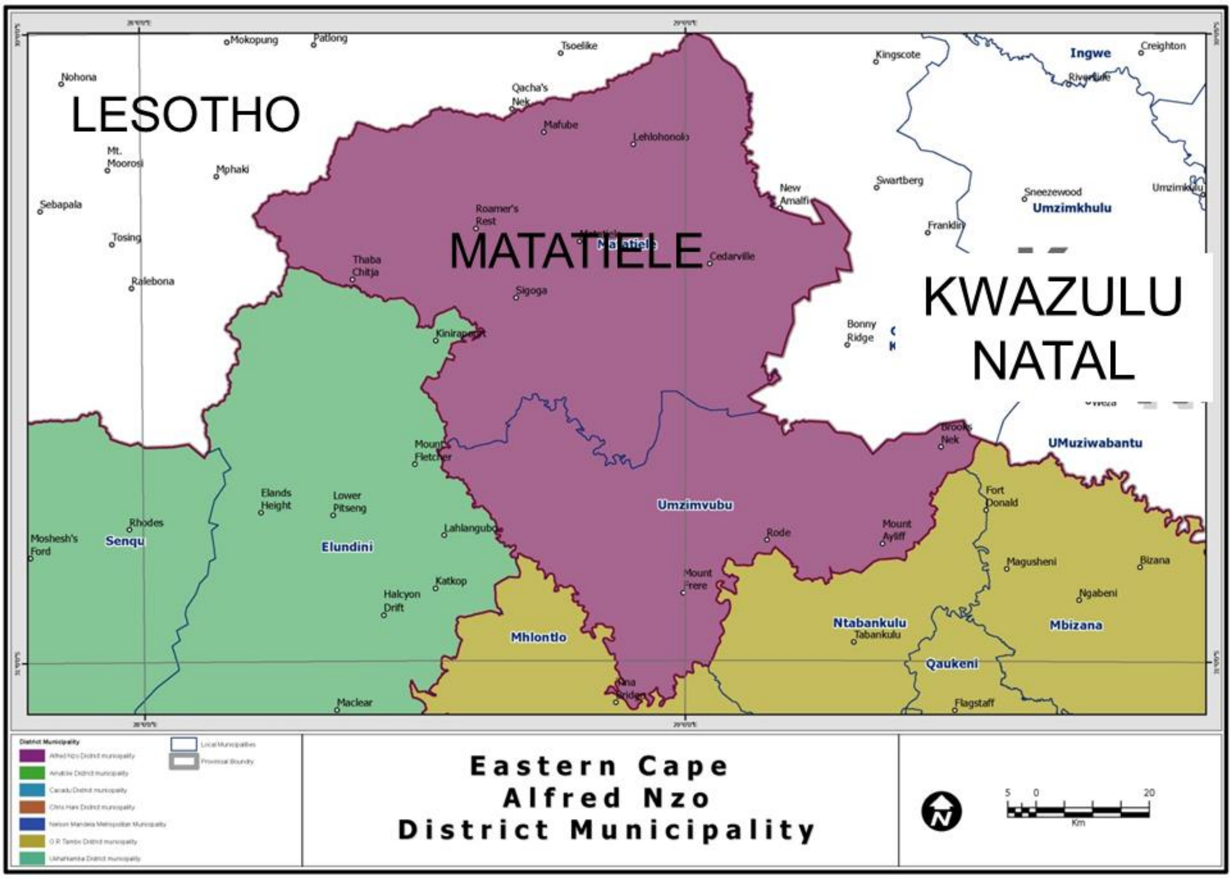

Figure 5.1: A map of the Alfred Nzo District Municipality, showing the Matatiele Local Municipality (Source: Alfred Nzo Municiplaity IDP 2013).

5.3.2. Methodology

The study was a cross-sectional study, using both qualitative and quantitative methods were used.

5.3.2.1. 5.3.2.1 Questionnaire, focus group discussions and transect walks

Data was collected using a pre-designed and pre-tested questionnaire, to assess the hygienic practices of milk and the knowledge of hygiene, as well their perception and awareness of hygiene and milk safety (Appendix A). Focus groups of a mean of 7 participants were facilitated, using pre-constructed questions to be discussed. Focus group Discussions (FDGs) were conducted to determine the perceptions of the participants on milk quality and safety, as well as further discussions on the milk handling and processing questions from the questionnaire. Transect walks were conducted to observe the milking process from the farmers across the study area.

5.3.2.2. Microbial analysis

Nineteen milk samples were collected using the random sampling method. Due to challenges encountered by the researchers in winter, the milk samples were collected only during the dry season. Even during the dry season, a limited number (19) of samples could be collected because of drought. The milk samples were collected aseptically (flame and 70% ethanol were used) into sterile glass jars. After each sample was collected, the neck of the glass jar was sterilized with a mobile flame. The researcher collected the samples wearing gloves which had been sterilised with 70% ethanol. A cooler box with ice was used to maintain the desirable temperature (approx. +4˚C) whilst the samples were being transported to the laboratory. The samples were then placed in a freezer set at temperature of -18˚C before analysis to inhibit microbial proliferation. The samples were then analysed in a microbiology laboratory.

