EVALUATION OF THE MICROBIAL ASPECT OF RURAL SMALL-SCALE DAIRY FARMERS RAW MILK HANDLING PRACTICES FROM PRODUCTION TO UTILISATION

by

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ABSTRACT

Milk is an essential source of nutrients for human beings and animals and can provide benefits socially and economically for poor households. Food security, nutrition, livelihoods, resilience and poverty alleviation for poor households are some of the benefits that can be derived from milk production. Although it is an expensive source of energy and the best source of high-quality protein and micronutrients that are essential for normal development and good health for children especially under the age of five. Rural milk producers can benefit from consuming and selling surplus milk to their rural communities at large. However, due to its high-water activity and nutritional value, it serves as an excellent medium for the growth of several kinds of microorganisms under inappropriate conditions which decreases its value and potential in the market. One aim was to analyse a microbial aspect of rural small-scale dairy farmer's milk handling process from production to utilisation. Also, to optimise and develop an ongoing feedback strategy and workshops to rural small-scale dairy farmers and extension officers and disseminate project information to optimise their rural small-scale farming dairy hygiene management.

This study was conducted to assess, isolate and characterise the total bacterial load of raw milk, especially common microorganisms that contaminate raw milk. In addition, assess various chemical adulterants in raw milk produced by rural small-scale dairy farmers; investigate whether the milk handling and practices of rural small-scale dairy farmers affected milk quality. Lastly, to examine the milk handling practices used by rural small-scale dairy farmers from production to consumption in Kwa-Hlabisa villages, KwaZulu-Natal, South Africa. A total of 53 rural small-scale dairy farmers were interviewed, but only 23 rural small-scale dairy farmers who still had lactating cattle were sampled for milk collection. Samples collected for laboratory analysis were 68 milk samples and 48 swabs samples respectively. The laboratory analysis included the assessment of bacterial load, isolation, and identification of bacteria, as well as the assessment of various chemical adulterants from the samples collected. Total plate count, biochemical identification tests and tests for raw milk adulteration samples were conducted. The bacteria in raw milk were also isolated and identified using standard methods.

Results showed that the majority of rural small-scale dairy farmers were males, managing their cattle in unclean environments and pursuing extensive grazing systems in the communal pasture area. The mean aerobic mesophilic bacterial counts (AMBC) of raw milk samples analysed were 6.06 log cfu/ml (teats) and 6.91 log cfu/ml (milking container). According to

South African standards of raw milk quality, the AMBC have values above the upper limits set. During this study, frequent bacteria isolated from raw milk samples taken from different critical points include *Enterobacter aerogenes, Enterobacter gergoviae, Klebsiella oxytoca, Pseudomonas aeruginosa, Pseudomonas maltophilia, Pseudomonas mallei, Shigella dysentery, Shigella sonnei, Morganella morganii, Alkaligenes denitrificans, and Xanthomonas*. Also, this study discovered adulterants like urea, hydrogen peroxide, alizarin, detergent, skimmed milk powder, sodium chloride, sugar, and glucose were detected in 34%, 32%, 29%, 29%, 15%, 12%, 6%, and 6% milk samples respectively. For formalin, starch and neutraliser adulteration, none of the milk samples was found positive.

The study concluded that contamination resulted from incorrect handling practices, therefore, the optimisation of sanitary handling practices to reduce microbial contamination is crucial. An ongoing feedback strategy has been launched. Future work involves workshops with farmers to disseminate project information and improve hygiene management techniques. This will help increase rural and local producer market productivity and consumer confidence, reducing the need for imports. At the same time, this will increase nutritional needs for rural small-scale dairy farmers, villagers, and in turn, the industry will hopefully include these farmers as regular milk producers, thereby enhancing the sustainability of small-scale indigenous farmers.

Keywords: Adulterants, Food security, Hygiene, Indigenous, Microorganisms, Nutrition, Rural small-scale dairy farmers, Standards, Sustainability.

DECLARATION

I Nkosinathi Humphrey Xulu declare that:

The research reported in this mini-dissertation, except where otherwise indicated, and is my original research. This mini-dissertation has not been submitted for any degree or examination at any other university.

This mini-dissertation does not contain other persons' data, pictures, graphs or other information unless specifically acknowledged as being sourced from those persons.

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Signed:

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As Research Supervisor, I agree to the submission of this mini-dissertation for examination.

Signed:

Dr Naidoo Denver (Supervisor)

Date December 2019

As Research co-supervisor, I agree to the submission of this mini-dissertation for examination.

Signed:

Dr Sumaiyah Jamal-Ally (Co-Supervisor)

Date

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE: DECLARATION 1- DRAFT PUBLICATION MANUSCRIPTS

Details of Contribution to Draft Publication Manuscripts that form part and/or include research presented in this dissertation.

Publication Manuscript 1 (work-in-progress)

Xulu NH & Naidoo D. Rural small-scale dairy farmers' traditional milking hygienic practices and its effect on raw milk quality in Kwa-Hlabisa, KwaZulu-Natal, South Africa.

Author contributions: NHX conceived paper with DN. NHX collected and analysed data, and wrote the paper. DH guided the data collection, analysis and contributed valuable comments to the manuscript.

Publication Manuscript 2 (work-in-progress)

Xulu NH, Naidoo D & Jamal-Ally S. Raw cow milk bacteriological and biochemical assessment collected from Kwa-Hlabisa, KwaZulu-Natal, South Africa

Author contributions: NHX conceived paper with DN & SJA. NHX collected and analysed data, and wrote the paper. DN & SJA guided the data collection and contributed valuable comments to the manuscript.

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LIST OF ABBREVIATIONS

AI:	Artificial Insemination
AIDS:	Acquired Immune Deficiency Syndrome
AJAS:	Australasian Journal of Animal Sciences
AMBC:	Aerobic mesophilic bacterial counts
BTB:	Bovine Tuberculosis
CFU:	Colony Forming Unit
DAFF:	Department of Agriculture Forestry and Fisheries
DDA:	Dairy Development Authority
EAC:	Eastern African Countries
EADD:	Eastern African Dairy Development
EACS:	Eastern African Community Standard
FAO:	Food and Agricultural Organisation
GDP:	Gross Domestic Product
HIV:	Human Immunodeficiency Virus
IDF:	International Dairy Freedom
ILRI:	International Livestock Research Institute
MAT:	Milk Adulteration Test
MDHS	Malawi Demographic and Health Survey
MDHS:	Malawi Demographic and Health Survey
MILK-SA:	Milk-South Africa
MPOO:	Milk Producers Organisation
MR:	Methyl Red
NGO:	Non-Governmental Organisation

ODM:	Once-Daily Milking
ONPG:	O-Nitrophenyl-β-D-galactopyranoside
RDP:	Reconstruction and Development Programme
RSSDF:	Rural Small-scale Dairy Farmers
SAI:	Sustainable Agriculture Initiative Platform
SCC:	Somatic Cell Count
SOP:	Standard Operating Procedure
SPC:	Standard Plate Count
SPSS:	Statistical Package for Social Sciences
SSA:	Sub-Saharan Africa
TB:	Tuberculosis
TBC:	Total Bacteria Count
TDA:	Phenylalanine Deamination
TSA:	Tryptone Soy Agar
VP:	Voges Proskauer
WWF-NSA:	World Wide Fund for Nature South Africa

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CHAPTER 1

THE PROBLEM AND IT'S SETTING

1.1 Introduction:

Milk is one of nutritious foods and is consumed throughout the world by many societies (Kahuta, 2013, Paraffin *et al.*, 2018). Milk can offer the desired protein in many households. Furthermore, milk can make a small but significant monthly income if market outlets are available (Mayberry *et al.,* 2018). More than 60% of milk produced worldwide comes from Europe, 26% from America, and 2% from Africa, especially in sub-Saharan countries (Portal, 2016). An estimate of about 150 million households across the world is involved in milk production. Most developing countries around the world produce their milk through small-scale rural dairy farmers and use milk for their livelihood, food security and nutrition (McGuire, 2015, Galié *et al.*, 2018).

In developing countries, milk provides relatively quick returns for rural small-scale dairy producers and is an important source of cash income (McGuire, 2015). Rural small-scale dairy farmers in developing countries have recognition value because of milk and milk products they have produced and the potential of reducing the challenges of malnutrition and poverty (Bennett *et al.,* 2006, Dumas *et al.,* 2018). Rural small-scale dairy farmers have an important role to play in contributing to the Sustainable Development Goals (SGD 1, 2, 3), which aims to end poverty; Zero Hunger and Good Health and Well-being respectively by 2030. Small-scale, market-oriented rural dairy farming has the potential to increase household income, reduce losses and generate processing and marketing employment (Bennett *et al.,* 2006). Rural small-scale dairy farming is, therefore, a viable vehicle for stimulating economic growth and alleviating poverty and improving food security and sustainability (Tanyanyiwa, 2016).

In addition to providing milk, dairy cattle also provide manure, marketable products such as calves and beef from culled dairy cows, and intangible benefits including financial security and social status (Weiler *et al.,* 2014). Despite all this, the rural small-scale dairy sector is not well-developed to match economies with similar dairy production conditions, room for improvement still exists. The South African rural small-scale sector is beleaguered with technical, economic, and institutional challenges which have impacted on lowered incomes for rural small-scale dairy farmers and poor livelihoods (Serebro, 2016). The deregulation of the dairy industry has impacted the commercial farmers and this is clearly reflected by the declining numbers of milk producers (Esterhuizen *et al.*, 2015). This has led to low production of milk in South Africa and a sharp increase in the demand for milk, which has led to milk being imported to South Africa over the last three years to meet the demand (Scholtz and Grobler, 2009).

This demand of milk is expected to be even higher in the year 2025 relatively because of the population growth but mostly because of the disposable income being spent on a greater diversity of food products to meet nutritional needs (Bennett *et al.*, 2006). This poses an opportunity for rural small-scale dairy farmers to penetrate the dairy industry to close the gap by imports. Given that small-scale rural farmers lack the capacity and challenges stated above these farmers do have the potential if they are trained in all aspects related to dairy farming. The demand for milk production has changed for the rural small-scale dairy farmer, from a subsistence level to a market-oriented supply, to produce additional income for their households (Kahuta, 2013).

South Africa contributes approximately 0.5% of global milk production (Bhaktawar and Van Niekerk, 2012). However, within the African context, South Africa is the third largest producers of fresh milk after Sudan and Kenya (Louw, 2013). In addition, produce up to 86% of milk commercially in the country, which can be further increased with the contribution from small-scale rural farmers. This possesses a need that the rural small-scale dairy farmers can play a role in milk production and dairy products as milk can be a reliable intermediate product of extensive cattle farming in the resource-poor sector (Schneider, 2018).

1.1.1 Challenges for Small-scale Dairy Farmers:

Sub-Saharan Africa's rural small-scale dairy sector has been chronically suffering from various challenges that reduce milk production (Kahuta, 2013). These challenges are associated with climate changes that result in a shortage of forage and drinking water during the dry season that affects dairy cattle. This is further impeded by the limited availability of seeds and other planting material for the improved production of grasses and legumes (Mhlanga *et al.*, 2018). Other challenges encountered by rural small-scale dairy sector include poor road network and milk marketing, high costs and inaccessibility of dairy production inputs and support services, inappropriate dairy production technologies, and limited value addition of milk. Grobler (2008), indicated that in South African rural small-scale and communal dairy farming was not thriving. In this study, personal communications with rural small-scale dairy farmers indicated that subsidies obtained were inadequate and that rural small-scale dairy farming business education and practices were lacking.

Furthermore, elders continued to adhere strongly to traditional practices and prevented the implementation of innovative methods by the younger farmers; mistrust with previous researchers and lack of feedback to the rural small-scale dairy farmers also played a major role in recent community engagement projects not being enthusiastically met. Inadequate access to artificial insemination services due to high costs, high cost of animal health care, and inefficient input supply were other identified challenges. Together with poor infrastructure in some parts of South Africa, inadequate marketing and milk collection systems, limited involvement of farmers in the output market, fluctuations in the supply of milk and a lack of up-to-date quality data on the small-scale rural dairy sector hindered the successful development of the dairy sector in South Africa (Maleko *et al.*, 2018). Much is yet to be done to promote economic development and enhance rural dairy development with an objective to improve food security and achieve sustainable agricultural development (Sibhatu and Qaim, 2017). The rural small-scale dairy farmers also lack basic dairy management skills; hundreds of litres of milk are wasted at farm level, cooling facilities, and milk processing facilities (Kahuta, 2013). Low milk production is experienced due to a shortage of fully trained dairy extension officers to guide the dairy farmers (Banda *et al.*, 2011).

1.2 Aims:

The aims of this study were:

- To analyse a microbial aspect of rural small-scale dairy farmer's milk handling process from production to utilisation.
- To optimise and develop an ongoing feedback strategy and workshops to rural small-scale dairy farmers and extension officers and disseminate project information to optimise their rural small-scale farming dairy hygiene management.

1.2.1 Specific Objectives:

- To evaluate the total bacterial load of raw milk of rural small-scale dairy farmers of Kwa-Hlabisa.
- To isolate and characterise particularly common microorganisms contaminating raw milk in the rural small-scale dairy farm of Kwa-Hlabisa.

- To assess different chemical adulterants, present in raw milk produced by rural small-scale dairy farmers of Kwa-Hlabisa.
- To survey traditional milk handling practices used by rural small-scale dairy farmers from production to consumption.
- To investigate whether the rural small-scale dairy farmer's milk handling and practices affect the quality of milk.

1.2.2 Research Questions:

- What type of Microorganisms is present in the raw milk of rural small-scale dairy farmers of Kwa-Hlabisa?
- Is there cross-contamination of microbes during rural small-scale dairy farmers milking management?
- Are there residual chemical adulterants, present in raw milk produced by rural small-scale dairy farmers of Kwa-Hlabisa?
- Do rural small-scale dairy farmer's milk handling practices affect the quality of milk?
- How do we feedback the information or develop a further knowledge exchange system to address the challenges mentioned in the introduction?

1.3 Problem Statement:

Maintaining milk quality is a function of handling practices on-farm hygiene and milk hygiene milk produced by small-scale rural dairy farmers are often spoiled at household level as a result of good dairy farming practices and quality hygienic milk handlings, such as milking environment, wind, milking utensils, feed, soil, faeces, farm staff and housing. Rural small-scale dairy farmers face enormous costs of keeping their low-output cows and high losses from discarded milk due to spoilage due to the increased cost of production. Despite the losses, there has been no study of factors leading to milk spoilage from production to utilisation level and this in a way limits the provision of extension services. This study was therefore conducted to evaluate the microbial aspect of the raw milk handling practices of rural small-scale dairy farmers from production to use in Kwa-Hlabisa villages. Milk produced by the rural small-scale dairy farmers often spoil since a guide to good dairy farming practice and hygienic milk handling quality (milking environment, wind, milking utensils, feeds, soil, faeces, farm personnel, and housing) at the household level are always compromised. With the increased cost of production, rural small-scale dairy farmers face enormous costs maintaining their low-output cows and the high losses from discarded milk due to spoilage. Despite the losses, the factors leading to milk spoilage from production to utilisation level have not been studied and this in a way limits the delivery of extension services. Therefore, this study was conducted to evaluate the microbial aspect of rural small-scale farmer's raw milk handling practices from production to utilisation in the villages of Kwa-Hlabisa.

1.4 Importance of the Study:

Milk production, processing, and marketing are of great importance to the wealth, food and nutrition security of rural small-scale dairy farmers in South Africa. For rural small-scale dairy farmers in South Africa to meet the relevant milking standards, strategies need to be identified to stimulate and improve milking handling practices and marketing. This can help bridge the gap between reduced milk producers and reduce the high selling price of milk on the South African market as a result of milk imports. Finally, the output of this study is expected to provide insights into the practices of rural small-scale dairy farmers and to bring supporters who intend to stimulate and improve milking production levels in Kwa-Hlabisa and other high potential areas. This could contribute to improving the livelihood food and nutrition security of rural households. This could lead to enhancing the livelihood food and housing safety of rural families.

1.5 Limitations of the Study:

It was challenging to get farmers to cooperate on the survey as they did not want to disclose private information. Many farmers stated their hesitation as past scientists never provided input and shared their results. Thus, one of the objectives of the present research included to further create a laboratory and normal working procedure (SOPS) rules for farmers. The rainy climate circumstances during the study did not favour the practice.

1.6 Assumption of the Study:

It was assumed that all the rural small-scale dairy farmers cows were still lactating at the time of the study, their records were kept up-to-date, and the conditions were favourable for milk production. Participants provided honest and accurate information during the survey.

1.7 Definition of Significant Terms:

Adulterants- An addition or subtraction of some of the legally prohibited substances into or from a more valuable or genuine product (Bastola, 2016). Milk adulteration can be caused by leaks in the cooling facilities or use of milk containers that are not properly cleaned. Also, milk adulteration can occur naturally from within the milking cow for example mastitis and through the addition of water (Poonia *et al.,* 2017, Ndungu *et al.,* 2016, Moran, 2005). It can also be through dust particles and other extraneous objects that might enter during milk processing (Poonia *et al.,* 2017).

Coliforms- A group of bacteria that comprises all aerobic and facultative anaerobic, gram-negative, non-spore forming rods able to ferment lactose with the production of acid and gas at 35°C within 48 hours. The presence of coliforms in dairy products indicates unsanitary conditions or poor hygiene during processing (Martin *et al.,* 2016, Fox *et al.,* 2017).

Colony forming unit- The number of bacteria as defined by the number of colonies on an agar plate. Often abbreviated CFU. One colony can represent one free cell or many cells if the strain grows in clumps or chains (Novakowski *et al.,* 2017).

Demographic characteristics- These are social factors of the dairy farmers e.g. age, marital status, sex, education level, and experience in dairy farming among others that in one way or the other influence dairy productivity (Cheruiyot and Otieno, 2017, Philemon, 2015).

Milk contamination- Milk contamination can result from a range of causes including process, plant and human error.

Milk production - In context implies the amount of milk produced per animal per given period or per day or per year (Cheruiyot and Otieno, 2017).

Practices- These are routine activities geared towards proper dairy farming (FAO and IDF, 2011).

Raw milk- The lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows or it generally refers to milk that has not been pasteurised, and it often has not been homogenised or processed in any product (Markham *et al.,* 2014).

Semi-zero-grazing (semi-intensive) system- involves the combination of zero-grazing and open range systems (Manzana *et al.*, 2014, Manzana, 2008).

Small-scale dairy farmer - A farmer maintaining a herd of cow between one to five dairy animals and a farm size of fewer than one hectares (Cheruiyot and Otieno, 2017). These are farmers keeping dairy cows with a herd of less than 5 milking cows on less than one hectare of land (Dennis, 2010). In this research, therefore farmers with a herd of fewer than five cows irrespective of the breeds were rural small-scale dairy farmers.

1.8 Organisation of the Thesis:

Table 1.1: The organisation of the thesis

	Chapter	**Overview**	**Objectives**	**Publication**
1	Proposal	Introduction, problem and it's setting	-	Not applicable
2	Literature Review Research Manuscript 1	Literature review: rural small-scale dairy farmers	-	Work in progress
3	Methodology	Community Engagement for Research and Design	-	Not applicable
4	Research Manuscript 2	Survey of rural small-scale dairy farmers' milking hygiene practices and its effect on raw milk quality in Kwa-Hlabisa, KwaZulu-Natal, South Africa	4&5	Work in progress
5	Research Manuscript 3	Bacteriological and Biochemical Evaluation of Raw Cow milk Sampled from the Villages of Kwa-Hlabisa, Kwa-Zulu Natal	1,2&3	Work in progress
6	Concluding chapter	Conclusions and recommendations	1,2,3,4&5	Not applicable

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

According to the Food and Agricultural Organisation (FAO), food and nutrition security is defined as the condition when all people at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy lifestyle (Grote, 2014, Burchi and De Muro, 2016). This definition is based on four pillars: availability, access (which is an individual entitlement for obtaining food), food safety (use of food) and stability through time (De Laurentiis *et al.*, 2016, Burchi and De Muro, 2016, Ndobo, 2013). South Africa's rural small-scale milk industry could promote food and nutrition security and address poverty alleviation. Since, there is an increasing demand on milk and dairy products because of increasing population and income as well as increasing awareness of health benefits of milk and dairy products (Al-Atiyat, 2014, Smith *et al.*, 2013).