Total microbial load

The total microbial load of the milk samples was estimated by determining total plate counts (TPC) using the spread plate method. Spread plates were prepared with Nutrient Agar and Tryptone Soy Agar. Milk dilutions of 10-0 to 10-8 were prepared, and 1 ml of each dilution was then pipetted into duplicate plates of nutrient agar and tryptone soy agar, separately. The dilutions were then spread using a hockey stick. The plates were incubated for 72 hours at 30˚ C. Colonies were counted in plates where growth was between 30 and 300 colonies. The mean colony forming units/ml of the duplicate plates was calculated after considering dilution factor. The analysis was done aseptically in a Laminar flow.

Coliform test

Coliforms were enumerated by the pour plate method using Violet Red Bile Lactose Agar (VRBL). The plates were incubated at 37°C for 24 hours as shown in Appendix D (SABS ISO 4832:1991). The violet colonies formed by coliform bacteria were then counted.

Detection of Escherichia coli (E. coli)

The presence of E. coli in the milk samples was tested by transferring 0.1 ml of the milk samples into flasks of MacConkey broths and peptone water and the incubating at 37°C and 44°C, respectively, for 2-6 days as shown in Appendix D (SANS 7251:2005 ed. 2), a sterile environment. The plates were then placed in an incubator of 37°C for 48 hours.

5.3.3. Data Analysis

5.3.3.1. Qualitative and quantitative data analysis

The data collected from the questionnaires was analysed using the Statistical Package for Social Science (SPSS 23.0) software program. Statistical analysis was done using the Chi Square test, means and standard deviations were computed). Means of duplicate microbial counts were also calculated. Qualitative data was analysed using content analysis.

5.4. RESULTS AND DISCUSSION

5.4.1. Demographic data

A total of 150 participants were interviewed, the participants consisted of smallholder dairy farmers or members of their households that met the inclusion criteria (as seen in chapter 3). Table 1 below shows the demographic data of the population. The mean (SD) of the participants' age was 58 ± 14.3, and males (58%) were the predominant owners of the cattle. The majority of farmers own less than ten cows (88%). Most of the participants were unemployed (68%), with Secondary (45.3%) and Primary (34%) school as the highest level of education. A majority of the participants had >R3000 as the total monthly income, with a mean (SD) of 5.75 ± 2.73.

Table 5.1: Demographic data (n=150)

VARIABLES	N	%
Age Range:		
20 to 35	9	6.1%
36 to 44	11	7.3%
45 to 54	29	19.3%
55 to 64	48	32%
>= to 65	53	35.3%
Gender:		
Female	53	35.3%
Male	97	64.7%
Level of education:		
No formal education	8	5.3%
Primary	52	34.7%
Secondary	68	45.3%
Tertiary	22	14.7%
Employment status:		
Employed full-time	8	5.3%
Employment part-time	13	8.7%
Unemployed	102	68.0%
Self-employed	27	18%
Household income:		
R 0-1000	23	15.3%
R 1001 – R2000	43	28.7%
R 2001 - R3000	41	27.3%
>R3000	43	28.7%
Owner of the cows:		
Female	50	33.3%
Male	87	58%
Both (married couple)	13	8.7%
Number of cows owned:		
1 – 10	138	88%
11 – 30	12	8%
>31	6	4%

5.4.2. Hygiene and handling practices of smallholder dairy farmers in Matatiele

5.4.2.1. Hygiene practices of smallholder dairy farmers

The majority (69.3%) of the participant had good knowledge of good hygiene practices as seen in Table 2 below. The participants' practices of washing hands for milking (95.3%), washing the utensils that will be used during the milking process with detergent (99.4%), washing the udder and teats of the cow before milking (96%), using a clean cloth to wipe the teats after washing them (70.7), and covering the container of milk after milking (93.4%) was high; all of which are in line with the recommended hygiene practices (as seen in chapter 2). The participants that reported to have knowledge of good hygiene practices were more compliant with washing of the udder and teats, washing utensils, using a clean cloth to clean the udder and teats, and the use of separate clothes for milking. These farmers had received training on agricultural, hygiene and handling practices.

Table 5.2: Association of hygiene knowledge and practices on the farms

Practice		**Knowledge of good hygiene practices**			
		Yes		**No**	
		n	**%**	**N**	**%**
Wash hands for milking	**Yes**	99	66%	44	29.3%
	No	5	3.3%	2	1.3%
	p= 0.90				
Wash utensils before use with detergent	**Yes**	103	68.7%	46	30.7%
	No	1	0.7%	0	0%
	p= 0.05				
Wash udder and teats before milking	**Yes**	102	68%	42	28%
	No	2	1.3%	4	2.7%
	p= 0.05				
Use of a clean cloth during milking	**Yes**	85	56.7%	21	14%
	No	19	12.7%	26	16.7%
	p= 0.00				
Cover milk container with lid after milking	**Yes**	97	64.7%	43	28.7%
	No	7	4.7%	3	2%
	p= 0.96				
Use of clean separate clothes for milking	**Yes**	52	34.7%	6	4%
	No	52	34.7%	40	26.7%
	p= 0.00				
Total		104	69.3%	46	30.7%

It was observed during the transect walks however, that the hands of the people responsible for milking were only washed at the beginning and the end of the milking process. During milking, the majority of the farmers did not wash their hands after touching unclean object such as the containers of the lubricants used, and the cow when calming it down; the farmers instead used the tail of the cow which had dirt and dung to wipe their hands during the milking process. The majority of the farmers (61.4%) did not have separate clothes used for milking, and instead used their usual clothes while milking.

Based on the questionnaire, the participants complied with the recommended hygiene practices, however, the transect walk revealed that the adherence to most of the practices was low. Although the farmers received training, they argued that adhering to some of the recommended practices was a challenge due to the limited financial resources available to them. The participants stated that the cost of complying with the recommended practices to produce milk of good quality was taking away from the money reserved for household use, worsening their household food and nutrition security situation. The high level of knowledge among the participants was different to various studies that showed poor hygiene practices and knowledge (Demirbas *et al.* (2009); Leus (2010); Neeta *et al.* (2015). The high use of detergent in this study was also contrary to a study conducted in Zimbabwe where detergents were used by 29% of the smallholder dairy farmers, to clean utensils (Gran *et al.* 2002; Mhone *et al.* 2011). The use of detergent reduced the possibility of contaminating the milk with the utensils used. Recommended hygiene practices are beneficial in assisting farmers to produce good quality milk that is safe however, there is a need to adapt these practices for rural communities where financial resources are limited.

5.4.2.2. Smallholder dairy farm facilities resources

Figure 5.2 shows the different sources of water for the participants. The majority of the community did not have taps exclusively for their households; only 39% of the participants had taps, and a third of the participants collected water from the river (36%). The participants stated that the scarcity of water in their villages is a great challenge in keeping to the recommended hygiene practices. They explained that most of the guidelines are dependent on access to water and the rivers and boreholes are not sufficient sources of water, especially because they have to travel a distance to acquire the water.

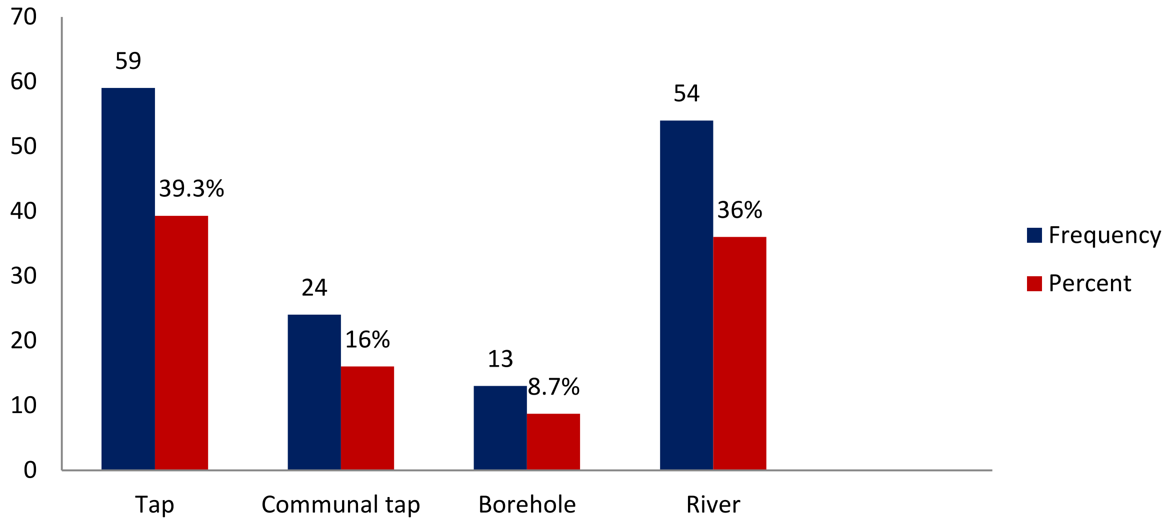

Figure 5.2: Different sources of water

Lack of infrastructure and resources such as water is a common challenge among farmers as this was reported by various studies among smallholder farmers in the Eastern Cape and Zimbabwe (Leus *et al.* (2010); Mapekula *et al.* 2009; Mhone *et al.* (2011). This was similarly observed in this study, and the participants said that this was the greatest challenge in progressing as dairy farmers. The high use of water from the river introduces a great risk of contamination because the water is not clean and the participants do not boil or clean their water before use. Gran *et al.* (2002) reported that 44% of water samples collected from rural water supplies such as rivers and boreholes, contained coliforms and 24% containing *E. coli* and this shows that water source is a very important factor to consider. The use of water from these sources as reported in this study could increases the risk of milk contamination.

5.4.3. Awareness and perceptions of smallholder dairy farmers of milk safety

The majority of the farmers were aware of the risks associated with the practices mentioned below in Table 5.3. The participants that responded no to having knowledge of good hygiene practices from trainings and teachings also had knowledge of the risks associated with the practices mentioned below. The participants that believed that the consumption of contaminated milk has no health risks, further stated that they sift out the foreign objects found in the milk and when the sensory attributes change, they perceived that to be fermented milk which was safe for human consumption.

Table 5.3: The association between knowledge, and perceptions and practices that could result in transmission of diseases between humans and cows.