However, milk contamination is a challenging problem in many developing countries. Micro-organism access the milk primarily through the cattle itself when infected with mastitis. Also, microorganisms can find their access to milk through unhygienic milk handling practice production chain or poor animal husbandry practice (Gwandu *et al.*, 2018, Knight-Jones *et al.*, 2016). Therefore, this study was designed with an objective to analyse the microbial aspect of rural small-scale dairy farmer’s milk handling practices from production to utilisation. This can make food available as it depends on domestic production and/or imports, while access to food refers to individuals who need to have adequate resources or entitlements for obtaining food. The use of food depends on adequate diets, nutritious values of food and clean water; and stability ensures that food can be accessed at all times and for this project safety (Grote, 2014, Ndobo, 2013).

2.2 Global Milk Production:

Milk and dairy products account for about 14% of global agricultural trade. World milk production has been projected to increase by 177 million tons by 2025, at an average growth rate of 1.8% per annum in the next 10 years (Outlook, 2012). Whole milk powder (WMP) and skimmed milk powder (SMP) has been the most traded agricultural commodities globally as a percentage of production traded (Stat, 2016). Fresh dairy products, with less than 1% of production traded, had the least traded agricultural commodity.

Dairy products have been projected to increase by 0.8% and 1.7% per year in developing countries between 0.5% and 1.1% in developed countries (Outlook, 2012). The projected increase of milk consumption in the developing country could be attributed to the fact that these countries realize the benefits milk has to human nutrition and food security, especially among the most vulnerable which are children (Louw, 2013). In addition, due to the alarming numbers of Vitamin D deficiency among children. Milk consists of carbohydrates and fats for energy, proteins for development and repair, as well as several vitamins and minerals that are essential for a child's diet. The presence of calcium, phosphorus and vitamin D in milk supports the healthy development of bones and teeth in children. This presents an opportunity for the rural small-scale dairy farmers, who could potentially be able to address the nutrition challenges from the food access perspective since milk could be more affordable to the socio-economic and disadvantaged communities (Paraffin *et al.,* 2018, Smith *et al.*, 2013).

The sheer size of the dairy industry and the growth rates can produce immense development payoffs for people’s livelihoods, for the environment, and for public health, could mean that the dairy industry can open new opportunities of income for the rural household and help fight poverty and improve the nutritional intake of rural household and families (Sibhatu and Qaim, 2017, Ohlan, 2016). Since it has been observed that South Africa is largely faced with income inequalities and absolute poverty. Nationally, South Africa appears to be food secured, when in actual fact is not because many households in rural areas are facing inadequate food and nutrition security (Ndobo, 2013, Masuku *et al.,* 2017). Nevertheless, milk can provide 6.4 % of calories and 8 % of proteins to South African rural household since many of them keep dairy herd as rural small-scale dairy farmers. Milk can be easily accessible and cheaper for many South African household in rural areas since they keep dairy herd as rural small-scale dairy farmers. Milk and dairy products are a major source of cheap and nutritious food to millions in the world (Ohlan, 2016).

Milk is a nutrient dense food supplying energy and significant amounts of protein and micronutrients including calcium, magnesium, selenium, riboflavin, vitamins B5 and B12, which are essential to reduce hunger and malnutrition particularly among the most vulnerable for example, pregnant women and children (Uddin *et al.,* 2012, Mahmoudi *et al.,* 2014). Increased milk consumption is therefore assumed to improve nutritional outcomes for households. In addition, dairy production increases incomes, households with dairy cattle can afford to purchase more food and a wider variety of foods. This 'income effect' normally contributes to the improvement of food and nutrition security in all household's livelihood (Datta, 2014). Dairying, in general, is counted as one of the activities expected to alleviate poverty and unemployment especially in drought-prone rural areas of developing countries including South Africa (Ohlan, 2012, Mpandeli and Maponya, 2014).

World milk production is largely derived from cattle, buffaloes, goats, sheep, and camels (Bingi and Tondel, 2015). Developing countries like South Africa produce most of their milk from cattle. Non-cattle milk is economically and nutritionally important and is part of milk consumption in many other parts of the world except South Africa (Handford *et al.,* 2016). Buffalo milk contributed 11% of the milk production in 2013, followed by goats 2%, sheep 1% and camel milk 0.4% (Handford *et al.,* 2016). Dairy animals are raised in four types of production systems, viz. 1) specialized landless system 2) market-oriented 3) subsistence-oriented or integrated dairy-crop system and 4) pastoral system. Specialized landless systems, the main objective is the production of milk only. Market-oriented and subsistence-oriented integrated dairy-crop systems target the joint production of several outputs, including milk, meat, and crops (Kefyalew *et al.,* 2016). In pastoral systems, livestock is the main source of production for livelihood no crops are grown (Tegegne *et al.,* 2013).

It is estimated that there are more than 150 million rural small-scale dairy farming households, and about 750 to 895 million people globally, which are engaged in milk production and most of them are coming from developing countries (Hostiou *et al.,* 2015, Payal *et al.,* 2018). Most rural small-scale dairy farmers keep livestock for the purpose of producing milk for self-consumption and sale (Rapsomanikis, 2015). Even though rural small-scale dairy production is increasingly becoming an important source of livelihood for many developing countries, but it is yet to reach its full potential (Payal *et al.,* 2018, Dhaka *et al.,* 2017).

There are still many threats and challenges the sector is currently facing especially in rural areas which still need to be addressed and South Africa is no exception to these challenges. In many developing countries, rural small-scale dairy farmers still lack the skills to manage their farms as enterprises; have poor access to support services like production and marketing advice; have little or no capital to reinvest with limited access to credit; and are handicapped by small herd sizes, low milk yields, and poor milk quality and hygiene practice (Malede *et al.,* 2015, Odero-Waitituh, 2017). The dairy herd size is pure and crossbred cows ranging from one to five in size and it can give the average milk yield of 11 litres per farm per day. In developing countries and in intensive dairy operations the milk production totals to one million LITRES per year by the small-scale dairy farmers and creates 200 on-farm jobs (Odero-Waitituh, 2017).

2.3 Overview of Dairy Sector in Africa:

Sub-Saharan Africa is a food-deficit region, with dairy products being particularly in short supply mainly in South Africa (Wada *et al.,* 2015, Goodison, 2015). The rural small-scale dairy farmers in the Eastern part of Africa has been observed to play a significant role in addressing the shortage of food and nutrition security of rural households, however, in South Africa, this is yet to be observed. (Duncan *et al.,* 2013). Africa has been observed to be populated with large numbers of livestock since the landscape allowing itself to livestock farming. The cultural beliefs also see livestock as wealth in the hands of the owner. Sub-Saharan Africa's food production per capita is generally below the world average and consumption of commercially produced dairy products remains relatively low in Sub-Saharan Africa, accounting for only third of the dietary energy supply and dietary protein supply compared to milk role in the diet of Europeans (Goodison, 2015). Livestock production particularly meat, eggs, and milk have been under pressure for the past decades in Southern Africa due to change in climate which is foreseen causing a staggering deficit in food and nutrition security (van Marle-Kőster *et al.,* 2015).

Country-by-country the consumption of milk in Africa is a complex story, one uncontested truth is the demand for milk is growing across the continent (Fawi and Ahmed, 2017). A recent survey published by global packaging company Tetra Pak has projected Africa to see an increase of more than 50 percent in liquid dairy consumption, growing from 15 billion litres in 2010 to almost 25 billion litres in 2020 (Kurt Davis Jr, 2011). Milk consumption in Africa is currently the lowest in the world, around 37 per capita annually, which is 67 litres below the world average of 104 litres per capita and only accounts for six percent of world consumption (African Dairy Market, 2014). However, growth will come at the expense of "loose milk", which is unpasteurised or raw milk produced and sold by rural small-scale dairy farmers in cans or plastic bags. Unfortunately, this implies more imported pasteurised milk until local production can develop the technology and packing capability to meet demand. Nevertheless, this low consumption can be mitigated by rural small-scale dairy farmers as it has been observed in countries like India and Pakistan. South Africa has many examples of high-cost spending on milk importation which is unnecessary since rural small-scale dairy farmers can be empowered to supply milk at a lower cost. Imports of milk have been observed to negatively affect the trade balance in countries like Mali and Niger and this can be the consequence for South Africa also (Kurt Davis Jr, 2011).

The second recognizable truth is that many rural households keep cows in large numbers within the continent. However, this truth is coupled with some troubling reality of poor utilisation of cows especially in the aspect of milk production by rural small-scale dairy farmers (Mbanjwa, 2016). In some Sub-Saharan African countries including South Africa, the production of milk by rural small-scale dairy farmers is below 200 litres of milk per year, compared to over 12,500 LITRES per cow in some developed countries. For example, Kenya has many cattle population compared to South Africa, yet the reports on milk production numbers are not even close to what one would expect given its cattle population (Oyekale, 2013). The cause of these terrible results in Sub-Saharan Africa is low quantity and quality of feeds, lack of reliable statistical information on milk market outlets, poor rural infrastructure, lack of collateral for loans, low technical skills on husbandry practices which is what this research is trying to address, reduced access to veterinary and artificial insemination (AI) services (Odero-Waitituh, 2017). Consequently, many rural small-scale dairy farmers in Sub-Saharan Africa fail to enter the processing aspect of the dairy business where most of the value is added because of the transaction cost (Louw, 2013).

2.4 Transaction Cost Limitations in Rural Small-scale Dairy Farmers in Africa:

The term transaction cost can be broadly defined as the costs related to a market exchange which act as the key barriers to market participation for resource-poor rural small-scale dairy farmers (Okoye *et al.,* 2016). Nevertheless, Williamson (1996) defined it as a "trade-off between the costs of coordination within an organisation and the costs of transacting and forming contracts in the market". This trade-off depends on the degree of transaction costs (Pingali *et al.,* 2007). On the other hand, Eggertson (1990) defines transaction costs as "the costs that arise when individuals exchange ownership rights for economic assets and enforce their exclusive rights" (Somda *et al.,* 2005).

Milk production has remained an important source of livelihood for many poor rural households in many developing countries; providing an important source of nutrients and contributing to household food and nutrition security (Payal *et al.,* 2018, Okoye *et al.,* 2016). Unfortunately, most rural small-scale dairy farmers in many developing countries (including

South Africa), are characterised by numerous market failures that has been hindering their participation as dairy producers or milk suppliers to further reduce poverty in rural households (Amorim *et al.,* 2013; Barrett, 2008; Wiggins *et al.,* 2010). Milk production in many developing countries has been through rural small-scale dairy farmers but their production is of a minimal yield (Holloway *et al.,* 2000; Thornton and Herrero, 2001).

In addition, many of rural small-scale dairy farmer's locations are dispersed making them be unattractive to suppliers of more organised and dependable market outlets such as processors. Furthermore, rural small-scale dairy farmers have been observed to be situated in remote areas which limits their access to dependable infrastructure, which can influence higher transaction costs, this has compromised their capacity to access structured markets (Jayne *et al.,* 2010). Limited access to input markets also has heightened the cost of production further restricting households to a low-input-low-output vicious cycle (Okoye *et al.,* 2016).

2.5 The South African Dairy Industry: A National Perspective:

Along with exports, the milk industry has contributed significantly to South Africa's national Gross Domestic Product and the South African economy directly and indirectly (Gertenbach, 2007). One area that it has noticeably contributed is the South African economy in the creation of job opportunities for rural households because of the labour-intensive nature of the industry. In South Africa by 2012, there were "400 milk producers employing 60 000 farm workers and providing 40 000 people with indirect jobs within the value chain milk processing and milling industry" (DAFF, 2014).

The South African milk industry comprises two sectors: 1) commercial producers and large processors, and 2) small to medium size producers, distributors, and processors. Commercial producers generally sold milk to large processors to produce dairy products for distribution to retailers or for exports (DAFF, 2014). Small to medium size producer distributors typically sold their products directly to consumers. According to the Milk Producers' Organisation (MPO, 2015) of South Africa, 96% of the total milk produced nationally was sold in the commercial market. Although the gross value of fresh milk fluctuates, gross milk production values from 2001 to 2011 s increased (DAFF, 2014). Raw milk purchases between 2011 and 2015 increased linearly (MPO, 2015). However, the industry had begun a decline in milk production by 4.9% in January 2016 compared to January 2015 production (MPO, 2016).

2.5.1 Microbiological Quality of Milk in South Africa:

Microbial quality of milk refers to the cleanness and purity of milk from bacteria including pathogens. The high bacterial count as well as the presence of pathogenic bacteria in milk not only degrades the milk quality and shelf-life of milk or milk-related products but also poses a serious health threat to consumers (John, 2016). Milk being a wholesome food with high nutritive value is often prone to early contamination and spoilage if not handled properly (Mahari and Yemane, 2016). The fewer the number of microorganisms in milk the higher the quality of milk. The microorganisms may originate from the cow or the environment (Quigley *et al.,* 2013).

South African milk standards were set out for the regulation of matters relating to milk and dairy products (Regulation R. 1555 of 1997). Milk regulation of South Africa for milk producer (including rural small-scale dairy farmer) gives a clear prescription regarding the bacterial content allowed in the milk, including total bacterial count, the presence of pathogens like *Escherichia coli* and *Coliforms* (Gildenhuys and Tabane, 2018). The quality of milk and the general status of hygiene practices in a dairy farm including rural dairy farms can be described using bacterial indicators. Methods like somatic cell count (SCC) and standard plate count (SPC) have been designed for the purposes of assessing the general quality of milk (Quigley *et al.,* 2013). Regulation R. 1555 of 1997 have stipulated that raw milk intended for further processing should not contain more than 200 000 CFU's per 1.0 ml of bovine milk.

The same legislation also stipulated that pasteurised milk should not contain more than 50 000 cfu per 1.0 ml of milk. Naturally, *Escherichia coli* is found in the intestinal tract of animals and human beings, therefore its occurrence in milk is commonly used as an indicator of faecal contamination of milk (Schoeman, 2013). South African milk regulation standard clearly states that raw milk projected to be used for further processing cannot contain Escherichia coli per 1.0 ml of bovine milk. Coliform bacteria, on the other hand, are used as an indicator of general hygiene throughout the milk handling process. The legislation stipulated that raw milk intended for further processing, may not contain more than 1,000 cfu/ml of coliform bacteria per 1.0 ml of bovine milk, while pasteurised milk may not contain more than 10 coliform bacteria per 1.0 ml (Martin *et al.,* 2016).

2.5.2 Milk Production by Small-scale Dairy Farmers in South Africa:

Milk production in South Africa is controlled by the large commercial market which is regarded as complex and intensive with economic viability based on economies of scale. This place the South African dairy industry in the fifth position as the largest agricultural industry in the country (Serebro, 2016). It has also been reported to be contributing to 0.54% of milk to the world (DAFF, 2014). This market marginalises rural small-scale dairy farmer's development although the National Development Plan states that small-scale dairy farmers in rural areas need to be developed to promote food and nutrition security, employment, economic growth, and sustainability (Tanyanyiwa, 2016). Rural small-scale dairy farming is successful in most developing countries in Africa and beyond, but this is not true in South Africa (DAFF, 2014).

The general approach to achieving successful rural small-scale dairy farming is needed. This involves adherence to good animal, farming, milking and hygiene practices, sustainability and food safety requirements; and a thorough knowledge of production and managerial practices, especially by rural small-scale dairy farmers (Mbanjwa, 2016). However, dairy farmers in rural area still do not have adequate access to suitable and enough land, finances, infrastructure, markets, and technical production and managerial knowledge (Swanepoel *et al.,* 2010). Therefore, because of these challenges rural small-scale dairy farmer's contribution has been observed to be insignificant to the mainstream dairy industry of South Africa (Gertenbach, 2007).

Characterisation of rural small-scale dairy farmers has been reported to be an important requirement towards understanding the constraints and opportunities facing the rural small-scale dairy farmers to be able to produce for the mainstream dairy industry (Baloyi, 2010). The rural small-scale dairy farmers are characterised by keeping up to 15 heads of milking cows and producing less than 100 litres of milk per day compared to emerging dairy farmers who have been producing more than 100 litres of milk per day (DAFF, 2014). In the rural small-scale sector, milk is largely obtained from indigenous cattle and their crosses with exotic beef breeds. These cattle breed also have numerous functions in the rural small-scale areas which include meat, cash through sales, draught power, manure production, social security, and ceremonies (Mapekula *et al.*,2009; Ndebele *et al.,* 2007). In addition, these indigenous cattle fail to let the milk down without the presence of the calf and late development. Rural small-scale dairy farmers practice dairy farming as a source of food and income, and it also provides them with by-products such as manure to support crop production (Urassa and Raphael, 2017).

In South Africa, the commercial dairy industry has been producing an estimated number of 229-million litres of fresh milk per annum from 0.79 million cows (DAFF, 2012). Nevertheless, these statistics still exclude milk production from the rural small-scale dairy sector (Gertenbach, 2007). The study done by Prinsloo and Keller (2000) showed that milk produced by the rural small-scale dairy farmer is mainly for their household utilisation and sales to neighbours. However, there are no records of the amount of milk produced by the rural small-scale dairy sector. Therefore, its' contribution to the household and national economy is largely unknown (Payal *et al.,* 2018). To design sustainable improvement programmes, it is crucial to evaluate the current production levels and milk consumption patterns of rural small-scale dairy farmers. Development of rural small-scale dairy production is a possibility to increase food and nutrition security and income for resource-poor farmers (Simelane, 2011).

2.5.3 Contribution of Rural Small-scale Dairy Farming to Household Food Security:

The FAO (FAO, 2010) has emphasised the fact that the rural small-scale dairy development sector plays an important role in reducing poverty, primarily in rural areas. A study conducted in Bangladesh by Hemme, *et al.* (2004), revealed that in addition to earning of increased income, rural small-scale dairy farming allows the farmers to move from subsistence to a more market-oriented approach. Rural small-scale dairy farming is known for its various benefits to the rural household. Some of the benefits are its contribution to food and nutrition security by means of providing protein to the human diet (FAO, 2008; Klapwijk *et al.,* 2014). Moreover, rural small-scale dairy farming provides a consistent source of household income through milk being sold while in the process creating employment for either the intermediaries or the milk processors (Uddin *et al.,* 2012).

Dairy farming contributes to the livelihoods of rural small-scale dairy farmers. Rural small-scale dairy farmers, particularly those who have been observed practising mixed methods benefit more from the flow products, such as milk, draught power, manure; as compared to the end products (meat and hides) (Rangnekar & Thorpe, 2001; Klapwijk *et al.,* 2014). This is because gaining from the end products implies that the farmer would have permanently lost ownership of their livestock and thus, the flow products are preferred. Individual households acquire income from the products of dairy which is used to meet household expenses, insurance, investment, and other needs. These benefits are considered to last for as long as the cows are still owned by the farmer (holding the milk quantity produced per age of animal as a constant).