		Knowledge of good hygiene practices			
		Yes		**No**	
		N	**%**	**n**	**%**
Can consuming contaminated milk cause illness?	**Yes**	91	60.7%	38	25.3%
	No	13	8.7%	8	5.3%
	p= 0.42				
Do you milk your cattle when you have communicable diseases?	**Yes**	22	14.7%	11	7.3%
	No	82	54.7%	35	23.3%
	p= 0.71				
Do you milk your cattle when you have open wounds?	**Yes**	8	5.4%	4	2.7%
	No	96	64%	42	28%
	p= 0.84				
Do you think personal hygiene is important for milking?	**Yes**	97	64.7%	42	28%
	No	7	4.7%	4	2.7%
	p= 0.67				
Total		104	69.3%	46	30.7%

All the participants discarded milk that contained blood and clots when milking. They stated that the presence of blood and clots in milk indicated that the cow had an infection or Mastitis, making the milk unsafe for human consumption. That milk was discarded by feeding to the dogs and cats. Two thirds of the participants reported that foreign substances such as grass, glass, dung and soil often enter the milk during milking (62%), and the milk is then sifted using a milk sifter or cloth. That milk is then consumed raw. Only 38% of the participants used a cloth to cover the milking container during milking to avoid contamination of foreign substances.

The majority (92%) of the participants did not milk the cows when they had open wounds on their hands and those who were infected with communicable diseases were prevented from milking (78%), this also applied to all the individuals responsible for milking. The participants reasoned during the FGDs that they were aware that humans can communicate certain disease although the majority were not informed on what those diseases were; Tuberculosis was the only disease mentioned by few of the participants, and that was the reason that they refrained from milking under those circumstances. This was in contrast to the findings of a study conducted in the rural areas of India where not all the participants were aware that disease could be transmitted through milk consumption and from humans to cows (Neeta *et al.* 2015).

The participants used sensory attributes to assess the safety of milk, and this was similar to a study conducted in the Eastern Cape where the farmers were reported to use colour (60%) and smell (18%) as the main indicators of milk quality (Mapekula *et al.* 2009). Milk was predominately discarded when there was blood or clots and this posed high risk of contamination and illness because the majority of the participants preferred raw milk. Majority of the farmers admitted to cow dung contaminating the milk and it was sifted out, with no pasteurisation thereafter. This increases the chance of contamination of milk by pathogenic bacteria such as E. coli, which could result in illness and food insecurity.

Awareness of the importance of hygiene was observed in this study. The participants perceived personal hygiene and equipment hygiene to be of more importance than environmental hygiene and this was alarming because the environment is a possible contaminant of milk, especially with hand milking. Majority of the participants in this study were aware of the risks of consuming contaminated milk. However, contaminated milk was regarded as milk with blood and clots only and these shows the limitations in their knowledge and awareness of milk safety.

5.4.4. Microbiological quality and safety of milk

All the samples collected were raw milk, all the participants that provided milk samples only consumed raw milk. The majority of the samples exceeded the legal minimum standard of the Total Plate counts (TPC) of raw milk as seen in Table 5.4 below. The samples that exceeded the legal standard TPC showed a range of 8.8×10^{5}- 3.3×10^{-10} cfu/ml. The highlighted samples in Table 5 had TPCs compliant with the South African legal standard for raw milk.

Table 5.4: Microbial load of milk samples collected from smallholder dairy farmers in Matatiele.

Sample Number	Village	TPC* (cfu/ml) in milk sample	SA DOH** standard for raw milk (cfu/ml)
1	Ncholu	7.0×10^{6}	<5.0×10^{4}
2	Mafube	4.0×10^{4}	<5.0×10^{4}
3	Mafube	2.2×10^{3}	<5.0×10^{4}
4	Hilbron	3.7×10^{3}	<5.0×10^{4}
5	Hilbron	5.1×10^{3}	<5.0×10^{4}
6	Khashule	8.1×10^{6}	<5.0×10^{4}
7	Khashule	3.8×10^{6}	<5.0×10^{4}
8	Khashule	4.2×10^{5}	<5.0×10^{4}
9	Rantsiki	3.1×10^{8}	<5.0×10^{4}
10	Madimong	2.1×10^{7}	<5.0×10^{4}
11	Bethel	2.3×10^{7}	<5.0×10^{4}
12	Malubaluba	2.8×10^{7}	<5.0×10^{4}
13	Malubaluba	3.3×10^{10}	<5.0×10^{4}
14	Malubaluba	1.1×10^{9}	<5.0×10^{4}
15	Malubaluba	6.3×10^{7}	<5.0×10^{4}
16	Ramohlakoana	5.7×10^{7}	<5.0×10^{4}
17	Hilbron	8.8×10^{5}	<5.0×10^{4}
18	Nkasela	6.0×10^{6}	<5.0×10^{4}
19	Nkasela	4.7×10^{6}	<5.0×10^{4}

*TPC = Total Plate Count

**SA DOH= South Africa Department of Health

The high percentage of samples exceeding the South African legal limit for total plate count (TPC) of raw milk indicates that the milk produced at the majority of these farms is of poor microbial quality. Similarly, various studies presented high TPCs of raw milk from samples collected from smallholder farmers in various areas such as Burkina Faso, Zimbabwe, Tanzania and Brazil (Altallah *et al.* 2009; Mhone 2011; Millogo *et al.* 2010; Swai & Schoonman 2011). The poor microbial quality of milk could be attributed to the faecal and environmental contamination of milk that was reported by majority of the participants as well as the poor storage of milk as reported in Chapter 4.

Faecal and environmental contamination is evident in Table 5.5, where 84.2% of the samples exceeded the South African legal limit for coliform count of 10 cfu/ml as shown in Section 2.4.2., and 57.9% of the samples were positive for *E. coli.* The majority of the samples had high coliform count and this could be a result of the high reported rate of contamination of milk by soil, dust and faeces. The high reported rate of contamination by these foreign objects could be due to the fact that milking was done in kraals, and milking sheds that are not cemented and clean. Additionally, the use of unsafe water increases the risk of faecal contamination because unclean water is a common host and communicator of coliforms (Gran *et al.* 2002; Leus *et al.* 2010). Unclean water from the river was commonly used by the participants to wash the cow's udder and teats, and the utensils, and this could have introduced coliform bacteria and *E. coli*.

Table 5.5: Coliform counts and presence of *E. coli* in milk samples collected from smallholder dairy farmers in Matatiele.

Sample Number	**Coliform count in milk sample (cfu/ml)**	**SA Legal limit on Coliform count (cfu/ml)**	***E. coli* in milk sample**	**SA legal limit on *E. coli***
1	1.6×10^4	10	Present	Absent
2	$>1.5 \times 10^4$	10	Present	Absent
3	$>1.5 \times 10^4$	10	Present	Absent
4	$10^{est.}$	10	Absent	Absent
5	$>1.5 \times 10^4$	10	Present	Absent
6	$>1.5 \times 10^4$	10	Present	Absent
7	<10	10	Absent	Absent
8	<10	10	Absent	Absent
9	$>1.5 \times 10^4$	10	Present	Absent
10	$>1.5 \times 10^4$	10	Present	Absent
11	1.0×10^3	10	Present	Absent
12	$>1.5 \times 10^4$	10	Present	Absent
13	2.0×10^2	10	Present	Absent
14	$20^{est.}$	10	Present	Absent
15	$55^{est.}$	10	Absent	Absent
16	$90^{est.}$	10	Absent	Absent
17	$40^{est.}$	10	Absent	Absent
18	3.4×10^2	10	Absent	Absent
19	1.4×10^3	10	Absent	Absent

est. = Estimate; SA= South Africa

The high percentage of milk samples that tested positive for *E. coli* found in this study is similar to the 1998 South African Department of Health Survey that reported that 51.3% of the milk samples collected tested positive for *E. coli* (Leus *et al.* 2010), and a study in Bloemfontein that detected an alarming 87.8% of the samples collected from smallholder farmers in peri-urban areas testing positive for *E. coli* (Leus *et al.* 2010). The high presence of coliform counts that exceed the legislative standards were similarly reported in the survey conducted by Leus *et al.* (2010). The high presence of coliform counts obtained by Leus et al. (2010) was similar to the results of studies conducted in Zimbabwe and Malaysia where 93.3% and about 90% of the samples respectively, had coliform counts exceeding the legal standards (Chye *et al.* 2004; Mhone *et al.* 2011).

The high TPCs in the milk samples of this study are of great concern because it has a direct impact on the quality of milk, most especially the sensory attributes of milk. Milk with high TPC could result in milk that is not acceptable to the commercial markets and consumers, preventing farmers from selling the milk and generating income. Coliform bacteria also affect the sensory attributes of milk due to its association to taste and texture changes in milk, however, coliform bacteria are also pathogenic bacteria that could pose a threat to human health when ingested.

Although the global prevalence of diarrheal illness caused by *E. coli* is decreasing, *E. coli* is still a major cause of diarrheal diseases of varying severity in developing countries (Chey *et al.* 2004). Consumption of milk contaminated with *E. coli* poses a serious health risk that could potentially be fatal for high risk groups such as children, the elderly, pregnant and lactating women, as well as HIV positive individuals.

Illnesses that result from consuming milk of poor microbial quality and safety impede any efforts intended to address food and nutrition security due to the negative impact on capacity to work. The quality of milk produced by the smallholder farmers has to be improved to levels that comply with the South African legislative standards. More efforts are needed to assist farmers in improving the quality of their milk, beyond training.

5.5. CONCLUSION

Smallholder dairy farming in Matatiele is a widespread agricultural practice, predominantly among the elderly and males. It is the main source of milk for numerous households and the main source of protein for some households. Some of the farmers had aspirations of participating in the formal dairy market for a sustainable source of income sufficient for their households. The farmers expressed the lack of water and financial resources as the main challenge in keeping to the recommended hygiene practices.

Majority of the farmers were well informed on the good hygiene practices, personal and equipment hygiene was perceived to be very important and well-practiced at the farms. The farmers however, did not perceive environmental hygiene to be highly important as this was not practiced at the farms even though they had knowledge of the recommended hygiene practices. Support of smallholder farmers, especially in rural areas where they do not have access to sufficient infrastructure and facilities is needed.

The milk samples collected from the smallholder farms were of poor quality. The TPCs and coliform counts of the milk samples exceeded the legal standards of raw milk and this would prevent them from entering the formal dairy market. The high occurrence of *E. coli* in the milk samples analysed is of great concern due to the potentially dangerous health implications that can result from the consumption of *E. coli* containing foods. This could be attributed to the poor hygiene conditions prevalent in the diary environment as observed as well as limited access to storage facilities such as fridges. There is a need to educate the farmers on contamination of milk and milk safety, and increase their awareness levels. Support of the smallholder farmers should not be limited to trainings and education, support with the provision of adequate facilities and infrastructure is needed.

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CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

These study findings indicated that smallholder dairy farming plays a significant role in improving the household food and nutrition security of the Matatiele community. The milk produced is used as a source of protein for the household and provides additional monetary benefits for some of the households that sell their milk to their neighbours. The farmers that sell their milk did not sell in formal markets, although they had the desire to reach formal markets.