Numerous studies have reported that rural small-scale dairy farming can contribute to livelihoods through generating income, providing employment and reducing food and nutrition insecurity, especially in South Africa since there is the prevalence of hidden hunger (Kibirige and Obi, 2015, Gelan and Muriithi, 2015). However, there are no records for milk production methods and the amount of milk produced and consumption patterns by the rural small-scale dairy sector. Therefore its contribution to the household and national economy is also largely unknown (Kumbirai, 2016). In 2006, the situation in South Africa indicated that many rural households are poor, vulnerable to food and nutrition insecurity, and marginalised from the economy. However, this can be reconciled with rural small-scale dairy farmers milk production as it contributes to household livelihood direct and indirect (Bennett *et al.,* 2006).

Indirect benefits include income received from the sales of milk and employment opportunities generated in both production and marketing (Mapekula *et al.,* 2010). Rural small-scale milk production also has a direct contribution to the intensification of the production systems for instance, by better use of crop residues and other by-products, and increased availability of manure for crop production (Smith *et al.*, 2013). Nevertheless, Bennett et al (2006) pointed out that these benefits are hardly realised at household level because large retailers and larger dairy industries around the world are promoting the use of new technology in manufacturing practices or highly expensive agricultural practices such as the use of milking machines, which are increasingly raising the standards but making it difficult for rural small-scale producers to participate. The failure of rural small-scale milk producers to compete with international dairy products hampers efforts to increase trade both intra-regionally and internationally on such commodities, preventing many farmers from realising an opportunity to improve their economic well-being (Bennett *et al.,* 2006).

Rural small-scale milk production is an important means of diversifying and intensifying a range of farming systems. Dairy animals have been reported to ensure better utilisation of resources like labour, land, farm and industrial by-products, and add value to crop production through the production of milk. Benefits arise through the marketing of milk, meat, hides and, in some cases, manure. Moreover, there are several non-marketed benefits from milk production, such as the value of manure used on the farm, the function of animals as security/saving and a means of financings sudden or periodic expenditures like medication or school fees, as well as their use as draught animals (Henriksen, 2009, Mapekula *et al.*, 2010). Milk production is based on ruminants that consume and digest otherwise more or less worthless farm wastes, like stalks, straw, hulls, vegetable residues and other plant material not useful for human consumption. These resources are often available at no or very low cost. Similarly, the residues from industrial production based on crops can be made available to small-scale dairy farmers and used as fodder. For example, molasses from sugar factories, brewers waste from breweries, oilseed cake from the oil plant industry, hulls and other wastes from the cereal and flour factories, pulp from various juice factories and the processing of vegetables (Henriksen, 2009).

2.5.4 Case studies:

Small amounts of animal food intake enhance the ability of children to learn and be active at school. A study by Hulett (2013) in Kenya showed that adding food from animal sources to diets has positive effects on the cognitive performance of Kenyan children. However, these effects are not equivalent across all domains of cognitive functioning, nor do all forms of animal source show the same beneficial effects (Hulett *et al.,* 2013). In addition, in another study, adding cow's milk or milk powder to the diet of stunted children is likely to be an effective and relatively inexpensive way of improving linear growth and thus reducing morbidity and improving development. In some populations, however, the incidence of lactose intolerance is high, which may cause problems if milk and milk products are consumed (Michaelsen, 2013). In South African rural areas, it has been noticed that there are high incidences of children who are living in food insecure homes and are victims of malnutrition and micronutrient deficient. Therefore, daily milk supplementation at junior and high school levels can be a cheaper way to combat malnutrition in school children of South Africa (Steyn *et al.*, 2016). This can even improve the level of performance at school as milk has a positive effect on physical, mental and performance of students at school (Visioli and Strata, 2014).

2.6 Challenges Faced by Small-scale Dairy Farmers in South Africa:

This section is aimed at identifying key challenges facing rural small-scale dairy farmers in South Africa, such as the lack of physical infrastructure, lack of markets, and high transaction costs. The migration of many people from rural to urban cities in South Africa has led to high demand for milk by South African citizens as food and source of income. To be able to meet up with this demand, South African rural small-scale dairy cattle's low milk production must be improved. This can be done through finding appropriate and working solutions to the improvement of rural small-scale dairy farmer's productivity (DAFF, 2012; Banda *et al.*, 2011).

Rural small-scale dairy farmers find it difficult to compete in the new market environment. They face different challenges, for example, access markets. In addition, rural small-scale dairy farmers lack market information, business, and negotiating experience, and a collective organisation to give them the power they need to interact on equal terms with other generally larger and stronger market intermediaries. The result is poor terms of exchange and little influence over what they are offered (Heinemann, 2002). A discussion of some of the common challenges facing rural small-scale dairy farmers, as revealed through international experience, are discussed below.

2.6.1 Knowledge and Training Management:

2.6.1.1 Lack of Human Capital:

Rural small-scale dairy farmers often have a low education level, with poor technological skills, which can be serious obstacles in accessing useful formal institutions that disseminate technological knowledge (Baloyi, 2010). Many rural small-scale dairy farmers' producers are not capacitated with financial and marketing skills and are unable to meet the quality standards set by fresh produce markets and food processors. Lack of production knowledge leads to lower quality of production (Khapayi and Celliers, 2016, Tanyanyiwa, 2016).

2.6.1.2 Lack of Information on Markets:

Rural producers and especially rural small-scale dairy farmers have little information about the market demand, which is costly to obtain. They may gather information through contact with other actors in the commodity chain, but the accuracy of this information is not certified since those actors might be exhibiting "opportunistic behaviour" (Bienabe *et al.,* 2004). Rural small-scale dairy lack information about product prices at the local level, about quality requirements, about the best places and times to sell their products, and about potential buyers. This, in turn, reduces their ability to trade their products efficiently and to derive the full benefit from the marketable part of their production.

2.6.1.3 Utilisation of New Technology:

Agricultural technologies, such as improved breeds of dairy cows and improved forages, have the potential to improve the livelihoods of rural small-scale dairy farmers through higher yields, better household income and improved nutrition. In the past 60 years, modern technologies in animal breeding, feeding and animal health care have been promoted to transform rural small-scale dairy production into market-oriented dairy enterprise in developing countries such as South Africa, Ethiopia and Kenya (Duncan *et al.*, 2013; Oosting *et al.*, 2011; Staal *et al.*, 2008). Despite many years of efforts, however, these technologies (e.g., improved breeds of dairy cattle, artificial insemination, improved forages and veterinary health care) are not commonly used by rural small-scale dairy and the productivity of dairy cows remains low (Ayele *et al.,* 2012; Duncan *et al.,* 2013).

Masika (2012) stated that there is a need to bring in innovation to enhance the use of mobile technology for rural small-scale dairy farming as is what happens to the bank through e-banking services. In rural small-scale dairy farming, ICTs seem perfectly suited to the chore of improved interaction among dairy farmers or stakeholders since they can expand communication, collaboration, and ultimately innovativeness among the growing array of actors in agriculture (Sife *et al.,* 2010). ICTs, especially mobile phones, can drive participatory communication, including communication from those on the margins of traditional research-extension processes. They are expected to play a significant role in supporting the many reforms that are needed to develop small-scale and emerging dairy farmers. Thus, many developing economies want to effectively meet food security needs and improve market development (Christoplos, 2010).

2.6.1.4 Poor Access to Government Extension Services:

Extension services are among the most crucial services for rural people in developing countries (Akpalu, 2013). Investments in extension constitute a huge proportion of government spending in many developing countries. The South African agricultural extension service is constantly challenged by researchers to positively impact on food security, advance rural development through agricultural activity and hence increase employment opportunities (van Niekerk *et al.,* 2011). Therefore, the government has continued to fund an agricultural extension for improvement of cattle productivity and its multi-functionality in the small-scale sector (Ndoro *et al.*, 2014). However, access to extension agents by the small-scale farmers in South Africa is very poor (Akpalu, 2013; Munyai, 2012). Chikazunga and Paradza (2012) argue that there is no strong government extension system available to support the small-scale sector in South Africa. Mbo'o-Tchouawou and Colverson (2014) identified some of the major problems affecting the whole extension support services in rural areas.

2.6.2 Animal Health:

2.6.2.1 Lack of on-farm Infrastructure:

Rural small-scale dairy farmers do not have access to on-farm infrastructure such as milking parlours, store-rooms or cold-rooms to keep their milk in good condition after milking. Lack of access to facilities such as storage and processing facilities constitutes a barrier to entry into agricultural markets since the emphasis of buyers is more on quality. Access to storage facilities increases farmers' flexibility in selling their products, as well as their bargaining power (Bienabe *et al.,* 2004).

Lack of community production and marketing infrastructure (NERPO, 2004; Ngeno, 2008) has constrained cattle production among the rural small-scale dairy farmers located in the rural areas of South Africa (NDA, 2008; DAFF, 2014). This has limited the expansion of the farmers in terms of income and growth of the farming businesses. Poor roads and road networks, for example, limits the capacity of farmers to transport inputs, produce and to access information. High transaction costs are also key elements limiting the progression of rural small-scale cattle farmers and it is largely attributed to the lack of infrastructure (Machethe, 2004).

2.6.2.2 Animal Health Management:

Animal health management refers to the welfare of an animal which is the physical and mental state of an animal and the way it handles the conditions surround it. The animal can be in a good state of welfare if it is healthy, comfortable, well-nourished, safe, able to express its innate behaviour (Moran and Doyle, 2015). Dairy cows must be kept healthy with effective health care programmes in place (Surkar, Sawarkar, Kolhe, & Basunathe, 2014). The starting point is by avoiding the entry of diseases onto the farm (Kazanga, 2012; Surkar *et al.*, 2014). Achieving this can be through the boundary of fence that will restrict the entrance of people and wildlife to the farm premises, but this is less observed in rural small-scale dairy farmers in South Africa (Kazanga, 2012).

Most of the rural small-scale dairy farmers in South Africa leave their cattle on an open field, especially for grazing. Avoidance of diseases onto the farm can also be managed by avoiding straight interaction of people with the dairy cows (Kazanga, 2012). The use of clean tools from the trusted sources and effective disinfectants to clean and sanitise tools and other facilities are very important to keep the dairy cow disease free (SAI Platform Dairy Working Group, 2010). The proper and effective system of disease management programmes has been reported as another way of managing animal health. Constant monitoring of animals for some symptoms of diseases and quickly separating that animal from the rest to avoid infection to others through the infected animal and has been reported to be the significant way of informing the health status of the cow (FAO and IDF, 2011).

2.6.2.3 Feeding Dairy Cattle:

The major constraints for the rural small-scale dairy farmers in South Africa are the availability of forage for dairy cow feeding because of climate and the quality of the soil. This is the reason why many rural small-scale dairy farmers who can afford supplement for their fodder normally add grain and (fermented forage rich in nutrient content especially lactic acid) to it (Lues, Jacoby, De Beer, Jansen, & Shale, 2012). The higher the quality of forage produced on the farm, the fewer concentrates (grain) must be bought or produced. The utilisation of pasture grazing, silage, and hay (although not nutritious as silage) assist in meeting the requirements of the fodder.

Locations with limited rain produce their hay or silage during the rainy season to compensate for the dry season. Previous studies have shown that maize delivers good quality silage in crop producing areas (Katsande, Matope, Ndengu, & Pfukenyi, 2013; Lues *et al.*, 2012; Nicholson, Thornton, & Muinga, 2004). The nutritive value of plant material removed from the land as in the case of hay, green chop or silage is affected by factors such as loss of foliage, type of transportation, hay or silage production practices (for example, duration of wind drying, fineness and compaction of silage material, weather condition) and feeding facilities. Dry matter yield increases with plant age while nutritive value decreases (Devereux, 2014).

The constraint in water and feed provision for dairy cattle reduces the expected milk production (Duguma & Janssens, 2016; Umar *et al.*, 2014). Incorrect feeding has also been identified as one of the major factors contributing to limiting increased production of milk (Duguma & Janssens, 2016). A study conducted in Zimbabwe has shown that there is poor nutrition quality in the feed consumed by rural small-scale dairy farmer’s cattle (Manzana *et al.*, 2014). Rural small-scale dairy farmers lack funding to buy supplementary feed during the dry season when the natural feed is limited (Chinogaramombe *et al.,* 2008; Lukuyu, Franzel, Ongadi, & Duncan, 2011).

During this season supplementary feed will be useful because it is rich in proteins and energy and this plays a significant role in increasing the volume of milk produced by a single cow but unfortunately only fewer farmers can afford to provide their cattle with this kind of feed (Duguma & Janssens, 2016). The improvement of feed in rural small-scale dairy farmers can be through cultivating pasture that uses a smaller amount of water during irrigation (Mapekula *et al.,* 2010). This is not easy since rural small-scale dairy farmers do not have proper training in producing these pastures (Mapekula *et al.,* 2010).

2.6.2.4 Scarcity of Drinking Water for Cattle:

Major sources of water for cattle in the rural small-scale farming system include rivers, dams, and boreholes (Amenu *et al.,* 2011). Nevertheless, some of these sources are not as reliable as they do not last throughout the year. Water from rivers and dams become turbid during the rainy season while some of these sources dry up during the off-rain period (Mutibvu *et al.,* 2012). The scarcity of water resources is increasing at a global scale and the severity of this development is expected to be high (Amede *et al.,* 2009). Climate change has largely influenced the state of global water security. This is depicted by frequent changes in rainfall distribution patterns coupled with frequent flooding and drought incidences (IFAD, 2009). Moreover, Amede *et al.* (2009), argued that the incessant scarcity of water in Sub-Saharan Africa is caused by the expansion of agricultural production, climate variability and more importantly inappropriate land use. Such incidences of water scarcity pose a huge constraint to cattle production (Mutibvu *et al.,* 2012).

2.6.2.5 Livestock Management:

Rural small-scale dairy farmers mostly keep indigenous and crossbreed cattle in their systems (Kibirige and Obi, 2015, MilkS.A, 2013). Indigenous cattle are reported to be well adapted to the local feed resources, local housing facilities, and scavenging systems. They have low nutritional requirements, heat tolerance, larger rumen volumes and possibly more efficient digestion of low-quality feed. Most importantly, their performance is also good in terms of feed efficiency. However, the major disadvantages of the local cattle in dairy include low productivity, failure to let the milk down without the presence of the calf and late maturation (MilkS.A, 2013).

Milk production by rural small-scale dairy farmers for the improvement of poverty in Sub-Saharan Africa has been reported to be extensively dominated by indigenous dairy production adaptive to the local environment (Nyamushamba *et al.,* 2017, Mersha and Cuvillier, 2015). These breeds range from Nguni, Mashona, Tuli, Malawi Zebu, Bovino de Tete, Angoni, Landim, Barotse, Twsana and Ankole (Nyamushamba *et al.,* 2017). Rural small-scale dairy farmers keep these breeds not only for milk production but for other purposes (Mersha and Cuvillier, 2015). Such as socio-economic, food provision, income, cultural and ecological roles, for example, the use of cow dung for traditional houses. The above-mentioned breeds are already conditioned to harsh milking environment such as high temperatures, droughts, floods, diseases and parasites caused by climate change. Breeds majorly kept by rural small-scale dairy farmers have an advantage compared to exotic breeds which have been raised in temperate climatic conditions and this improves production for food and nutrition security (Nyamushamba *et al.,* 2017).

The fact that many of the rural small-scale dairy farmers are in remote areas and their dairy cows are prone to tick infestation which reduce milk production, cause blood loss and transmit a number of diseases makes indigenous breeds advantageous since most of them are resistance to tick-borne diseases (Nyamushamba *et al.*, 2017). Extensive grazing is a common practice by rural small-scale dairy farmers since they are poor in resources. This practice has been observed to harbour many challenges when it comes to feeding quality and quantity especially during the dry season which has been a major constraint to rural small-scale livestock production (Tada *et al.*, 2013, Nyamushamba *et al.,* 2017). Indigenous cow milk production systems are economically efficient despite the output from the individual cow being low, the inputs (in terms of feed, infrastructure, and health medication) are also usually lower (Tarwireyi and Fanadzo, 2013).

2.6.2.6 Diseases and Parasites Prevalence Among Small-scale Farmers:

The prevalence of diseases constitutes a major challenge to cattle production in the rural small-scale dairy sector (Agholor, 2013). Research showed that most farmers in the rural small-scale sector observe ticks as the most important ectoparasite that affects animal production and health (Dold and Cocks, 2001; Rajput *et al.,* 2006). According to DAFF (2008) ticks cause loss of blood, retardation in growth and loss of weight, irritation due to biting (tick worry) and hence reduced feed intake. Moreover, by penetrating the animal skin to suck blood, ticks cause damages to hide and skins, introduces toxins and predispose cattle to secondary infections and hence reduces animal health (Mtshali *et al.,* 2004, DAFF, 2008). In South Africa, one of the main tick-borne diseases with a significant economic impact on cattle production in the rural small-scale sector is Cowdriosis (*ehrlichia ruminantium*) with common name heart water.

Musemwa *et al.* (2008) reported that cattle diseases and parasites prevalence is one of the most important factors and it has caused a decline in cattle productivity in South Africa's rural areas. Thus, animal health concerns affect the number and quality of animals and its products to be sold and in many cases increase morbidity and mortality hence they are barriers to trade (Chawatama *et al.,* 2005; Mwacharo and Drucker, 2005). One of the major causes of parasites and disease transmission between different communities is the uncontrolled movement of animals and animal products (Musemwa *et al.,* 2008).

2.6.2.7 Feed Shortage:

Availability of feed challenge is faced as a result of the dependence on natural fodder by rural small-scale dairy farmers which is dependent on the natural rain season. In the dry season, the fodder availability and quality deteriorate and thus affecting the productivity of the dairy animals (Mapiye *et al.,* 2006; Klapwijk *et al*. 2014). The feed contains energy, protein, and water that are essential for animal growth, production and health (Kazanga, 2012). The consequence of feed shortage to the rural small-scale dairy farming system is poor milk yield, poor quality, distortion of the oestrus cycles, poor body condition, and long calving intervals. This is because they have limited land, access to water and they cannot afford to buy feed regularly (Atuhaire *et al.,* 2014).

Social issues such as farmers' cattle feed and feeding management skills may determine the quantity and quality of feed resources available for feeding the animals. The availability of feeds is likely to be a major problem when farmers have poor feeds and feeding management skills (Pen, 2010). Munyai (2012) reported a lack of knowledge of rangeland management and stocking rates. That leads to a decline in vigour and the eventual death of preferred species (biodiversity loss) in South Africa's smallholder farming communities. Also, social issues such as communal ownership and the allocation of rangelands rights by traditional leaders (Cousins, 1996) allows individuals to have free access to rangeland resources hence leading to lack of individual control. Lack of individual control by farmers has consequently led to poor management and protection of the natural grazing lands and complicates the introduction of improved management practices (Cousins, 1996).

2.6.3 Milk Production:

2.6.3.1 Constraints on Production:

Producing for the market calls for production resources that include land, labour force, and capital. Poor access to these assets affects the way in which rural small-scale dairy farmers could benefit from opportunities in agricultural markets, especially in terms of the volume of products traded and the quality of those products (Malede *et al.,* 2015, Baloyi, 2010). Rural small-scale dairy farmers lack consistency in terms of producing for the markets due to insufficient access to production resources (Nguyen Hung *et al.,* 2013).

2.6.3.2 Low Quantity and Poor Quality:

Due to their low endowment in production factors, such as land, water, and capital assets, many rural small-scale dairy farmers produce low quantities of milk that are of poor quality, which leads to their products being neglected by output markets (Bienabe *et al.,* 2004,). Increasing concentration in the food value chain is a global trend, caused by increasingly demanding consumers and concerns about food safety, which tend to make it very difficult for rural small-scale dairy farmers to enter high-value markets considering the low quantity and poor quality of their product.