The farming practices predominately used in Matatiele were based on Indigenous knowledge systems. Some of the farmers had received formal trainings however, they opted to use IKS because they believed that IKS were more accommodating of the resources available to them in the community. The IKS were similar to the recommended agricultural practices with some exceptions on cow husbandry. The participants stated that there were other benefits in keeping to IKS-based systems such as the type of cow shed used and the frequency of cleaning the shed; this was related to the availability of dry cow dung which is used for flooring and as an energy source. IKS was identified as a part of the lifestyle and belief system of the people in the community, emphasising a need to interphase the systems with modern systems.

Resources were the major challenges communicated by the farmers in transitioning to formal markets. Lack of access to safe water was the main challenge for most of the farmers; rivers were the main source of water for the majority of the farmers and this limited access to water and potentially introduced bacteria that could contaminate the utensils and ultimately, the milk. Cold storage facilities were another challenge for the farmers. The milk produced was stored on the floor by the majority of the farmers and this creates an opportunistic environment for bacterial proliferation, which could potentially result in milk of poor quality.

The study findings showed that the participants relied solely on sensory attributes to determine the quality of milk, particularly sight and taste. Their awareness on the dangers of drinking contaminated milk was high in regards to contaminations caused by blood as this was related to cow diseases. The participants however, had limited knowledge and awareness of the possible risks of contaminants such as grass, glass and soil. Through this study, it was established that the participants sifted out the contaminants before consumption and the milk was consumed raw by the majority. This highlighted environmental sources of milk as a possible means of contamination of the milk.

The study findings revealed that the milk produced by the smallholder dairy farmers was of poor quality. The majority of the farmers produced milk with a Total Bacterial Count above 5 x 10^{4} and coliform counts of 10 cfu/ml; exceeding the legal minimum level of bacteria in raw milk. The detection of E. coli was also high and this shows that the milk produced by these smallholder farmers is potentially hazardous for human consumption and the farmers would not be successful in commercialising their milk and reaching the markets. Overall, this study shows that there is some potential in improving the quality of milk produced by smallholder farmers in this rural community as this was achieved by some farmers from the same environment. Improving the awareness of milk safety and quality and the possible contaminants of milk would have a positive impact on the quality of milk produced by the farmers in this rural community.

6.2. RECOMMENDATIONS

There is a need for further research into IKS practiced in other communities among other cultural groups and assesses the possible impact on those systems on milk quality and safety. There is a need to interphase IKS with modern systems and incorporate IKS into policies and programmes addressing food and nutrition security, agriculture and nutrition. Education particularly on the implications of poor agricultural, handling and hygiene practices on milk quality and safety is required. Furthermore, education on the implications of milk quality and safety on health and market access is required. The lack of access to safe and clean water in the community should be addressed as this ultimately presents challenges with all the recommended practices. Proper measures to test milk produced by smallholder farmers for microbial quality should be taken to encourage the farmers to comply with the recommended hygiene and handling practices.

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APPENDICES

APPENDIX A: ANIMAL HUSBUNDARY, MILK UTILISATION, MILK HANDLING AND HYGIENE PRACTICES, AND KNOWLEDGE QUESTIONNAIRE.

Participant number: ____________

Demographic Information

1. Age ______________

2. Gender

F	M

3. Study Area _________________________________

4. Land Size (hectors) __________________

5. Household size ____________________

6. Head of household

Father	Mother	Grandparent	Oldest sibling

7. Marital status (of head of household)

Single	Married	Divorced	Widowed

8. Highest level of education

Primary school	High School	Tertiary

9. Employment status

Full-time	Part-time	Self-employed	Unemployed

Section B

10. How often do you milk in a day?	Once	Twice	Three times	More	
11. Where do you milk your cattle?	Self-constructed Milking shed	Registered milking shed	In the field	Kraal	Other
12. How often is the milking area cleaned?	Twice/ day	Daily	Every other day	Weekly	Never
13. How often do your cattle get ill?	Often	Sometimes	Seldom	Never	
14. What actions do you take to address the illness?	Treat cattle yourself	Call the veterinarian	Get assistance from NGO’s	Do not treat	Other
15. Has a veterinarian ever visited your neighbourhood?	Yes	No			
16. Has a veterinarian ever treated your cattle?	Yes	No			
17. Has an inter-vet ever visited your neighbourhood?	Yes	No			
18. Has an inter-vet ever treated your cattle?	Yes	No			
19. Do you milk a cow that seems to be ill?	Yes	No	Sometimes		
20. Do you milk a cow that has been diagnosed with mastitis or any teat and udder infection?	Yes	No	Sometimes		
21. Do you consume the milk from the ill cattle?	Yes	No	Sometimes		
22. Do you milk a pregnant cow?	Yes	No	Sometimes		

23. Do you consume the milk from the pregnant cow?	Yes	No	Sometimes		
24. Do you chain the back legs of cattle when milking it?	Yes	No	Sometimes		
25. Do you wash the udder of the cow before milking?	Yes	No	Sometimes		
26. Do you use water to clean the teats and udder?	Yes	No	Sometimes		
27. Do you use a clean cloth to clean the udder and teats?	Yes	No	Sometimes		
28. Do you dry the teats after washing, before milking?	Yes	No	Sometimes		
29. Do you start by milking a little from each teat into a small cup?	Yes	No	Sometimes		
30. Is that milk used for consumption?	Yes	No	Sometimes		
31. Do you dip the teats after milking?	Yes	No	Sometimes		

Section C

32. Does dirt or foreign objects enter the milk when you are milking?	Yes	No	Sometimes	Don't know	
33. Where do you get the water you use for	Tap	Communal tap	Borehole	River	Other

washing the teats and udder?					
34. When do you wash your hands?	Before milking	After milking	During milking	Before and after	Never
35. When do you wash the milking container?	Before milking	After use in the house			
36. What type of container do you use during milking; to collect the milk?	Aluminum buckets	Plastic buckets	Other		
37. Is the milking container washed with water and detergent?	Yes	No	Sometimes		
38. Do you use hot water to wash the container?	Yes	No	Sometimes		
39. Do you cover the container when you take the milk home, after milking?	Yes	No	Sometimes		
40. Do you have separate clothing used for milking?	Yes	No	Sometimes		
41. How often do you wash the clothes?	After every session	Daily	Bi-daily	Weekly	

Section D

42. Do you use the milk for household consumption?	Yes	No	Sometimes		
43. Do you sell the milk to neighbours?	Yes	No	Sometimes		
44. Do you sell the milk raw?	Yes	No	Sometimes		

45. Do you sell the milk after boiling?	Yes	No	Sometimes		
46. Do you sell the milk fermented/ sour?	Yes	No	Sometimes		
47. How do you prefer your milk?	Raw	Pasteurized			
48. Do you prefer your milk to be…..	Home-made	Commercially processed			

Section E

49. Do you transfer the milk to a different container for household use?	Yes	No	Sometimes		
50. What is the shape of the container you use to store the milk?	Round container	Rectangular container	Square container	Other	
51. Do you mix the fresh milk with the left over milk from the previous day?	Yes	No	Sometimes		
52. Do you boil the milk before consuming?	Yes	No	Sometimes		
53. Do you sift/filter the milk?	Yes	No	Sometimes		
54. Do you consume the milk fresh?	Yes	No	Sometimes		
55. Do you consume the milk fermented?	Yes	No	Sometimes		
56. Where do you keep the milk in the summer?	On the floor	In the fridge	In a tree	In or on the kitchen cabinet	
57. Where do you keep the milk in the winter?	On the floor	In the fridge	In a tree	In or on the	

				kitchen cabinet	
58. Do you think personal hygiene is important for milking?	Yes	No	Sometimes		
59. Do you think that you could become ill from drinking milk?	Yes	No	Sometimes		
60. Do you drink milk from ill cattle?	Yes	No	Sometimes		
61. Do you milk cattle when you are sick?	Yes	No	Sometimes		
62. Do you ever discard milk because you believe it is bad?	Yes	No	Sometimes		
63. If so, what are the indicators you use for determining that the milk is bad?	It has become sour and thick	Signs of dirt or foreign objects	Mold growth in or on the milk	Blood in the milk	Other: __________

Section F

64. Do you know about good hygienic practices?	Yes	No			
65. Have you received training or attended a workshop on hygiene practices?	Yes	No			
66. Do you use the knowledge to inform your practices?	Yes	No			

67. Who offered the training?	Extension workers	Project officers	Community member	Veterinarian	Other. __________
68. Do you have knowledge of the implications of poor hygiene practices on your farm?	Yes	No			
69. Have you received training on the implications of poor hygiene practices on the farm?	Yes	No			
70. Do you use the knowledge to inform your practices?	Yes	No			
71. Who offered the training?	Extension workers	Project officers	Community member	Veterinarian	Other. __________
72. Do you know about cattle management?	Yes	No			
73. Have you received training or attended a workshop on cattle management?	Yes	No			
74. Do you use the knowledge to inform your practices?	Yes	No			
75. Who offered the training?	Extension workers	Project officers	Community member	Veterinarian	Other. __________
76. Do you use indigenous knowledge to inform your practices?	Yes	No			

APPENDIX B: TRANSECT WALK CHECKLIST

Participant number: ___________

Transect walk checklist

Section A

	Yes	No	N/A
1. There is a milking shed available.			
2. The milking shed has a roof.			
3. The milking shed has walls and a gate to close it up.			
4. The milking shed has concrete or cement floors.			
5. The milking shed is clean.			
6. The equipment used for milking is kept clean.			
7. The equipment used for milking is sterilized before use.			
8. The individual milking has clothes specifically used for milking.			
9. The clothes used specifically for milking are kept clean.			
10. The individual milking has a head cover specifically used for milking.			
11. The equipment storage area is clean (free of dust and dirt)			
12. The individual milking washes hand with water only before milking.			
13. The individual milking washes hand with water and soap before milking.			
14. The individual milking does not contaminate their hand by touching unclean object after washing hands.			
15. The individual milking washes their hands immediately after milking.			
16. The milk is transported to the house in a closed container.			
17. The milk storage area if kept clean.			
18. The milk storage area is free of foul odours.			

Section B

1. The hind leg is tied before milking	Yes	No	N/A
2. The cow about to be milked is clean.			
3. The teats are dipped.			
4. The teats are wiped with a clean towel.			
5. Fore strip done.			
6. Fore strip done into a cup			
7. The fore strip milk discarded.			
8. Teats dipped for 20-30 seconds.			
9. Teats wiped with clean towel.			
10. Milking done with clean, dry hands.			
11. Teats lubricated with milk.			
12. Teat dipping done with a disinfectant at the end of the milking session.			
13. Teats dried with a clean towel.			