2.6.3.3 Milking Intervals and Milking Frequency:

There are many reasons why rural small-scale dairy farmers do not practice the system of milking more than once a day. The first reason is that there is a shortage of husbandry information and infrastructure cost implications. Another reason is that cow's use the full day grazing on the grazing site that is far away from the rural small-scale dairy farmers homestead (Dugmore *et al.,* 2004). Once a day milking system has been reported to be a contributing factor towards low milk yield in rural small-scale dairy farming (Millogo, Ouedraogo, Agenauml, & Svennersten-Sjaunja, 2008). The main reasons rural small-scale dairy farmer practice once a day milking system includes:

I. It gives more time to work on other farm-related work or spend time with family.

II. Once a day milking system helps the rural small-scale dairy farmer to spend less on infrastructure, reduce maintenance structure and save energy.

III. Inability to feed the animals adequately throughout the year and this the case in most sub-Saharan African countries. This is caused by the scarcity and poor quality of on-farm feed resources and the high cost of purchased concentrate supplements, thus rendering the dairy cows deficient in protein especially during the dry season (Kessy *et al.,* 2016). Therefore, diets often do not meet both maintenance and production requirements. While commercial farmers do their milking at least twice a day and most three times a day which contributes to their high yield of milk production (Vijayakumar *et al.,* 2017).

Milking a cow at least two times a day is regarded as part of a good management routine. In some economic environments, notably high-cost, high-return dairy production systems, it is desirable to maximise milk production and it can be profitable to increase milking frequency to enhance milk yield (Stelwagen *et al.,* 2013). Not completing milking for numerous successive days has been reported to be the cause for reduced milk yield and can reduce the cow's milk yield for the entire lactation period (Løvendahl & Chagunda, 2011). Rural small-scale dairy farmers have been observed to be not well informed about the effect of milking intervals and frequency and the impact it can cause in milk yield (Dugmore, Oosthuizen, & Du Toit, 2004). According to (Ben Chedly, Lacasse, Marnet, & Boutinaud, 2013) who undertook an investigation on Once-Daily Milking (ODM) and observed a reduction of about 40% milk yield in the cow that is milked only once a day.

The sad part is that even if the dairy cow was the high producer of milk quantity once is milked only once day milk starts to decrease drastically to the point it adapts to this ODM (Lyons *et al.,* 2014). The mechanism involved in milk production in cow's mammary gland is complex, but the researcher suggests the decrease in the epithelial cell. The decrease in epithelial cells leads to a decrease in milk production by cows (Williams *et al.,* 2012). Other factors include metabolic and infectious diseases, nutrition, and stage of lactation, incomplete milking, pregnancy, climatic factors, animal welfare factors and other management factors (JUMA, 2015).

2.6.3.4 Milking, Milk Handling, and Processing:

The FAO and International Dairy Federation (IDF) have agreed that milking is one of the most vital stages in the whole process of milk chain (FAO and IDF, 2011). Both organisations agree that for characterisation of milk to be in a good hygienic state, the milk should have the lowest physical and chemical bacterial contamination (Kazanga, 2012). Ensuring that there is no contamination throughout the milking process and finishing the milking process within the shortest time shows good milking management skills (Kurwijila, 2006). Description of milking hygiene can be as follows:

i. Carefully guiding that milking practice does not cause injury to the cow and they do not lead to milk contamination.
ii. Keeping clean hygienic conditions where the milking process is being carried out.
iii. Make certain that milk is held appropriately after milking (FAO and IDF, 2011).

Milking a relatively clean cow can help to avoid milk being contaminated with bacteria from the cow‘s udder and the sides of it. Cutting off long hair that grows on the udder can be of benefit to keep the udder clean (Abebe, 2016). Milk secreted from a clean cow's udder is sterile and when it gets in contact with the sides of the udder when it gets contaminated (Zewdu, 2015). Also, a proper housing structure that reduces dirt during the milking process must be provided to increase milk quality of which in rural small-scale dairy farmers of South Africa they do not have, and milking is done inside the kraal (Gillah *et al.*, 2014). Washing and disinfecting the teats before milking begins also plays a very significant role in terms of milk hygiene (Olofsson, 2013). During the situation where the teats are clean, removal of dirt on the udder with a hairbrush instead of using water can be done. Warm water must be used when teats are dirty, and a clean towel must be used to dry the teats as well as the whole udder after washing with warm water. Drying the udder and teats with separate towels must be used for each cow, this reduces the chances of milk cross-contamination and transmission of mastitis during the milking process. Nevertheless, most rural small-scale dairy farmers in South Africa do not dry the teats after washing; they use the water remains as a lubricant during the milking process. Besides the prevention of contamination, cleaning of the udder and teats helps to stimulate milk discharge (Johnson, 2000).

Good quality milk production by rural small-scale dairy farmers can be achieved if the observation of the following steps of milking is done daily:

i. “Washing the udder with warm water and wipe with a clean towel before milking, this helps reduce milk contamination and stimulates milk ejection. If the udder is generally free of dirt, then water is not necessary although physical removal of any dirt is recommended.
ii. Removal of the foremilk from a black strip cup, this helps to check for abnormalities in the milk like discoloration, clots or blood. Discard the foremilk.
iii. Completing the milking process within 5-8 minutes from cleaning the udder, after 5 minutes the stimulatory effect of the release of oxytocin wanes.
iv. Dipping of teats in a post-milking disinfectant as this prevents infection of the udder.
v. After use, milking utensils must be cleaned with cold water first and then hot water with disinfectants (i.e. soap), rinsed and dried in the sun on a drying rack. Non-perfumed soap is preferred.
vi. Milkers must be healthy and not suffer from chronic and contagious diseases in terms of Tuberculosis (TB), Influenza and open wounds.
vii. Healthy cows should be milked first while cows suffering from mastitis should be milked last and milk from the infected quarters should be discarded.
viii. Milk should be cooled immediately after milking”.

Milk hygiene also involves disposal of milk from sick cows or under antibiotic treatment which can be termed as accidental milk adulteration. This means that they should be milked last and their milk is discarded (Kurwijila, 2006). According to FAO and IDF, this milk is not fit for human consumption (FAO and IDF, 2011). Poor hygiene has made the percentage of cows with mastitis to be higher compared with those cows under good hygienic management (Kazanga, 2012). Good hygiene is also important to the person milking the cow in the case where milking is done by hands. If care is not taken the person milking the cows can be the cause of bacteria infecting the sterile milk being harvested. These incidences are highly prevalent in rural areas of developing countries where milking is done by hands. The milker should not be under the influence of communicable diseases or have sores on any of his or her body. The milker should be cleaning his or her hands between the milking of two cows to prevent moving bacteria from one udder of a cow to another (Hofer, 2015).

In the production of fresh milk free of microorganisms and in good quality, the hygiene and use of utensils free of pathogenic organisms are very important. Milking vessels should be cleaned each time when use (Amentie *et al.*, 2016). Correct cleaning of the utensils starts with cold clean water to rinse the milking utensils. This eases the removal of milk residues on the surface of the vessels. Rinsing is followed by cleansing with boiled water and soap or simply soap with and water. The non-perfumed soap is usually recommended for this exercise. After rinsing the soap from the vessel, the last step in cleansing utensils is to dry them immediately, in the sun if possible. The utensils must always be stored upside down and off the ground when they are not in use (Kurwijila, 2006).

2.6.3.5 Reproduction and Breeding Management:

In South Africa crossbreeding of traditional with imported stock for rural small-scale dairy farmers has been considered as a solution to producing dairy cattle with a high yield of milk production (Galukande *et al.,* 2013). Productivity improvement is done by selection within the traditional herds or by introducing a crossbreed animal (Biscarini, Nicolazzi, Stella, Boettcher, and Gandini, 2015). Traditional cattle with the introduced dairy breed are reported to have a more effective performance in their reproduction than traditional cows when it comes to earlier age at first calving and shorter calving intervals (Hammoud and Salem, 2013). Milk produced by the crossbreed has been observed to be higher in volume when compared to traditional cows (Tadesse and Dessie, 2003). The milk yield of the first generation of crossbreed is more than twice as the milk yield of traditional dairy cattle breed (Myburgh *et al.,* 2012).

Crossbreeding allows the improvement of standard production traits such as milk production, growth rate and production of total animal protein (Mapekula, 2009). Improved variety of cattle and other livestock can increase production efficiency and can reduce the number of resources and inputs rural small-scale dairy farmers require for livestock production. Higher levels of milk production can help rural small-scale dairy farmers respond to the growing demand of milk in South Africa with the potential to improve income provided the necessary extension and marketing services and opportunities are accessible (Henriksen, 2009). Furthermore, livestock is expected to be affected by climate change in several ways: feed and water limited by droughts, increasing heat stress and changes in disease prevalence (Rust and Rust, 2013). Heat stress, for example, reduces milk production efficiency, lowers the animal’s welfare and is expected to result in a significant loss due to death. Crossbreeding can increase the resilience of the species to heat stress by reducing the number of resources they require, thereby increasing the stability of livestock and farmers’ livelihoods (Rust and Rust, 2013).

2.7 Management of Milk Production Among Small-scale Dairy Farmers:

The FAO and the IDF reported that good dairy farming practices by rural small-scale dairy farmers influence the safety of milk produced for human consumption. This is irrespective of the type of grazing given to dairy cows or grazing with a supplement or zero grazings in rural areas (FAO and IDF, 2011). Good dairy farming practice can be attained by milking dairy cows that are healthy, practising good milking hygiene, proper dairy cow feeding, provision of enough and clean water, animal welfare and a good environment (Olofsson, 2013). These are some of the characteristics influencing good dairy farming practice, these are animal health, livestock management, milking, milk handling, and processing, feeding dairy cattle, milking interval, and milking frequency, and reproduction and breeding management (Firman *et al.,* 2017). These good dairy farming practices characters will be discussed in detail below.

Observing things like the behaviour of the animal as the herdsman can tell whether the animal is sick or not. Observation of the cow's eating and drinking behaviour will help identify sickness. If there is a change in behaviour, it suggests that there is something wrong with the cow (Bonnier, Maas, & Rijks, 2004). A technique that is frequently used by farmers to determine its unhealthy status is cow's poor body condition. Looking at how well fleshed the cow is can help to tell the farmer whether the cow is healthy or not (Devereux, 2014). Also, its behaviour in eating and drinking water can help in disease uncovering, for example, does the cow eat, drink and ruminate right, its urination frequency and is defecation habitual (Braun, Zürcher, & Hässig, 2015).

2.8 Intentional and Accidental Use of Milk Adulterants by Rural Small-scale Dairy Farms:

Adulteration of milk refers to the addition of foreign matter such as flour, margarine, and water into the milk (Karimuribo *et al.,* 2015). Food adulteration considers not only the intentional addition or substitution or abstraction of substances that adversely affect the nature, substances, and quality of foods, but also there is accidental contamination during the period of growth, harvesting, storage, processing, transport, and distribution. Milk adulteration can negatively affect its microbial quality, taste and market value (Omore *et al.*, 2005). The adulteration can be categorised into two groups: (i). Accidental milk adulteration and (ii). Intentional milk adulteration.

2.8.1 Accidental Milk Adulteration:

Accidental or unintentional milk adulteration can be caused by leaking of the cooling facilities or use of milk containers that are not properly cleaned. In addition, accidental milk adulteration can occur naturally from within the milking cow for example mastitis (Poonia *et al.*, 2017, Ndungu *et al.*, 2016, Moran, 2005). It can also be through dust particles and other extraneous objects that might enter during milk processing accidentally (Poonia *et al.*, 2017). The most common accidental milk adulterations from the rural small-scale dairy farmer is antibiotic residues found in milk. Antibiotics residues happen as a result of the feedstuffs, drugs given to cows orally or through injection or intramammary infusion to treat mastitis (John, 2016).

Although few studies have been reported of such incident in South Africa, it is a common incident in countries like Kenya, Tanzania and East, and Central African countries (Orwa *et al.,* 2017, Ahlberg *et al.,* 2016). This incident arises because animal health professionals are less accessible in most rural small-scale dairy farmer villages to help them with observing the withdrawal period or complete the withdrawal period during the drug administration to the dairy cows (Ndungu *et al.,* 2016, Ladbury, 2018). Also, extra-label dosages for animals, contamination of animal feed with the excreta of treated animals, or the use of unlicensed antibiotics can be a cause (Olatoye *et al.,* 2016). In recent studies conducted in Kenya milk samples from three regions tested positive of tetracycline or sulphonamides and aminoglycosides which are among the most common antibiotics in rural small-scale livestock production (Ladbury, 2018, Olatoye *et al.*, 2016).

Heavy metals which are also found present in milk is also regarded as accidental milk adulterations in rural small-scale dairy farmers and this occurs in different ways. Dairy cattle in rural villages may graze on pastures or feed contaminated with heavy metals and consequently deposit the metals in their milk (bioaccumulation is a problem in ruminants) (Pilarczyk *et al.,* 2013, Ziarati *et al.,* 2018). Heavy metals in milk can also come from the milking and storage containers especially since most rural small-scale dairy farmers do not have access to right containers; from the utensils used during processing; or through adulteration with contaminated water (Pilarczyk *et al.,* 2013, Zain *et al.,* 2016, Ismail *et al.,* 2017). Although few studies have been conducted in South Africa to assess the extent of this problem, globally several reports have shown high levels of lead (Pb) and cadmium (Cd) in milk and milk products, with contamination with mercury (Hg) and arsenic (As) a lesser but still present problem (Ismail *et al.*, 2017).

Furthermore, heavy metal contamination can occur through the utensils and machinery used in the processing and distribution of milk, some studies have shown that processed milk has higher levels of heavy metal contamination than raw milk produced by rural small-scale dairy farmers (Kumar *et al.,* 2018, Anetta *et al.,* 2012). Thus, the drivers of human disease risk due to milk contamination with heavy metals seem to conflict with those due to contamination with bacteria. When considering bacterial hazards, food safety recommendations would be to opt for short, urban-to-urban value chains where possible and to choose processed milk over raw milk, whereas the opposite may be true with regards to heavy metals (Ismail *et al.,* 2017, Pilarczyk *et al.,* 2013).

2.8.2 Intentional Milk Adulteration:

Intentional milk adulteration basically occurs as a result of two motives: adulteration with the motive to cause physical or economic damage or adulteration with the aim of not causing damage or not being noticed (Everstine, 2013, Nalla, 2017). Intentional adulteration with water and other substances is reported to be as an aim to increase the volume or alter the properties of milk. The most common milk adulteration in rural small-scale dairy farming has been the addition of water. Adulteration of milk intentionally by water is a common practice in many developing countries to increase the volume of milk for profit or for the milk to be able to take care of the whole household which can be a coping strategy (Karimuribo *et al.,* 2015, Debnath *et al.,* 2015). The water added to the milk may sometimes be contaminated with faeces, microorganisms and dangerous chemicals (Debnath *et al.,* 2015). However, in South Africa, this incident has not yet been observed possibly because there are few studies regarding rural small-scale dairy farmers that have been conducted.

Adulteration is illegal because it alters the natural composition of milk and can introduce harmful bacteria and other dangerous substances into milk and its effect on health. Water adulteration lowers the specific gravity and increases the freezing point of milk; normal whole milk has a specific gravity range of 1.026 to 1.032 while its freezing point is minus 0.54°C. Hence, milk collection centres and processors routinely determine the specific gravity of raw milk and reject milk suspected of having been adulterated (Kurwijila, 2006). This practice also causes milk contamination; disqualify milk processing into other dairy products by lowering butterfat and protein content. It is not fair to the consumer because they are not receiving the quality product for the price paid. Adulterated milk leads to a loss for processors and consumer.

Because milk goes from the farm to the consumer without being tested for quality, the risk of accidental or intentional contamination with foreign matter can be high and go unnoticed.

2.9 Summary:

This chapter has highlighted rural small-scale dairy farming's status globally, in Sub-Saharan Africa and South Africa. These farmers operate with a small number of cattle's producing low volumes of milk around three to five litres per cow per day in rural areas. Although much of this is consumed within the household, many farmers like to sell small volumes into traditional milk marketing chains which feed the product into urban retail outlets. Studies show that through this, rural small-scale dairy farmer's livelihoods could be improved through consumption and selling the milk produced by these farmers and resolve the challenge of food and nutrition security in rural areas. Nevertheless, these farmers have met with many constraints in milking handling practices and milk management due to the lack of technical and financial support.

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CHAPTER 3.

RESEARCH METHODOLOGY

3.0 Introduction:

This chapter three explores the methods and procedures used to achieve the research objectives for this study. The outline for this chapter includes the description of the study area and rural small-scale dairy farming community; research methodology that includes the study design, subjects or respondents, sampling technique, research tools, data collection procedure, data analysis, and ethical considerations.

3.1 Description of the Study Area and Rural Small-scale Dairy Farming Community:

The study was carried out in the municipality of Hlabisa, one of the five municipalities of cat egory B within the municipality of uMkhanyakude District (IDP 2015:16). Hlabisa Local Municipality currently falls within the uMkhanyakude District Municipality within the KwaZulu-Natal Province's northwestern corner. It covers the former Hlabisa Transitional Local Council and preceding uThungulu Council areas. The estimated population for Hlabisa municipality is 71925 and with approximately 13184 rural households (Hlabisa municipality draft IDP 2013:2014).

The majority of the population of the municipality of Hlabisa resides in rural villages scattere d throughout the municipal area, characterised by service backlogs and poverty (IDP 2015:16). This manifests itself in different forms, including a high rate of functional illiteracy, low disposable income, and many households living below the poverty line and a relatively high unemployment rate. (Hlabisa municipality draft IDP 2013:2014). Poverty also appears in the form of service backlogs, especially in water, sanitation, and roads. Major steps have been taken to address these issues. Nonetheless, there is still a very high number of households without proper access to these services. The municipal areas are comprised of four traditional areas of authority, namely Mpukunyano, Mdletshe, Hlabisa and Mpembeni.

The municipality covers 3729 km^2 and has an average population density of 53.15 km^2. Approximately one-third of this area (1218 km^2) is covered by nature reserves (mainly the Umfolozi, Hluhluwe and St Lucia reserves) located 280 km north of Durban and the oldest declared park in Africa. (Hlabisa municipality draft IDP 2013:2014). Hlabisa town is found at

27°7'60 "north latitude, 31°49'0" east longitude at an altitude of 451 m above sea level. It consists of 960 km^2 of hilly topography in KwaZulu-Natal, central Zululand, and is known for its rich efforts in wildlife and conservation. The park is the only state-run park in KwaZulu-Natal where all the Big Five Game occurs. Due to conservation efforts, the park now has the largest population of white rhino in the world (IDP 2017:18).

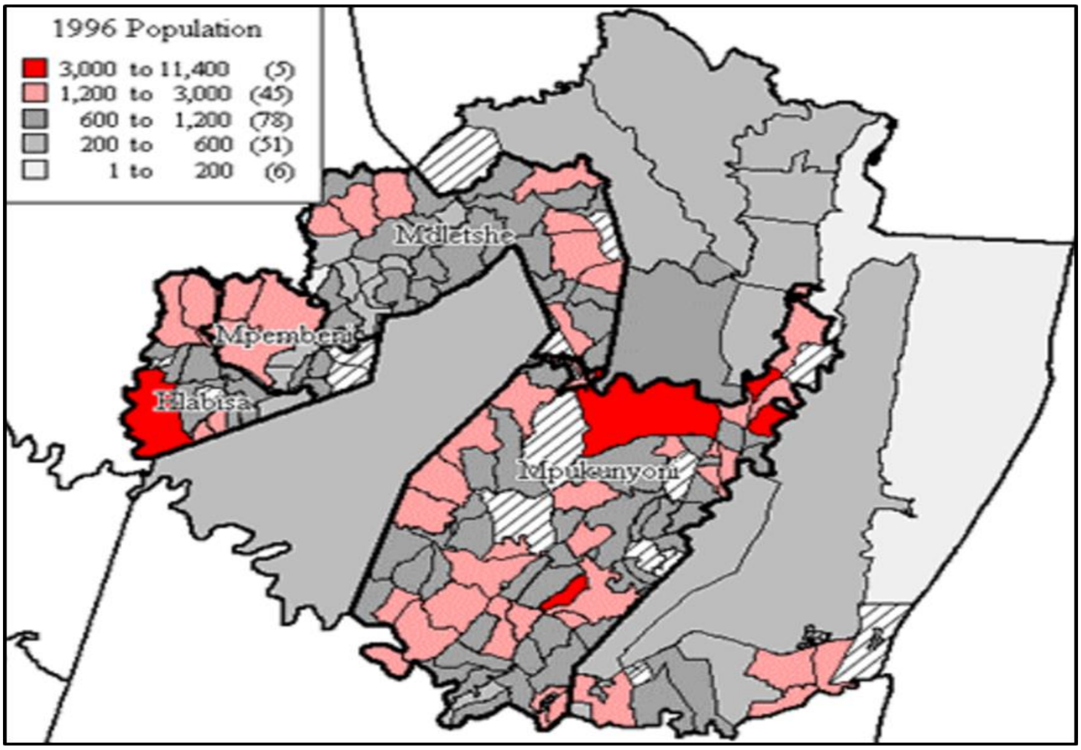

Figure 3.1: The Map indicating Hlabisa traditional authority areas and wards, Hlabisa wards are indicated in red within the traditional areas.

The most substantial land use in Hlabisa is subsistence agriculture, dispersed settlements, plantations, and agriculture are found throughout the municipality. The agricultural sector was considered one of the major economic activities in the area of the municipality of Hlabisa. It occurs primarily in the form of small-scale subsistence and rural production. Also, a common practice in the area is subsistence livestock farming. The area's agricultural potential is not particularly high because the area does not receive adequate or regular rainfall, so irrigation is required for any viable farming. Most of the farming is in the dry land. The lack of water or rivers across the region makes it difficult for farmers to engage in commercial agriculture, which requires intensive irrigation.

3.2 Research Methodology:

For this study, a convergent parallel mixed research design was followed, and it is a type of design that allows for qualitative and quantitative data to be collected in parallel, analysed separately and then the results merged together (Creswell, 2013). Researchers have used the mixed research method and practice for many years and refer to it with various names such as integrated, combined, multimethod (Driscoll *et al.,* 2007). A mixed research method can be defined as a research methodology that involves collecting, analysing, and integrating (or mixing) quantitative and qualitative research into a single study or a longitudinal investigation programme. Using the mixed research method allows the researcher to gain a clearer understanding of the research problem or issue being investigated, which would not be better understood when choosing to use a single approach alone (Creswell, 2013).

The advantages of using mixed research method are that it helps researchers to compare any similarities or differences between qualitative and quantitative findings or results. It allows the participants opinions to come forth on that subject or subject of study. It also allows more flexibility in research designs, allowing for more complete data to be collected than using a single approach. The mixed research method requires multifaceted planning and implementation; a multidisciplinary team of researchers willing to be open-minded in working together for the success of the research and time because it is labour intensive (Wisdom & Creswell, 2013).

3.3 Respondents of the Study:

The subjects of the study were lactating indigenous cattles' from the rural small-scale dairy farmers and the respondents were rural small-scale dairy farmers themselves in Hlabisa municipality.

3.4 Sampling Technique:

3.4.1 Farmers:

For the purpose of this study, a random sampling technique was used to select households and a random survey was conducted of 53 rural small-scale rural dairy farmers who were actively involved in dairy production. A list of households owning dairy farms was obtained from records maintained by the Kwa-Hlabisa local municipality. Before the formal interview, a preliminary visit was conducted to locate the farms, farmers consent, and a brief description were provided of the research objectives

A single-visit-multiple-subject formal survey technique was used to collect data through interviews, conducted in the local language by the researcher and two enumerators using a pre-tested, structured and unstructured questionnaire. Data obtained from the participants were on socio-economic demographic characteristics, milking system, milking frequency, milking hygienic practices (milkers' hand washing, milk utensils, and udder before milking), farmers' awareness of cattle and milk-borne zoonoses, transmission routes, farm sources water, housing management to better understand the research problem.

3.4.2 Cattles:

A simple random sampling was adopted to obtain the participant from rural small-scale dairy farms from which milk samples were collected. Milk samples were collected from 23 cattle that were lactating. This was due to cattle belonging to other rural small-scale dairy farmers, milk had dried out from cattle's teats due to permanent blockage and were no longer milking. Before sampling, the questionnaire was used to gather information on environmental hygiene, personal hygiene, milk collection, storage utensils, storage conditions and water used in sanitation and milking procedures. Milk assessment for the smell, colour, any deposits and cleanliness of containers was carried out using standard methods.

First of all, sampling for microbiological evaluation involved collecting swab samples from the milking bucket and the collective bucket. The milking and collective buckets were swabbed at the bottom round corners using sterile dry swabs before the milking process. A 100 cm^2 area was swabbed several times in all directions by rubbing firmly across the area. The swabs were immersed in a sterile 50 ml centrifuge tube in 5 ml of Tryptone Soy Agar and stored in cold storage prior to analysis. In addition, after being thoroughly mixed and stored in a cooler box with ice blocks, 50 ml of pooled raw cow milk was sampled into the centrifuge tubes with boric acid for preservation from milking and collective bucket. The swab and milk samples were transported the of University of KwaZulu-Natal Laboratory for storage at −18 ° C. Microbiological contamination analysis was carried out in Pietermaritzburg, University of KwaZulu-Natal Microbiology Laboratories.

3.5 Research Instruments:

3.5.1 Farmers:

Semi-structured questionnaire was used to assess the hygienic status of milk production. Approximately 53 farmer households and/or milking staff were interviewed from 11 purposively selected villages in the study area. Consequently, the milk production, handling and hygienic practices used and other conditions thought to affect the hygienic quality of milk were assessed.

3.5.2 Cattles:

The following materials were used in all the eleven villages during the sampling periods:

- 400 numbers of sterile 50 ml sample vials.
- 1 cooler box.
- 3 bags of crushed ice.
- 1 box of 100 sterile gloves.
- 4 packets of 25 sterile swabs each.
- 100 separating plastics

3.7 Procedure of Data Gathering:

This study had two parts: Questionnaire-based survey for farmers and bacteriological quality analysis of milk from the lactating cattles.

3.7.1 Farmers:

Rural small-scale dairy farmers/households in the targeted population were visited at their milking-time either in the morning or evening between 06:30-8:00 am and 03:00-06:00 pm respectively. Information on-farm structures, their physical arrangement, milking and milk handling practices, milk production and cleanliness of farm premises were obtained during the visit by observing the farm set up and farmers' interviews using a semi-structured and structured questionnaire. During the farm visits the level of cleanliness of the milking area, cleanliness of the milk handling utensils, personnel and cow preparation before milking was observed and recorded on the inspection form. Additionally, the type of milking utensils and cleanliness were inspected.

3.7.2 Cattles:

A total of 116 milk and swab samples were collected from 23 rural small-scale milk producing farmers in Hlabisa (Kwa-Madondo; Kwa-Khalokazi; Kwa-Mevana; Khonto; Matshamnyama; Madlwambe; Nhlanhleni; Ogengele; Mabundeni; Mngovuzo and Egwegwede) in KwaZulu-Natal Province. The samples collected were milk (34 samples collected directly from teat and 34 collected directly from pooled milking containers), 24 swabs from milk utensils and 24 swabs directly from teats. To sample from cows, the farmer first washed the entire udder with water to remove dust and then dried it. Then 40 ml of milk was collected directly into a sterile centrifuge tube with 5 ml of boric acid for preservation. From pooled milking container, 40 ml of milk was directly poured into a sterile centrifuge tube with 5 ml of boric acid for preservation.

Swabs were taken directly from the clean dry utensils and from lactating cattle's teats before milking but after washing with water. The milking container was swabbed at the bottom round corners using sterile dry swabs just before milk was placed in the container. An area of 100 cm^2 has been swabbed by rubbing firmly across the area several times in all directions. The teat side was also swabbed several times by rubbing firmly on the teat. The swabs were immersed in 5 mL of Tryptic Soy Agar (TSA) prepared inside sterile centrifuge tubes and placed before analysis in the cooler box. Each specimen was labelled before being placed inside the cooler box and was transported to Microbiology Research Laboratory, University of KwaZulu-Natal. Upon arrival, the samples were stored in a refrigerator at -18°C temporarily for 24 hours before processing.

Figure 3.2: Small-scale dairy farmer hand milking.

Figure 3.3: Small-scale dairy farmer with milk.

Figure 3.4: Calf sucking during milking process.

Figure 3.5: Milking and storage containers.

3.8 Data Analysis:

3.8.1 Farmers:

The data collected were checked for inconsistency and entered, coded and transferred to Excel spread sheet and SPSS version 25.0 respectively. All the data collected were coded and captured in the SPSS then used for data analysis. Descriptive and frequency analysis were done for the survey questionnaire administered to the rural small-scale dairy farmers.. Data presentation in a descriptive format was done to provide a relevant, valid, reliable and meaningful interpretation of results for the specific objectives.

3.8.2 Cattles:

3.5.2.1 Bacteriological Investigation of Samples:

Milk samples were immediately investigated in the laboratory using total plate count, biochemical test kits and milk adulteration tests. Before plating each milk sample was diluted.. The dilutions were made in the sterilised solution of distilled saline water. One (1ml) of milk from each sample was poured into 9 ml of sterilised distilled saline water in a test tube for dilution (1:10). One microlitre was plated on the TSA and the inoculum was spread using a hockey stick. The plates were then left on the bench for half an hour, then incubated at 37^{o}C and examined for bacterial growth after 24 hours.. Plates for their bacteria loads were observed in replicates.. The colony count was carried out and the total viable bacterial count was calculated by multiplying the number of colonies with the reciprocal dilution used. The mean for all the samples was calculated.

Based on the different morphology on Tryptone Soy Agar, which was aerobically incubated at 37oC for 24 hours, incubated milk and swabs samples were streaked to isolate bacteria. Plates that showed no growth were further incubated for 48 hours before being discarded as negative. Repeated subculture on Tryptone Soy Agar purified bacterial isolates. Unique colonies were sub-cultured to obtain pure isolate colonies. Unique colonies were sub-cultured to obtained pure colonies of isolates. After incubation, purity of culture was checked by gram’s staining method. The pure isolates were maintained on agar plates and their likely identities were established using Biochemical Identification Test Kits. The identification kit was a comprehensive test system that can be used to identify gram-negative *Enterobacteriaceae* and Non-fermenters species.

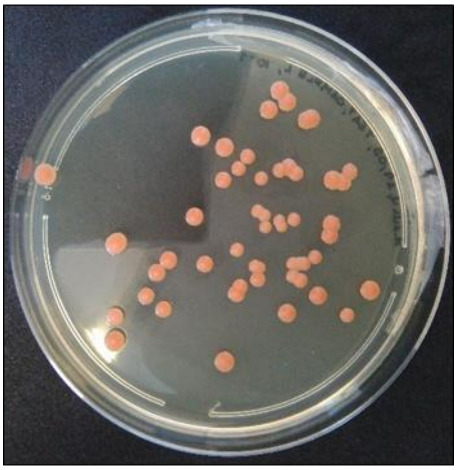

Figure 3.6: *Pseudomonas aeruginosa* isolate**.**

Figure 3.7: *Enterobacter aerogenes* isolate**.**

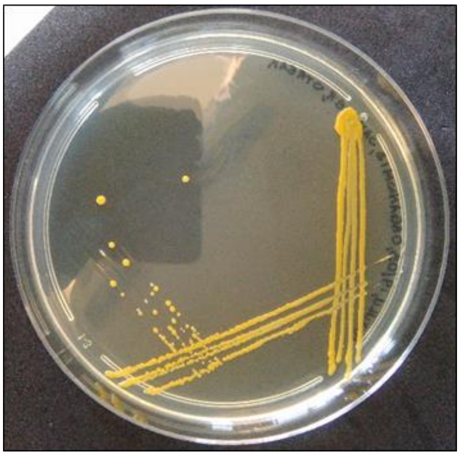

Figure 3.8: *Staphylococcus aureus* isolate.

Figure 3.9: *Morganella morganii* isolate

3.5.2.2 Biochemical Tests for Adulterants' Analysis:

All the milk samples collected from rural small-scale dairy farmers were screened for the presence of commonly used adulterants and preservatives by using milk adulteration kit which was supplied by HiMediaPvt. Ltd, India. These tests included the alizarine test, urea test, detergent test, salt test, starch test, sugar test (sucrose), formalin test, skim milk powder test, glucose test, and hydrogen peroxide test. These entire tests were performed in a sterile manner as per the instructions of the manufacturer.

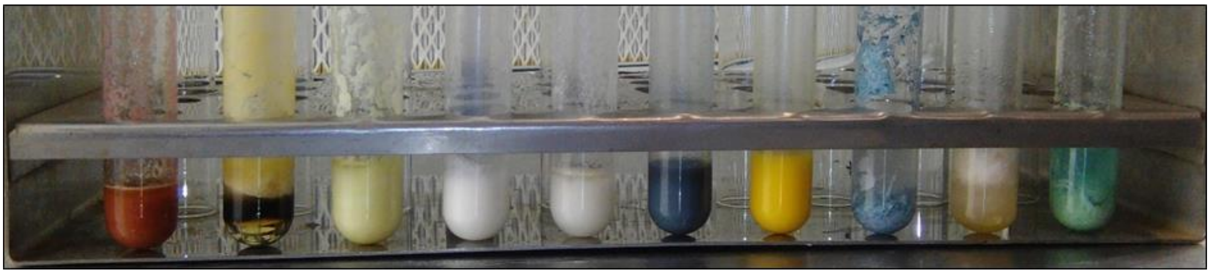

Figure 3.10: Adulteration test analysis of raw milk from a farmer in Khalokazi**.**

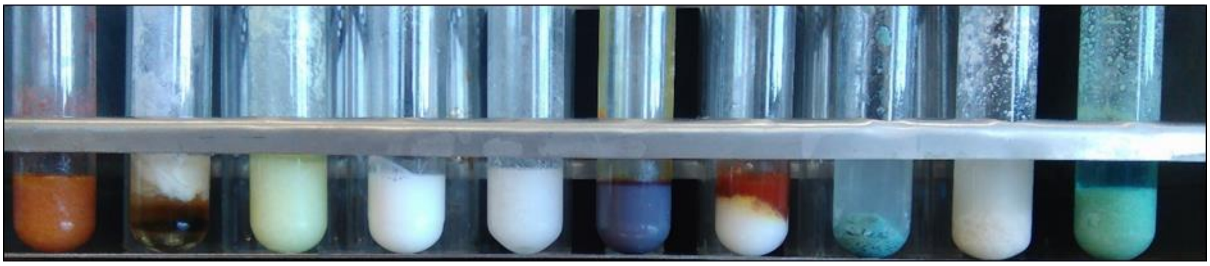

Figure 3.11: Adulteration test analysis of raw milk from a farmer in Matshamnyama.

Figure 3.12: Adulteration test analysis of raw milk from a farmer in Nhlanhleni.

3.9 Ethical Considerations:

Ethical considerations are important especially in research dealing with personal issues such as personal hygiene because they provide a basis for moral conduct in respect of human dignity, integrity and authority. The Humanities and Social Science Research Ethics Committee at KwaZulu-Natal University (Protocol Reference No HSS/1072/016 M) granted permission to conduct this study. After explaining the purpose and importance of the study prior to the start of data collection, verbal consent was obtained from each rural small-scale dairy farmers. Verbal consent was used because most rural small-scale dairy farmers do not know how to read and write. Ethical standards prevented any fabrication and falsifying of data and therefore promote the pursuit of knowledge and truth which was the primary goal of the research.

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CHAPTER 4.

RURAL SMALL-SCALE DAIRY FARMERS' TRADITIONAL MILKING HYGIENIC PRACTICES AND ITS EFFECT ON RAW MILK QUALITY IN KWA-HLABISA, KWAZULU-NATAL, SOUTH AFRICA.

4.1 Abstract:

Milking practices have improved with the advancement in technology and have transformed both small and large-scale hygienic production methods, however, some producers in rural and peri-urban areas have not adopted these new methods and hand milking is still the most frequently used method. This study was conducted in a typical South African rural area, where the state of environmental health is still developing. The objective was to examine the effect of rural small-scale dairy farmers' traditional hygienic milking practices on the quality of raw milk. A face-to-face interview was conducted among 53 rural small-scale dairy farmers using a pre-tested questionnaire. The socio-economic results revealed that most participants were old-aged (58.5%), household size between 8-11 (38%) and those without any formal education was (18.9%). Most of the participant's families were experienced in farming (81.1 %) with the pension being the family's main source of income (38%). Results furthermore indicated no knowledge in dairy farming (79.2%) with no use of milking clothes (75.5%) and milking done by hand (100%) using non-food grade plastic bucket (79.2%). Most of the farmers were not using the towel to dry the teat (86.8%) with the streams being the source of water (62.3%). Statistical significance ($p < 0.05$) indicated that hand washing after milking; back leg tying; washing milking utensils; use of towel; teat dipping; milking when sick; covering of milk, mixing of fresh and old milk and not boiling milk before consumption affected the milk quality. It was therefore, concluded that traditional hygienic practices are likely to contribute to the contamination of the milk and compromising the quality of raw milk produced by rural small-scale dairy farmers.

Keywords: Consumption, Extension services, Health risk, Hygiene practices, Socio-economic, Training.

4.2 Introduction:

Milk has been identified as the most important source of micro and macronutrients that improve the nutritional status of individuals and populations particularly in rural communities of South Africa that are vulnerable to food insecurity. Milk plays a vital role in several ways through providing employment, food security and sustainable income for the millions of people in rural communities of Sub-Saharan Africa (Msalya, 2017b, Paraffin *et al.,* 2018). Consumption of milk and milk products has been speculated to continue to increase from their current levels because of population increase, economic growth, urbanisation as well as health awareness of milk and milk product (Paraffin *et al.,* 2018, Al-Atiyat, 2014). Statistically, milk consumption has risen by nearly 4% per year as well as the consumption of animal meat by 5% per year in developing countries. (Nabarro and Wannous, 2014).

In African countries except for South, Africa milk is one of the easily accessible food by rural small-scale dairy farmers and is produced and sold directly or readily processed commodity. It is a cash crop in the milk shed areas that enables families to buy other foodstuffs and significantly contributing to household food security (Bereda *et al.,* 2012). Market-oriented rural small-scale dairy farming has been observed to increase household income, reduce losses and generate employment in processing and marketing. Potentially, rural small-scale dairy farming is a viable tool to spur economic growth and alleviate poverty (Chagunda *et al.,* 2016). Interventions in rural small-scale dairy farming should be relevant to the informal market given that the informal market is and will continue to be important in the near future. Given the long tradition of using milk and milk products by African societies, there is no doubt that increasing rural small-scale dairy production and productivity would bring about a noticeable impact on improving the welfare of women, children and the nation's population at large (Bereda *et al.,* 2012).