APPENDIX C: FOCUS GROUP QUESTIONS SHEET

Group number: ____________

Focus Group Discussion Questions

1) How do you assess and manage quality and safety?
2) **Explain** why raw milk is the most preferred in this community than commercial milk *(perceived safety issues, accessibility, taste & nutritional benefits)*
3) What methods of milk preservation do you use? *(techniques, methods, reasons)*

APPENDIX D: ETHICAL CLEARANCE LETTER FROM THE UNIVERSITY OF KWAZULU NATAL.

UNIVERSITY OF KWAZULU-NATAL™

INYUVESI YAKWAZULU-NATALI

29 January 2016

Miss Atlehang Makakole 208500366
School of Agriculture, Earth and Environmental Sciences
Howard College Campus

Dear Miss Makakole

Protocol reference number: HSS/1242/015M
Project title: Assessing the food and nutrition security potential of smallholder diary farming in rural Eastern Cape, Matatiele, and the evaluation of milk handling and hygiene practices

Full Approval – Expedited Application

In response to your application received 31 August 2015, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

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)
Humanitities & Social Scinces Research Ethics Committee

/pm

Cc Supervisor: Dr Unathi Kolanisi
Cc Academic Leader Research: Professor Onisimo Mutanga
Cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
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APPENDIX E: LABORATORY REPORT FOR MILK SAMPLES TESTS

FaCT
Food and Cosmetic Technologies
cc reg. no. 9903838/23

ANALYTICAL AND MICROBIOLOGICAL TESTING LABORATORY

Physical address
61 Hannah Road
Congella
4013

Postal address
P.O. Box 17229
Congella
4013

Contact numbers and e-mail address
Telephone: (031) 205 6410
(031) 205 6411
E-mail: admin@factlabs.co.za

sanas Testing Laboratory
T0314

TEST REPORT

Report date	FaCT number	Your reference number
23-02-2016	320216	None
CUSTOMER NAME AND POSTAL ADDRESS: **ATHLEHANG (UKZN)**	CUSTOMER CONTACT NUMBER/S: **Telephone:** Not Available **Facsimile:** Not Available **Cell. no.:** 076 416 9204 **E-mail:** athlehangmakatole@yahoo.com	FOR ATTENTION: **Athlehang Makatole**

1. **Re.:** Microbiological Analysis
2. **Sample quantity and type:** 19 x Products
3. **Sample condition:** Received in condition intended
4. **Date/s received:** 11/02/16
5. **Date re-testing started:** 15/02/16
6. **Date last test completed:** 22/02/16
7. **Tested by:** Karishma Dookharan
8. **Tests/analysis and method numbers:**

Test/analysis	Method no.
Coliform count (products)	*MM 02 (VRBL agar at 37ºC for 1 day - SABS ISO 4832:1991)
Detection of presumptive *E. coli* (products)	*MM 04 (Detection method using broths and peptone water at 37ºC and 44ºC for 2-6 days - SANS 7251:2005 ed. 2)

9. **The asterisk (*) in the method number column indicates a SANAS accredited test method. All methods without the asterisk are not included in the SANAS Schedule of accreditation for this laboratory.**
10. **Note:** Opinions and interpretations (otherwise referred to as "comments") expressed herein are outside the scope of SANAS accreditation.
11. **Reason for revision/copy if applicable:** Not available

ANALYTICAL AND MICROBIOLOGICAL TESTING LABORATORY

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TEST REPORT

MICROBIOLOGICAL ANALYSIS

Sample description	Coliforms (cfu/g)	Presumptive *E.coli*/0.1g
1. Frozen Milk 1	1.6×10^3	**PRESENT**
2. Frozen Milk 2	$>1.5 \times 10^4$	**PRESENT**
3. Frozen Milk 3	$>1.5 \times 10^4$	**PRESENT**
4. Frozen Milk 4	$10^{est.}$	Absent
5. Frozen Milk 5	$>1.5 \times 10^4$	**PRESENT**
6. Frozen Milk 6	$>1.5 \times 10^4$	**PRESENT**
7. Frozen Milk 7	<10	Absent
8. Frozen Milk 8	$>1.5 \times 10^4$	**PRESENT**
9. Frozen Milk 9	<10	Absent
10. Frozen Milk 10	$>1.5 \times 10^4$	**PRESENT**

Key:
est. - estimate

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TEST REPORT

MICROBIOLOGICAL ANALYSI

Sample description	Coliforms (cfu/g)	Presumptive *E.coli*/0.1g
11. Frozen Milk 11	1.0×10^3	**PRESENT**
12. Frozen Milk 12	$>1.5 \times 10^4$	**PRESENT**
13. Frozen Milk 13	2.0×10^2	**PRESENT**
14. Frozen Milk 14	$20^{est.}$	**PRESENT**
15. Frozen Milk 15	$55^{est.}$	Absent
16. Frozen Milk 16	$90^{est.}$	Absent
17. Frozen Milk 17	$40^{est.}$	Absent
18. Frozen Milk 18	3.4×10^2	Absent
19. Frozen Milk 19	1.4×10^3	Absent

Key:

est. - estimate

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