As a nutritious food and a source of regular income, milk plays a key role in household food security in many developing nations (Chitiga-Mabugu *et al.,* 2013). In rural small-scale dairying, milk is available for the family needs first and surplus milk is marketed or sold. One of the most important, but often ignored, direct benefits of rural small-scale milk production is the immediate nutritional benefit provided to growing children, for example, calcium and vitamin A, which greatly contributes to a balanced and nutritious diet. When children consume modest amounts of animal proteins, it alleviates poor growth, poor cognitive development, and impaired physical health (James and Palmer, 2015). According to the Malawi Demographic and Health Survey (MDHS), about 5% of infants under the age of 2 years receive alternate milk other than breast milk and 14% of non-breastfeeding infants consume milk other than infant formulas (Chikhungu, 2013). Kalumikiza (2012) found children below the age of 5 years among the dairy farming households consumed more milk than any other age group in the central region of Malawi. Consumption of milk by children was mainly due to the respondent's belief that children needed more milk for good growth and health. In most cases, children tend to be given some milk during or immediately after milking (Chagunda *et al.,* 2016).

Good nutrition is also a major factor in the ability to fight disease and resist infections (Barbosa *et al.,* 2015). There is growing recognition for the nutritional value of milk and dairy products in communities where there are a high prevalence of immunodeficient (HIV/AIDS) diseases and in aged populations, for example, fighting osteoporosis (Burgess, 2014). Lack of regular income is one dominant cause of poverty. Both crop farming and meat production not only require investment but only yield periodic returns. Dairying, even on a very small-scale, can provide modest but regular returns. This not only directly benefits the family but fosters an appreciation and gradual adoption of saving and loan approaches (Rischkowsky and Pilling, 2007). Rural small-scale dairying can also be successfully carried out with a limited land base provided access to water, fodder and basic animal health services are available (Bingi and Tondel, 2015). The growth of milk production in Bangladesh is a good example where even with minimal land resources available, landless rural small-scales can sustainably produce milk that will contribute to nutrition security and fight against diseases and infections.

Although milk is a highly nutritious food, however, it is also an excellent growth medium for bacteria (Oumer *et al.,* 2017). Raw milk has the potential to transfer zoonotic diseases if the milk handling is poor and milk handling procedures must minimise associated health risks (Hamid *et al.,* 2013). Therefore, good milk quality could be attained through enough feed, good environmental sanitation, and milking procedure. Also, cleaning udder and teat with warm water or with disinfectants before milking is very important (Suranindyah *et al.,* 2015). Disinfectant is preferred for this exercise. Drying teat/udder with a clean towel, one per clean towel per cow is important to keep milk hygiene. To assure milk quality it is suggested to scrub teats and teat ends thoroughly with a paper towel or direct a stream of sanitising solution on the teats and wash by hand (Suranindyah *et al.,* 2015).

There is a need for the person milking the cow to wash his or her hands and nails with clean warm water and soap before milking to prevent milk contamination from the milker's hands. The person milking the cow needs to wear clean clothes and shoes. Dirty clothes and shoes can be a source of bacteria that can contaminate the milk. The tendency to dip hands in the milking bucket during milking by some rural small-scale dairy farmers to use the milk as a lubricant in the milking process is to be avoided at all time. The person milking the cow should not be suffering from any communicable disease or have open sore or abscess on any of his/her uncovered body. Coughing or sneezing over the milk or milk container should be avoided (Kazanga, 2012).

The sanitation and design of the barn are very important for clean milk production. A dirty barn will promote the growth of bacteria, which can either contaminate the milk during milking or can infect the udder. The floor of the barn must be durable and easy to clean, preferably made of concrete. Milking should be done in a well-ventilated barn with adequate lighting. Another major source of milk contamination is the use of inappropriate or unclean utensils. These are milking, storage or transportation utensils that cannot easily be cleaned or sanitised. These include the use of jerry cans and buckets made of non-food grade plastic. The inappropriate utensils can harbour microbes in the cracks or crevices that develop because of its continuous usage. Metal containers such as aluminium and stainless-steel cans are recommended under the code of hygiene practices.

Milking vessels and utensils must be cleaned every time after use. Cold clean water should be used first to rinse the milking utensils; this will ease the removal of the milk residuals on the surface of the utensils. These should be followed by sanitisation with boiled water or/and soap. Soap without perfume is preferred. Then dry the utensils as quickly as possible in the sun on a drying rack. The utensils must be stored upside down off the ground when they are not in use (Kazanga, 2012). As there is no standard operating procedure for sanitation for rural small-scale dairy farmers, one of the aims of this research is to fill this gap with respect to rural small-scale dairy farmers. Therefore, this study was carried out to survey the rural small-scale dairy farmer's milking hygiene practices and its effect on raw milk quality in Kwa-Hlabisa, KwaZulu-Natal, South Africa.

4.3 Materials and Methods:

4.3.1 Description of the Study Area:

The study was conducted and carried out among rural small-scale dairy farmers in Hlabisa, KwaZulu-Natal Province, South Africa. Hlabisa Local Municipality falls within the uMkhanyakude District Municipality located within the northwestern corner of the province of KwaZulu-Natal. It includes the former Hlabisa Transitional Local Council and areas of the previous uThungulu Council. The estimated population for Hlabisa municipality is 71925 with approximately 13184 households (Hlabisa municipality draft IDP 2013:2014).

The municipality is typically characterised by isolated rural communities with high levels of poverty. The most significant land use activity is subsistence agriculture and, plantations and agriculture are found throughout the municipality with dispersed settlements. Hlabisa is found at a latitude of 27 º7'60" latitude north, 31°49'0" longitude east at an altitude of 451m above sea level. Hlabisa's main drawcard is the tourism industry centred on the Hluhluwe-Umfolozi Game Reserve, 280 km north of Durban, and the oldest proclaimed park in Africa (IDP 2015:16). It consists of 960 km^2 (96,000 ha) of hilly topography in central Zulul land, KwaZulu-Natal, South Africa and is known for its rich efforts to conserve wildlife. The park is the only state-run park in KwaZulu-Natal where all the Big Five Game reside (Hlabisa municipality draft IDP 2013:2014). Due to conservation efforts, the park has the largest white rhino population in the world. Local municipality of Hlabisa is one of the five local municipalities that make up the local municipality of uMkhanyakude. With access to a well maintained road network, it is strategically located (Hlabisa Municipal Housing Sector Plan, 2009).

4.3.2 Sampling Procedure:

A random sampling technique was used to select the households for the purpose of this study and a random survey of 53 rural small-scale rural dairy farmers who were actively involved in the dairy production was conducted. A list of households owning dairy farms was obtained from records maintained by the Kwa-Hlabisa local municipality. Before the formal interview, a preliminary visit was conducted to locate the farms, obtain farmers consent and to provide a brief description of the research objectives.

4.3.3 Method of Data Collection:

A single-visit-multiple-subject formal survey technique was used to gather data through interviews, conducted in the local language by the researcher and two enumerators using a pre-tested, structured and unstructured questionnaire. Data obtained from the participants were on socio-economic demographic characteristics, milking system, milking frequency, milking hygienic practices (milkers' hand washing, milk utensils, and udder before milking), farmers' awareness of cattle and milk-borne zoonoses, transmission routes, farm sources water, housing management to better understand the research problem.

4.3.4 Ethical Considerations:

Ethical clearance was obtained from the Humanities and Social Science Research Ethics Committee at the University of KwaZulu-Natal (Protocol Reference No HSS/1072/016M). Informed written consent was also obtained from all study participants and confidentiality was assured using codes in records.

4.3.5 Statistical Analysis:

The computer Statistical Package for Social Sciences (SPSS) was used for data management and entry. All the collected data were coded and entered into SPSS. The computer program version 25.0 of the SPSS software was used for data analysis. Descriptive statistics such as frequencies, distribution and percentages were used to analyse the data. The Pearson Chi-Square test evaluated the significance of relationships between variable socio-economic characteristics of rural small-scale dairy farmers and hygiene milking practices. P-values < 0.05 were considered significant.

4.4 Results:

4.4.1 Socio-economic Demographic Characteristics of the Participants.

Table 4.1 illustrate the frequency distribution of the demographic of the participants. Most participants were over 40 years with n= 15 (28.3%) between the age of 41-50 years n= 15 (28.3%) greater than 50 years n=31 (58.5%). Males (66%) were more represented in the study. Approximately half of the participants gained primary school education, while 32.1% gained secondary school education with only 2% gaining tertiary education. More than 50 percent (n=27) had more than seven people in the household with only 8% (n=4) having fewer than four people in each household. The main source of income was through pension (38%) and off-farm employment (34%). Only 4 percent of participants sell their milk when it comes to using milk as a form of business. Forty-three (81.1 percent) of the participants had more than 10 years of farming experience. The majority of participants (68%) had between 1 and 5 cows that they milked. The percentage of the land size owned by the participants was 54.7% having between 0.5 to 1.5 hectares and 5.7% having more than 4.5 hectares of land.

Table 4.1: Socio-economic demographic characteristic of the participants.

Parameter	Category	No. Of participants	Percentage (%)
Age	15-20 years	1	1.9
	21-30 years	3	5.7
	31-40 years	3	5.7
	41-50 years	15	28.3
	>50 years	31	58.5
Gender	Female	18	34
	Male	35	66
Education	No informal education	10	18.9
	Primary education	25	47.2
	Secondary education	17	32.1
	Tertiary education	1	1.9
Household size	1-3 members	4	8
	4-7 members	22	42
	8-11 members	20	38
	≥12 members	7	13
Source of income	Dairy farming	1	2
	Other agricultural duty	12	23
	Off-farm employment	18	34
	Remittance	2	4
	Pension	20	38
Farm experience	1-5 years	3	5.7
	6-10 years	7	13.2
	>10 years	43	81.1

4.4.2 Dairy Cattle Housing Characteristics:

In the study participants (100%) used the same house to keep the animals and milked most of the cows n=50 (94.3%) some of the animals were housed in the barn's cow dung surface type n=3 (5.7%) others were in earthed soil surface and none were of the concrete surface. With regard to the milking area being cleaned, most of the participants n=27 (50.9%) cleaned their milking area once a year, followed by milking area not being cleaned n=18 (34%) and twice a year and sometimes at n=4 (7.5%).

Table 4.2: Housing characteristics of the farm.

Parameter	Categories	Frequency	Percentage (%)
Floor type	Earthen surface	3	5.7
	Cow dung surface	50	94.3
	Concrete surface	0	0
Barn cleaning	Once a year	27	50.9
	Twice a year	4	7.5
	Sometimes	4	7.5
	Never cleaned	18	34.0
Housing system	Permanently closed	0	0
	Open house	54	100

4.4.3 Milking Hygienic Practices:

Table 4.3 represents the frequency distribution by the participants of the different milking practices observed. Only n=11 (20.8%) indicated participation in one form of dairy training. Of this 20.8 percent, less than 10 percent went to milking practices training. The owner mainly performs milking responsibilities and their family members as n=27 (50.9%) and n=19 (35.8%) of the owner and the family member get involved in milking respectively only six of the workers employed by the owner help in the milking of the cows. It was observed that n=13 (24.5%) and n=48 (90.6%) wear milking clothes and tying the back legs of the cows respectively, which are good qualities of milking practice.

The only milking system observed by the study was the manual system of milking which is the least in terms of the quality of milking practice with once n=53 (100%) milking frequency per day. Approximately n=2 (3.8%) of the participants use individual towels and n=5 (9.4%) use common towels for wiping the udder after washing, while, the remaining n=46 (86.8%) do not use towels for drying. During the milking process, the main source of water use is stream water that accounts for 60.3%, while the tap water that is good for a quality milking process is used by n= 7 (13.2%) of the participant. Most n= 37 (69.8%) of the participants observed udder and the teat washing while n=16 (30.2%) observed no udder and teat washing. All the participants n=53 (100%) observed hand washing s in preparation for milking, but of this n=53 (100%) only n=44 (83%) practice correctly, which is before the onset of milking and after the last milking. Most respondents n=34 (64.2%) only use cold water to wash the milking container, n=2 (3.8%) only use warm water and n=3 (5.7%) cold water and detergent and only n=14 (26.4%) wash milking container with warm water and detergent. Milking when sick is not a good milking practice and most n=43 (81.1%) were not milking when sick, only n=10 (18.9%) were milking. The majority of participants n=40 (75.5%) covered their milk after milking.

Table 4.3: Milking methods and hygienic milking practices followed by rural small-scale dairy farmers.

Parameter	Categories	Frequency	Percentage (%)
Dairy training	Yes	11	20.8
	No	42	79.2
Type of training	General farm management	7	13.2
	Pasture establishment	2	3.8
	Proper milk handling	2	3.8
Milk responsibilities	Owner	19	35.8
	Family member	27	50.9
	Neighbour	1	1.9
	Worker	6	11.3
Milking clothes	Yes	13	24.5
	No	40	75.5
Tying of back legs	Yes	48	90.6
	No	5	9.4
Milking system	Manual system	53	100
Milking frequency per day	Once	53	100
Use of towel	Common towel	5	9.4
	Individual towel	2	3.8
	No use of a towel	46	86.8

Sources of water	Tap	7	13.2
	Well	4	7.5
	Tank	9	17.0
	Stream water	33	62.3
Udder and teat washing	Yes	37	69.8
	No	16	30.2
Washing of hands	Yes	53	100
Hand wash during milking	Before the onset of milking	6	11.3
	During milking of each cow	3	5.7
	Before the onset of milking and after the last milking	44	83
Washing hands with water/detergent	Cold water only	42	79.2
	Warm water only	2	3.8
	Cold water with detergent	2	3.8
	Warm water with detergent	7	13.2
Milking when milker is sick	Yes	10	18.9
	No	43	81.1

In this study, most of the participants (79.2%) use plastic containers for collecting milk and only (1.9%) use stainless-steel to collect and the remaining (18.9%) use wooden containers. Most participants (90.6%) wash milk handling containers; however, 64.2% wash containers with cold water and only, 5.7% wash containers with detergent and cold water and only 3.8% wash containers with hot water. Not all participants (100%) remove foremilk during milking. With regard to milk filtering to storage containers, all participants (100%) practice milk filtering. Milk preservation, 50.9% of the participants ferment before preservation, 43.4% preserve their milk in a cooler place on the floor and 5.7% use smoking to preserve their milk. Most participants (75%) cover their milk immediately after milking and only 24.5% do not cover.

Table 4.4: Milking utensils and milk handling practice.

Parameter	Categories	Frequency	Percentage (%)
The material of milking container	Stainless-steel container	1	1.9
	Plastic container	42	79.2
	Wooden container	10	18.9
Washing of milking container	Yes	5	90.6
	No	48	9.4
Washing of milking container with water/detergent	Cold water only	34	64.2
	Warm water only	2	3.8
	Cold water with detergent	3	5.7
Covering of milk after milking	Yes	40	75.5
	No	13	24.5
Method of preservation	Smoking milk vessel	3	5.7
	Cooler place	23	43.4
	Ferment	27	50.9

Table 4.5 below shows the overall relationships between variable socio-economic characteristics of rural small-scale dairy farmers and traditional hygienic milking practices. The relationship indicated that milking practices viz. age, family education status, dairy herd size, family household size, source of income and experience in milking were significant ($p < 0.05$) in improving and decreasing milk quality at different levels of the milking process.

Table 4.5 Relationship between socio-economic variables with hygienic milking practices.

Parameter	P-values					
	Age	Education	Herd size	Household size	Source of income	Dairy experience
Use of ppe	0.432	0.209	0.327	0.332	0.150	0.588
Back legs tying	0.634	0.964	0.766	0.051*	0.815	0.526
Hand wash	0.634	0.607	0.821	0.069	0.154	0.641
Hand wash	0.000*	0.107	0.965	0.199	0.026*	0.355
Utensils material	0.594	0780	0.039	0.949	0.629	0.946
Washing of container	0.556	0.447	0.456	0.658	0.756	0.526
Washing utensils	0.001*	0.595	0.702	0.439	0.293	0.480
Source of water	0.932	0.788	0.836	0.707	0.092	0.827
Multi-use of container	0.094	0.514	0.821	0.121	0.085	0.747
Washing teat, udder	0.962	0.237	0.651	0.545	0.055	0.989
Use of towel	0.318	0.988	0.841	0.041*	0.000*	0.459
Teat dipping	0.716	0.681	0.016*	0.062	0.080	0.228
Milking when sick	0.233	0.893	0.188	0.418	0.003*	0.156
Covering of milk	0.262	0.232	0.277	0.297	0.853	0.007*
Milk storage	0.294	0.892	0.650	0.619	0.132	0.737
Transferring milk	0.510	0.888	0.223	0.580	0.168	0.747
Fresh & old mix	0.667	0.114	0.310	0.073	0.037*	0.848
Boil before consumption	0.465	0.826	0.319	0.117	0.041*	0.916

***significant at p-value =0.05**

4.5 Discussion:

This study was aimed at surveying the rural small-scale dairy farmers' milking hygiene practices and their effect on raw milk quality in of Hlabisa villages, KwaZulu-Natal. In this study, 58.5% of participants involved in dairy farming were above 50 years of age supporting Ogola et al (2015) (Table 4.1). According to the literature, ageing rural small-scale dairy farmer populations are generally a dominant characteristic in rural dairy farming (Heide-Ottosen and Vorbohle, 2014). Factors such as availability of alternative professions, and opportunities with higher paying sectors affect the participation of the younger population in rural dairy farming (Leavy and Smith 2010). Furthermore, the results of the present study showed that 66% of the participants in milk production were males instead of females, which contrasts with Bereda et al (2012) who reported that dairying offers more opportunities for females to be closely involved in the daily management than males. Males of old-age were involved in rural dairy farming since they are physically fit had more dairy experience and were able to handle the heavy milk cans with ease. In addition, the amount of work involved in dairy farming requires well-coordinated labour division arrangements for efficiency within a household. Furthermore, age had a positive significance ($p<0.05$) to time when farmers were washing their hands (Table 4.5). The probable reason could be that older participants with good experience in dairy farming could have realised the importance of hand washing for proper milking hygiene practices to obtain raw good quality milk.

The study showed that 66% most of the participants who handled milk were men; this may be because men are responsible for weekly or seasonal farming duties, such as planting forage, organising animal health service providers to attend to cattle or milking and feeding cattle. This can be due to the society's that animals are controlled by men. (Table 4.1). Moreover, this indicates that the access to resources in traditional societies is determined by the patriarchal system in which males in all the household-related authorities have dominance over women.. This is because resource inheritance favours men over women in these communities. Men own and control basic resources such as land and livestock. The study also found that most of the participant's educational levels were between no-formal and secondary school education but much higher in primary level. This is in line with the report from the Illu Aba Bora Zone, Southwest Ethiopia Bereda et al (2014), where most household heads' the educational level falls between no-formal and primary school education. Tsegaye (2016) stated that a low-level of education of households can have a negative impact on the development of the rural dairy sector. This is evident from the low-level use of dairy innovations such as artificial insemination and cultivation of improved forage crops. This indicated that more intervention is needed to raise awareness among rural small-scale dairy farmers to improve their hygienic dairy production and husbandry practices.

The household size obtained in the present study was very high which is consistent with the findings of Duguma and Janssens (2016), Ayza et al (2013) both whom reported the mean of 8.2 and 7.2 persons in Bahir DarZuria and Mecha woredas, respectively. The participants stated that large family size was a very important source of the labour-power for daily activities on the farm. In addition, household size had a significant impact ($p<0.05$) on the practice of tying back legs of the cow before milking. This may be because large households work together, and they divide the farm's work. Only 2% of the participants were full-time dairy farmers, about 99% were also engaged in various off dairy farm economic activities where 23% were dependent on other agricultural activities, 34% off-farm employment, 38% pensioners and 4% were depending on remittance. The leading cause of low participation in full-time dairy farming was the lack of a commercial mind among most of these rural small-scale dairy farmers, with most milk produced for personal consumption only. Poor production systems and inadequate backstop also negatively affected the farmer's engagement to this job creating opportunities for financial improvement.

The survey result showed that 79.2% of the participants received training on how to keep the animals but of that 79.2%, shows that only 3.8% were directly related to proper milking and clean milk handling. Seblewengel et al (2017) reported that improved husbandry practices through training of farmers' are an important strategy for enhancing competence among the rural small-scale dairy farmers and thus increasing adoption. It has been also reported that the provision of appropriate training can improve dairy farming practices and increase the rate of technology adoption in resource-poor families. A report by Murai and Singh (2016) indicated that dairy farmers should be regularly trained to develop the desired level of knowledge and skills in scientific dairy farming. As reported by Kazanga (2012) that dirty milking clothes or shoes can be a source of bacteria that can contaminate the milk. 75.5% of participants in the present study are engaged in milking without proper milking clothes and this has a negative effect on the quality of the milk to be produced.

Results of this study showed that 100%, of milking, is done by hand with milking frequency of 100% once a day. These findings are in line with Olofsson (2013) who reported that all rural small-scale dairy farmers in Mapepe, Choma and Batoka districts in Zambia practice a whole-hand milking technique without the use of lubricants. Bacteria and pathogens may also originate from the hand of the milker, hand hygiene is particularly important in hand milking. Thus, the cleanliness of the cow in general, as well as the immediate environment during milking, may also have an impact on milk hygiene and udder health, which is the reason why the properties of the environment and milking place of the cows should also be considered.

Contrary to the findings of this study, which reported that dairy farmers in Hlabisa, milking only once a day is due to the limited availability of family members during the day. Yilma findings (2012) presented that in Holetta, Selale and Debre Zeit, 83.3%, 93.3% and 96.7% of crossbred cows are milked twice a day, respectively. Ayenew et al (2009) also reported that 83.8% of the dairy farmers in northern Ethiopia were milking their cows twice a day. The frequency of milking was also reported by (ILRI, 2008) in other urban dairy farms in Ethiopia. Local crossbreeds ODM was primarily due to the low milk yield. It may also be due to different traditions in the rearing of local and exotic crosses, respectively. However, this also has a huge impact on the household's nutrition as milking does not provide enough milk for the household with large family members once a day. Additionally, poor households are deprived of improving their livelihoods by getting milk for better nutrition, food and income.

Production of milk by good hygienic quality for consumers requires good hygienic practices, such as clean milking utensils, milker hand washing, udder cleaning and use of individual towels during milking and handling, before delivery to consumers or processors (Getachew 2003). In this study, 79.2% of participants washed their hands with cold water only and 13.2% used warm water and detergent to wash their hands. Participants also reported washing their hands before and after milking. The study found that there was no practice of medical examination of farm workers, particularly milkers although they said they did not engage in milking when they were sick because of preventing the contamination of milk with man-borne diseases, for example, typhoid, typhus, and tuberculosis. In line with this study, Duguma and Geert (2015) reported that the majority of farmers in Jimma practised hygienic milking, such as hand washing, milk containers, and udder before milking.

In this study, 3.8% and 9.4% of the farmers used individual and common towels to wipe udder after washing, respectively. This contrasts with the findings of Zelalem and Faye (2006) who reported that small and large-scale dairy producers used a common towel for drying udder in Ethiopia central highlands. Duguma and Geert (2015) reported that only 13% of the farmers in Jimma city, Southwestern Ethiopia, use an individual towel and this is higher than the findings of this study. It was also observed that after washing, 86.8 percent of dairy farmers do not wipe the teat and udder (Table 4.5). The effect of not wiping teat and udder may be the transmission of diseases, especially mastitis and zoonosis to an individual who later consumes that milk. The high percent of not wiping the teat and udder may be due to the fact that farmer uses the dripping water on the teat as a lubricant during the milking process as it has been observed that all the farmers do not use the lubricant during milking.

As observed in the current study, 62.3 percent of participants used stream water as their main source of water to clean the udder or teats, wash their hands and milking utensils, and the other 7.5 percent used well water source, 17 percent used tank water source, and 13.2 percent used tap water source for cleaning and washing purposes. Contrary to the findings of this study Kebede and Megerrsa (2018) reported that 98.9% participants use pipe water in Addis Ababa, and the other 1.1% use well water. According to Zelalem (2009), when water from non-tape sources is used for cleaning purposes, it is important that producers should at least filter, and heat treat it before use because the quality of water determines the number of bacterial counts.

In this study, 79.2% of the respondents use plastic containers for collecting milk and only 1.9% use stainless-steel for collecting milk. In agreement with this study, Duguma and Geert (2015) reported that approximately 92.6% and 3.7% Jimma farmers collected milk using plastic buckets and stainless-steel cans, respectively. Plastic containers tend to harbour microbes in the cracks or crevices that develop due to their continuous use. Metal containers such as aluminium and stainless-steel cans are recommended under the code of hygiene practices. Majority of participant's 64.2 percent clean containers for milk treatment before and after using cold water only without any detergent.. The survey result showed that all the participants (100%) use the separate house for keeping the animals and most of the cows (94.3%) were housed in cow dung type floor barn. In contrast with the present findings, Kebede and Mergerrsa (2018) reported that most participants used the concrete barn floor in Addis Ababa.

Table 4.5 above shows the interaction between the socio-economic characteristics (age; education; herd size; household size; source of income and dairy experience) and the parameter of hygiene milking practices.. The age and source of income were the most significant ($p<0.05$) against hand washing and utensil parameter washing. This may be because the farmer uses their own income from other farm income to adhere to good milking practices that will ensure high-quality milk production. Also, that rural dairy farmer not only relied on dairy farm income but also had a considerable off-farm income. According to a Burton study (2006), good hygiene practices are a feature often associated with farmers over the age of 40. Likewise, Mdluli *et al.* (2014) found that farmers belonging to older age groups had good hygiene practices. However, against the use of towel parameter, the household size and source of income was the most significant ($p<0.05$). The likely reason for this is that households with large family size participate in the farm activities and the farm's division of labour. While the herd size had a significant relationship ($p<0.05$) to the dipping parameter of the teat. The results may be because the larger the dairy farmer's herd size, the more expensive it is for the farmer to afford the dipping chemicals. The reason may also be that farmers are not informed about the importance of teat dipping in relation to the production of good quality milk for consumption. Dairy experience had a significant relationship ($p<0.05$) to milk coverage when taken to storage. The possible reason could be that many participants belonged to old-age group and they might also have resumed farming at an early age resulting in a greater amount of farming experience. Finally, Table 4.6 showed that the source of income had a significant relationship ($p<0.05$) with mixing old and fresh milk and boiling milk before consumption.

4.6 Conclusion:

From the results of this study, it can be concluded that most farmers followed some standard of milking hygiene practices such as the washing of milk containers, hands of milkers and udder before milking. However, intervention is needed to develop infrastructure, enhance the input supply system, and undertake capacity development and training to enhance the skills of farmers and pastoralists in dairy production, processing, and marketing.

In this regard, future work involves workshops among dairy cow producers on the importance of adequate udder preparation, hygienic milking technique, use of clean dairy utensils, washing utensils and milker hands using properly treated water to improve milk hygienic quality and shelf-life.. If possible, potable water should be available to effectively clean and sanitise milk utensils and udder preparations, otherwise boiled water should be used for such purposes.

However, this aspect also requires improvement of infrastructure with government intervention.

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CHAPTER 5

RAW COW MILK BACTERIOLOGICAL AND BIOCHEMICAL ASSESSMENT COLLECTED FROM KWA-HLABISA VILLAGES, KWA-ZULU NATAL.

5.1 Abstract:

The study was conducted in Hlabisa since March 2018 to assess raw milk bacterial contamination intended for human consumption. Isolate and characterise particularly common raw milk contaminating microorganisms and evaluate various raw milk adulterants. A total of 68 raw milk samples from various sampling points of teats were collected aseptically; milking and collective buckets. For the detection of coliforms such as Escherichia coli and Enterobacter aerogenes, the bacteriological analysis was conducted. Biochemical tests for detecting various adulterants in these milk samples were also carried out using the milk adulteration test kit for detecting alizarine, formalin, urea, starch, neutraliser, detergents, salt, skim milk powder, sucrose, glucose, hydrogen peroxide. Results showed that the total number of bacteria was found to be 6.06 log cfu / ml (teats) and 6.91 log cfu / ml (milking and collective buckets) higher than the recommended milk standards. Samples of 13 pathogenic bacterial species reported contamination *Enterobacter aerogenes, Enterobacter gergoviae, Klebsiella oxytoca, Pseudomonas aeruginosa, Pseudomonas maltophilia, Pseudomonas mallei, Shigella dysentery, Shigella sonnei, Morganella morganii, Alkaligenes denitrificans,* and *Xanthomonas.* Adulterant analyses in samples tested positive for urea 34 percent, hydrogen peroxide 32 percent. Alizarin and detergent were tested positively in 29% of the milk samples and skim milk powder was detected in 15% while sodium chloride was detected in 12% of the milk samples. Sucrose and glucose were both detected at 6%. Formalin, starch, and neutraliser were not detected in any samples. This study showed the presence of various pathogenic gram-negative staining bacterial species from raw milk that can be attributed to sub-optimal sanitary conditions in production and shows different chemical adulteration of milk from Hlabisa villages caused by the lack of standard operating sanitation.

Key Words: Adulteration, Bacteria, Gram-negative, Milk standards, Pathogenic, Hygiene.

5.2 Introduction:

Milk is one of the best and most stable food compositions providing a variety of proteins, fats, minerals, calcium, phosphorus, potassium, and a variety of vitamins (A, B2, B12, and D), lactose, and all the amino acids needed to maintain, grow and develop the body. It is an important diet in all age groups, but mostly children under five years of age. (Mahmoudi *et al.*, 2014). Its significance has been observed in many developing countries in Africa as the main backbone for improving the nutritional status of people suffering from hidden hunger (Msalya, 2017a). Moreover, for millions of people in the communities of developing countries, milk has been the path out of poverty. Milk is not only the source of food in developing countries but also provides social and economic benefits for small-scale producers, small market agents and consumers in terms of higher farm gate prices, job creation and competitive consumer prices (Swai and Schoonman, 2011, Knight-Jones *et al.*, 2016).

The production of fresh milk in South Africa generates annual revenue of around 10 billion rands, while the annual revenue of all dairy-based products amounts to around 40 billion rands. South Africa, however, has experienced a decline in the number of milk producers since 1997, leading to increased milk imports and this is projected to be even higher by 2025. (Serebro, 2016). Rural small-scale dairy farmers in South Africa, therefore, have the potential to contribute to rural growth, meeting the demand for milk shortages, reducing unemployment, poverty, and gender inequalities. Rural small-scale dairy farmers ' prospect of contributing to the above-mentioned challenges has not yet been exploited in South Africa. Rural small-scale dairy farmers are not involved in high-income markets in South Africa. In order for rural small-scale dairy farmers to contribute to rural development and transit to commercial farming, appropriate sanitary and hygienic measures need to be maintained at each critical point of production and addressed effectively (Khapayi and Celliers, 2016).

The lack of standardised hygienic operating procedures for rural small-scale dairy farmers at various stages of procurement, processing and distribution results in their early spoilage by microorganisms (Hamid *et al.*, 2013). Contamination by microorganisms could also result from the udder, barn, milk collection materials, various ingredients added to dairy products and workers in the dairy farm. (Garedew *et al.*, 2012, Mesfine *et al.*, 2015). Gram-negative staining bacteria that have been reported to contaminate milk as a result of milking cows affected by mastitis and poorly sanitised utensils used during milking, transportation, and storage (Mesfine *et al.,* 2015). As a result, infected milk can spread various zoonotic diseases either during milk processing or from infected cows. These diseases include brucellosis, typhoid fever and food poisoning for salmonella, tuberculosis, gastroenteritis, Q-fever, dysentery, diphtheria and staphylococcal intoxication (Abbas *et al.,* 2013).

A greater number of pathogens were isolated from milk between 2006 and 2014, including *Brucella (B.) abortus, Campylobacter spp., Clostridium spp., Escherichia coli, Corynebacterium spp., Leptospira spp., Mycobacterium spp., Salmonella spp., Staphylococcus (S.) aureus, and Streptococcus (S.) agalactiae* (Gwandu *et al.,* 2018). And were linked to the incidence of diseases such as tuberculosis (TB), brucellosis, diarrhoea, typhoid, rift valley fever and allergies among milk consumers in different parts of the country. (Gwandu *et al.,* 2018; Msalya, 2017). The prevalence of these pathogens in milk was associated with diseases involving cow mastitis, goat mastitis, bovine TB (BTB) and brucellosis in animals (Gwandu *et al.,* 2018). In addition, milk adulteration has also been identified as one of the major challenges and has been shown to affect nutritional and processing quality (loss of quality) and increase chemical or microbial contamination (Swai and Schoonman, 2011, Karimuribo *et al.,* 2015).

Milk adulterants in rural villages can be present in raw milk in different ways (Abbas *et al.,* 2013). Cows may consume or excrete contaminated soil, grass or feed in their milk. Urea may be present in milk due to feed supplements, particularly if the feed does not have all the protein, minerals and vitamins needed to keep the cow healthy and produce high-quality milk. In addition, urea being a crop fertiliser can end up in cow's milk through cow feeding on crops that have been fertilised with urea. Alizarin can be present on cow's raw milk because of cow feeding on the roots of the plant called madder. This plant grows naturally on the field with natural limestone deposits, which is thought to stimulate higher alizarin production within the roots of the plant.

The presence of detergent and soap residues in raw milk may be due to the use of detergent concentration not recommended after the milking process by the manufacturer to wash and disinfect the milking utensils. Hydrogen peroxide residues can be found in raw milk in rural villages if hydrogen peroxide is used by a drinking water treatment plant to remove organic impurities. It can also be caused by cows drinking in streams and rivers contaminated with cosmetic materials produced from this hydrogen peroxide, such as human hair bleaching and toothpaste. Sucrose can be found in milk as a result of dairy cows feeding on sugar cane or sugar beet roots, which contain a high concentration of sucrose, and is a natural source of sucrose.

The aim of this study was, therefore, to evaluate the quality of raw milk by indirectly determining contamination by milk adulterants and to isolate and characterise common microorganisms contaminating raw milk during procurement, processing, and distribution by a small-scale rural dairy farmer in Hlabisa villages, KwaZulu-Natal, South Africa.

5.3 Material and Methods:

5.3.1 Description of the Study Area:

The study was conducted in Kwa-Hlabisa local municipality is one of five Category B municipalities within the uMkhanyakude District Municipality. It is located adjacent to District Management Area 27 and the local municipalities of Jozini, Big 5 False Bay and Mtubatuba (IDP 2015:16). The municipal area is entirely rural and consists of four traditional areas. The most important land use is subsistence agriculture, and dispersed settlements, plantations and agriculture are found throughout the municipality (IDP 2013:2014). The municipality faces poverty challenges of varying magnitudes, with the most common being income poverty and human poverty. Income poverty refers to the lack of sufficient income to meet basic food needs and essential non-food needs (IDP 2014:15).

Human poverty also refers to the lack of basic human capacity and stems from the high representation of members who are unable to read, write and count food insecurity, malnutrition, decreasing life expectancy, increased disease and deaths related to preventable diseases and poor access to basic services (IDP 2016:21). Many settlements are still without reliable energy sources and depend for light and power on candles, paraffin and firewood. Water is delivered below Reconstruction and Development Programme (RDP) standards with some areas showing high dependency on boreholes and natural sources (IDP 2014:15).

The local economy is predominantly agriculture, but the area has a high potential for development of tourism. The town of Kwa-Hlabisa is found at a latitude of 27^{o}7'60 "north, longitude of 31 ° 49'0" east at an altitude of 451 m above sea level. It consists of 960km² of hilly topography in central Zululand, KwaZulu-Natal, and is known for its rich wildlife and conservation efforts (IDP 2017:18). Road R618 and Wildlife Park provide opportunities for local economic development. The park now has the largest white rhino population in the world due to conservation efforts (IDP 2014:15).

5.3.2 Sample Size and Sampling Method:

A simple random sampling was adopted to obtain the participant from rural small-scale dairy farms from which milk samples were collected. The sample size of 53 rural small-scale dairy farmers was selected, but milk samples were collected from 23 rural small-scale dairy farmers who had lactating cattle.at the time of data collection, The rest of the rural small-scale dairy farmers had dried their cattle and by the time the study was conducted, others were no longer milking because of permanent blockage to cattle's teats. Before sampling, information on environmental hygiene, personal hygiene, milk collection, storage utensils, storage conditions and water used in sanitation and milking procedures was collected through the questionnaire. Milk assessment for the smell, colour, any deposits and cleanliness of containers was carried out using standard methods.

First of all, sampling for microbiological assessment involved collecting swab samples from the milking bucket and the collective bucket. Before the milking process, the milking and collective buckets were swabbed at the bottom round corners using sterile dry swabs. An area of 100 cm^2 was swabbed several times in all directions by rubbing firmly across the area. The swabs were immersed in 5 ml of Tryptone Soy Agar in a sterile 50 ml centrifuge tube and stored in cold storage prior to analysis. In addition, 50 ml of pooled raw cow milk was sampled into the centrifuge tubes with boric acid for preservation from the milking and collective bucket after being thoroughly mixed and stored in a cool box with ice blocks. The swab and milk samples were transported for storage at −18 ° C to the University of KwaZulu-Natal Laboratory. Microbiological contamination analysis was conducted in Pietermaritzburg, University of KwaZulu-Natal Microbiology Laboratories

5.3.3 Preparation of Serial Dilution and Isolation

Milk samples were immediately analysed in the laboratory using total plate count, biochemical identification tests, and adulteration tests for milk. Each sample of milk was diluted before plating. The dilutions were made in a sterilised solution of distilled saline water. One ml of milk from each sample was poured into 9 ml of sterilised distilled saline water in a test tube for dilution (1:10). One microlitre was plated on the TSA and the inoculum was spread using a hockey stick. The plates were then left on the bench for half an hour, then incubated at 37 ^{o}C and examined for bacterial growth after 24 hours. Plates in replicates were observed for their loads of bacteria. The colony count was performed and the total viable bacterial count was calculated by multiplying the number of colonies with the reciprocal dilution used. The mean for all the samples was calculated. Based on the different morphology on Tryptone Soy Agar, which was aerobically incubated at 37 ^{o}C for 24 hours, incubated milk and swabs samples were streaked to isolate bacteria. Plates that showed no growth were further incubated for 48 hours before being discarded as negative. Bacterial isolates were purified by repeated subculture on Tryptone Soy Agar.

5.3.4 Identification of Different Bacterial Isolates from Milk Samples

Unique colonies were sub-cultured to obtain pure isolate colonies. The pure isolates were maintained on agar plates and their likely identities were established using Biochemical Identification Test Kits. The biochemical identification kit was a comprehensive test system that can be used to identify gram-negative *Enterobacteriaceae* and Non-fermenter species (HiMediaLabs).

5.3.5 Biochemical Tests for Adulterants' Analysis

All milk samples were screened for the presence of commonly used adulterants and preservatives using the milk adulteration kit supplied by HiMediaPvt. India, Ltd. These tests included the alizarine test, urea test, detergent test, salt test, starch test, sugar test (sucrose), formalin test, skim milk powder test, glucose test, and hydrogen peroxide test. All these tests were performed in a sterile manner as directed by the manufacturer.

5.3.6 Ethical Considerations

The Humanities and Social Science Research Ethics Committee at KwaZulu-Natal University (Protocol Reference No HSS/1072/016 M) granted permission to conduct this study. After explaining the purpose and importance of the study prior to the start of data collection, verbal consent was obtained from each rural small-scale dairy farmers. Verbal consent was used because most rural small-scale dairy farmers do not know how to read and write. Ethical standards prevented any fabrication and falsifying of data and therefore promote the pursuit of knowledge and truth which was the primary goal of the research.

5.4 Results:

5.4.1 Identification of Bacteria via Biochemical Tests:

In addition to adulteration and gram staining, various biochemical tests were performed for bacterial identification. The biochemical tests were based on the principle of pH change and the use of substrates. On incubation, organisms undergo metabolic changes which are indicated by a colour changes in the media that is either visible spontaneously or after addition of a reagent.

These biochemical tests can be used for identification of gram-negative Enterobacteriaceae and Non-fermenters species. These tests included test like O-Nitrophenyl-β-D-galactopyranoside (ONPG), Lysine utilisation, Ornithine utilisation, Urease, Phenylalanine Deamination (TDA), Nitrate reduction, H_2S Production, Citrate utilisation, Voges Proskauer's (VP), Methyl red (MR), Indole and Malonate utilisation (Table 5.1) for identification of Enterobacteriaceae. Non-fermenter species identification included tests like Indole, Esculin hydrolysis, Citrate utilisation, Arginine, Nitrate reduction, O-Nitrophenyl-β-D-galactopyranoside (ONPG), Alkaline phosphatase, Phenylalanine deamination, Urease, Cetrimide tolerance, Lysine and Oxidase (Table 5.2). Based on these test's bacteria were identified.

Table 5.1: Biochemical test results of Enterobacteriaceae.

Gram stain	ONPG	Lysine	Ornithine	Urease	TDA	Nitrate	H_2S	Citrate	VP	MR	Indole	Malonate	Identified bacteria
-	-	+	+	-	-	-	-	-	+	-	-	+	*Enterobacter aerogenes*
-	+	+	+	+	-	+	-	+	-	-	-	+	*Enterobacter gergoviae*
-	+	+	-	+	-	+	-	-	+	+	+	+	*Klebsiella oxytoca*
-	-	+	+	+	-	+	-	-	-	+	-	-	*Morganella morganii*
-	-	-	-	-	-	+	-	-	-	-	-	-	*Shigella dysenteriae*
-	-	-	+	-	-	+	-	-	-	-	-	-	*Shigella sonnei*

Note: Based on % strains showing reactions the following symbols have been assigned from laboratory results and standard references: + = positive (more than 90%); - = Negative (more than 90%); V = 11-89% positive.

Table 5.2: Biochemical test results of Non-fermenters.

Gram stain	Indole	Esculin	Citrate	Arginine	Nitrate	ONPG	Alkaline	Phenyl	Urease	Cetrimide	Lysine	Oxidase	Identified bacteria
-	-	-	+	-	+	-	+	-	-	+	-	-	*Alkaligenes denitrificans*
-	-	-	+	+	+	-	+	-	+	-	-	-	*Cdc group ve type 1*
-	-	-	+	+	+	-	+	-	+	-	+	-	*Pseudomonas aeroginosa*
-	-	-	-	+	+	-	+	-	-	-	+	-	*Pseudomonas mallei*
-	-	+	-	-	+	-	+	-	-	-	+	-	*Pseudomonas maltophilia*
-	-	+	+	-	-	-	+	-	+	-	+	-	*Xanthomonas spp.*

Note: based on % strains showing reactions the following symbols have been assigned from laboratory results and standard references: + = positive **(more than 90%); - = Negative (more than 90%); V = 11-89% positive.**

Various samples of milk tested positive for *Enterobacteriaceae species viz. Enterobacter aerogenes, Enterobacter gergoviae, Klebsiella oxytoca, Morganella morganii. Shigella spp., Shigella sonnei. The non-fermenters were identified: Alkaligenes denitrificans, CDC Group Ve type1, Pseudomonas aeruginosa, Pseudomonas mallei, Pseudomonas maltophilia, and Xanthomonas spp.*

5.4.2 Milk Adulterants Analysis:

Sixty-eight samples were analysed using the MAT kit for the presence of chemical adulterants. Biochemical tests were performed on all these samples and results are presented in Table 5.3.

Table 5.3: Percentage of milk samples adulterated with common adulterants.

Sample no.	Adulterants	Samples tested positive n=68	Percentage found in milk
1.	Alizarine	20	29%
2.	Formalin	-	-
3.	Urea	23	34%
4.	Starch	-	-
5.	Neutraliser	-	-
6.	Detergent	20	29%
7.	Sodium chloride	8	12%
8.	Skim milk Powder	10	15%
9.	Sugar	4	6%
10.	Glucose	4	6%
11.	Hydrogen Peroxide	22	32%

5.5 Discussions:

Milk sampled from procurement, processing and distribution for rural small-scale dairy farmers in the Kwa-Zulu Natal area of Hlabisa was analysed in this study. Results indicate the presence of the following bacterial species: *Enterobacter aerogenes, Enterobacter gergoviae, Klebsiella oxytoca, Morganella morganii, Shigella dysenteriae, Shigella sonnei, Alkaligenes denitrificans*, *CDC Group Ve type1*, *Pseudomonas aeruginosa, Pseudomonas mallei, Pseudomonas maltophilia,* and *Xanthomonas species* (Table 5.1 and Table 5.2). Some of these bacteria identified from the milk samples were potentially pathogenic, which could have an impact on food safety among Kwa-Hlabisa households if milk were to be distributed, thus compromising food and nutrition security. However, some of them like *Enterobacter spp., Morganella morganii,* and *Klebsiella spp.* are rarely associated with foodborne infections. Nevertheless, these bacteria are used as indicators for evidence of poor hygiene practices, inadequate processing or post-process milk contamination by rural small-scale dairy farmers. Food safety is therefore an important pillar of food and nutrition security and priority must be taken into account in the milk processing and milk handling among rural small-scale dairy farmers

Therefore, the presence of coliforms (Enterobacter spp., Morganella morganii, Shigella spp. and Klebsiella oxytoca) in the milk samples of this study implied that milk produced by Hlabisa rural small-scale dairy farmers was of poor quality to be consumed. This meant that the rural small-scale dairy farmers did not properly perform good milking practices. *Klebsiella oxytoca, the main pathogen of Klebsiella, causes pneumonia while Morganella morganii and Enterobacter are mainly opportunistic pathogen associated with soft tissue infection, respiratory tract infection and urinary tract infections.* The Enterobacteriaceae associated with identified foodborne was Shigella. Shigella species identified from Hlabisa's raw milk were Shigella sonnei and Shigella dysenteriae. Both species are responsible for shigellosis or bacillary dysentery, a disease that causes high fever, neurological disturbance, and mucus-pyo-haemorrhagic dysentery (Sansonetti, 2001; Ekwanzala *et al.*, 2017).

The detection of coliform and pathogenic bacteria from milk showed that there could be poor hygiene either from the udder of cattle or utensils used to get milk. It also indicated poor and inappropriate management of milking, ineffective milking practices and ineffective or deficient care of cattle. In terms of milk production and preservation, the lack of domestic infrastructure such as running water, electricity and refrigerators contributed significantly to the predicament of rural small-scale dairy farmers. Lues *et al.* (2012), reported that good management practices can improve and control clinical and sub-clinical udder infections, a practice that can positively affect most cattle in this study. Farmers using the calves to suckle from their mothers to stimulate lactation and start directly with hand milking without washing the teat and udder were suspected to have contributed to milk contamination. This practice has obvious hygiene implications for the respective individual families of rural small-scale dairy farmers, especially for the immunocompromised individuals and young children.

Moreover, none of the milking shed structures had a cement floor and therefore the milking area could not be properly cleaned or sanitised. Gillah *et al.* (2014), concluded that contamination from external sources is significantly reduced when cows and floors are cleaned, manure removed daily, utensils sterilised and cow udders and teats washed. The milking environment has a huge impact on the quality of the milk produced. Most farmers used plastic buckets as milking utensils, which are difficult to clean and can be a potential for bacteria to thrive, causing milk contamination (Gillah *et al.* 2014). Similarly, Bereda *et al.* (2012) and Lues *et al.* (2012) reported widespread use of plastic buckets as milking utensils in rural dairy units and rural dairy producers. The presence of coliform isolates can also be attributed to the neglect of post-milking teat dipping and the lack of herd health management. Contaminated water, the absence of detergents or disinfectants to wash udders and milk utensils, and environmental contamination may also be a cause.

In the present study, the detection of non-fermenting gram-negative bacteria was also found to provide more information about the sanitation of the dairy farm compared to SPCs. At least three of the *Pseudomonadaceae* family (*Pseudomonas aeruginosa*, *Stenorophomonas maltophilia* and *Burkholderia mallei*) were isolated; *Xanthomonas species*; *Alkaligenes denitrificans and CDC Group Ve type 1* were other isolated non-fermenting bacteria. *Pseudomonadaceae* family have been reported as important opportunistic agents of foodborne infections transmitted through contact with the skin and wounds, but also through the inhalation of aerosol droplets and the consumption of drinking water in highly immune-compromised patients. They disperse and easily adhere to surfaces forming a biofilm that interferes with cleaning and disinfection procedures. They are distributed ubiquitously in various environmental sources such as tap water or contaminated solution. Zanetti *et al.* (2014) found a significant correlation between the overall occurrence of non-fermenting gram-negative bacteria in tap aerators and the prevalence of infection in intensive care units among exposed patients.

The presence of the Pseudomonadaceae family in milk may have serious implications for the health of lactating dairy cows in the mammary gland. *Stenotrophomonas* was found to be abundant in highly concentrated cow feed; it was also identified as more predominant in clinical mastitis milk samples. Clinical mastitis is the main cause of permanent teat blockage, most frequently observed in Kwa-Hlabisa rural small-scale dairy farmers ' dairy cattles, resulting in less milk being produced by these rural small-scale dairy farmers. *Stenotrophomonas identified in this study was mainly Stenotrophomonas maltophilia species.* Previous studies have shown that S. Maltophilia isolates were involved in herd outbreaks of mild mastitis in cattle in Japan. *S. Maltophilia has also been found to be an emerging global environmental gram-negative bacterial pathogen that can cause various serious human infections (Ohnishi et al. 2012 & Gelasakis et al. 2018).*

Previous studies have shown that highly concentrated feed in faeces causes a significantly high percentage of an environmental pathogen such as *Stenotrophomonas*. Contamination of the faeces on the barn floor plays an important role in bacterial multiplication and bacteria can be transferred between the lying surface and the teats. Therefore, faecal contamination among dairy cows may be the main source of *Stenotrophomonas* infection. Other non-fermenting gram-negative bacteria detected in raw milk are *alkaligenes* (formerly *Achromobacter*) denitrificans, which can occasionally cause infections mainly in the elderly and in immune-compromised hosts (conjunctivitis, otitis, sinusitis, upper and lower respiratory tract infections, meningitis, bacteraemia, and endocarditis).

Contamination of milk is high, particularly in traditional farming systems and in informal milk markets, and this was in line with this study using literature and milk sample analyses. Consumer concerns that have been exposed to various forms of milk hazards and related risks have been reported over the past two decades (Msalya, 2017). It can be shown that the bacterial and coliform count levels reported in previous reports, such as TBC values of 6.73 log cfu / ml in (Nonga and Mtambo, 2015) and 6.51 log cfu / ml in (Karimuribo *et al.,* 2015) were higher than those accepted in East African dairy regulators. In South Africa, the regulations on milk and dairy products also stipulate that raw milk intended for further processing may not contain more than 200 000 CFU per 1,0 ml of bovine milk (Louw, 2013). However, in this study, it was shown that the levels of raw milk bacterial contamination from rural small-scale dairy farmers were higher than the recommended amount approved by milk and dairy product organisation 6.91 log cfu / ml from milk containers.

The milk samples also indicated the presence of various types of chemical adulterants that may lead to severe health problems (Table 5.3). Adulteration (intentionally or accidentally) of food products, particularly milk, is a serious problem in rural areas and can lead to severe health problems for milk consumers (Handford *et al.*, 2016). Gastrointestinal problems such as gastric ulcer, colon ulcer, diarrhoea, and electrolyte disturbances are common causes of carbonated milk. Hydrogen peroxide adulteration disturbs the activity of antioxidants in the body that causes a disturbance in natural immunity that leads to increased ageing (Abbas *et al.*, 2013). Weakening, sensory disturbances and loss of acquired speech can be caused by the presence of ammonia in milk. Blood pH and acid-base balance in the body can be disturbed by the presence of chlorides in milk (Swetha *et al.*, 2014).

In this study, formalin, starch, and neutraliser detection tests were negative (Table 5.3). The absence of formalin, starch, and neutraliser adulterants may be due to the lack of knowledge of this practice by rural small-scale dairy farmers. Other reasons for the absence of formalin and neutraliser adulterants may be that they are not easily and cheaply available in rural areas. This unethical activity is usually used by milk farmers to prevent the loss of milk due to spoilage during their storage and sale in different parts of the world (Sinha, 2012). In this study, all samples did not present formalin, and the results of this study did not support the results obtained by Barham *et al.*, 2014 (20% and 15%) and Singuluri and Sukumaran, 2014 (32% and 32%) in these formalin studies, but were detected in a low percentage. The presence of formalin as an adulterant in raw milk causes vomiting, diarrhoea, and abdominal pain, and also leads to decreased body temperature, shallow respiration, weak irregular pulse, and unconsciousness (Afzal *et al.*, 2011). It can also cause blindness by damaging the optic nerve and is carcinogenic in nature.

The absence of starch in this study's examined milk samples was consistent with the findings of Nirwal *et al.*, 2013 and Singuluri and Sukumaran, 2014. However, Barham *et al.*, 2014 and Swetha *et al.*, 2014 recorded the higher percentage of starch (27% and 35.5%) in raw milk samples. Swetha *et al.*, (2014) mentioned that a higher amount of starch may cause diarrhoea in the colon due to undigested starch. Its accumulation in the body can be very fatal for diabetic patients. Neutralisers such as carbonates and bicarbonates are alkalis that are easily available to rural small-scale dairy farmers and these adulterants are generally used to mask the pH and acidity values of badly preserved milk that passes it off as fresh milk (Faraz *et al.,* 2013). The current study reveals that there was no presence of adulterant neutraliser, although studies conducted by Singuluri and Sukumaran, 2014, Ramya *et al.,* 2015, Chanda *et al.,* 2012 presented the presence of neutraliser in their reports.

The alizarine test conducted was to detect milk quality whether it is acidic or alkaline. Of the 68 raw milk samples, 29% were acidic and none of the samples were alkaline (Table 5.3). However, the study conducted by Hemanth Singuluri and Sukumaran (2014) shows that all fifty collected samples were alkaline The acidic nature of milk indicates that milk may be colostral milk or mastitis milk as it may contain an abnormally high percentage of proteins. Such milk should not be consumed and should therefore be discarded. Milk's alkalinity nature may also be considered as mastitis milk; therefore, further testing is needed to detect mastitis. Adding urea to milk provides whiteness, increased milk consistency, and levels of solid-not-fat as naturally present in milk (Kandpal *et al.,* 2012). Results from this study showed that 34% of samples were positive for urea.

The occurrence of urea in milk overburden the kidney as they have to do more work to throw out the body's contents of urea. In some cases, this may lead to renal failure. It also leads to swollen limbs and impaired vision. In addition, urease is also harmful to the heart and liver (Kandpal *et al.,* 2012). The presence of urea in this study implied that dairy cattle consume urea-fertilised feed, which can be excreted in milk. Kandpal et al (2012) stated that the presence of detergents helps emulsify and dissolve the oil in the water giving the foamy solution. According to the present study, 29% of milk samples showed positive results for detergent presence (Table 5.3). Results obtained from this study almost match the results obtained by Singuluri and Sukumaran, 2014 (44%), Barham *et al.,* 2014 (41%) but differ from Kandpal *et al.,* 2012 (100%). Detergents octylphenol and nonylphenol cause breast cancer and decrease testicular sperm production (Ali *et al.,* 2005). In one of its reports, the ICMR (1993) states that detergents cause food poisoning and gastrointestinal complications.

Sodium chloride in milk mask the high-water content. In the present study sodium chloride was found to be 12% in milk samples among the total of 68 milk samples examined, which contrasted with the results of Barham *et al.,* 2014, Nirwal *et al.,* 2013 and Singuluri and Sukumaran, 2014 who reported 19%, 51% and 82% positivity respectively. It has been reported that high levels of sodium chloride in milk may affect the acid-base balance of the body and may cause regression loss of acquired immunity, kidney problems, speech and sensory disturbances (Brindha *et al.*, 2017).

Glucose and skim milk powder are used to increase the weight or relative weight of natural milk. The extent of glucose adulteration in this study was insignificant, only 6% of the samples showed glucose. The results of the study were almost like the findings of Barham et al (2014), who reported 10%. However, Nirwal *et al.* (2013) reported a very high level of glucose-adulterated milk (80%) and none of the samples were reported positive in the study conducted by Singuluri and Sukumaran (2014). Furthermore, the results of this study reveal that 15% of milk samples were adulterated with skim milk powder, which was almost the same as Barham *et al.* (2014) (19%), whereas Singuluri and Sukumaran (2014) reported a higher percentage (80%) of skim milk adulteration. These results are consistent with the findings of Lateef *et al.* (2009), which found that rural small-scale dairy farmers use skim milk powder to adulterate milk to maximise their profit by adding cheap substances such as glucose and skim milk powder to increase the total solids content of milk.

Six percent of the milk samples collected from Kwa-Hlabisa were detected as an adulterant. The reason for the presence of cane sugar in raw milk is unknown. Sugar, however, is a cheap source of sweetener. It can therefore be assumed that cane sugar is added to the diluted raw milk to improve its taste. Hydrogen peroxide is used for milk as a chemical preservative. It usually increases the shelf-life of milk during the summer season when the ambient temperature is very high. In this study, 32% of the samples were positive for hydrogen peroxide, higher than the results obtained by Ghulam Shabir Barham *et al.* (2014) (20 % and 15 %) and Hemanth Singuluri and Sukumaran (2014) (32 % and 32 %). This could be because the rural small-scale dairy farmer uses this approach most of the time since they do not have refrigerators to preserve their milk.

5.6 Conclusion:

The present study showed that raw cow milk consumed by rural small-scale dairy farmers was unhygienic due to microbial contamination. Faecal pollution from cow's dung is probably an important source of microbial contamination of the milk. It was also concluded that the raw milk samples contained various types of chemical adulterants that could lead to severe health problems. Programmes such as "good hygiene practices" and "good farming practices" should be adopted at every step of milk handling and processing. In addition, raw milk should not be used without processing (at least boiling) and a strict control and balance system should be developed to control chemical adulteration.

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CHAPTER 6

OVERVIEW, CONCLUSION AND RECOMMENDATION

6.1 Overview:

Rural small-scale dairy farming in agriculture can be a key livelihood activity for most rural households in South Africa as well as in many other developing countries (Stewart *et al.*, 2015). Despite their large contributions towards household food production, rural small-scale dairy farming in South Africa is currently unable to fully assess the potential of income generation from farming due to limited market access (Mdluli *et al.*, 2014). Successful entry or integration into high-value markets, is hindered by many constraints and barriers experienced by these rural small-scale dairy farmers who are resource-limited (van der Heijden and Vink, 2013).

This study aimed at analysing the microbial aspect of rural small-scale dairy farmer's milk handling process from production to utilisation. Furthermore, to optimise and develop an ongoing feedback strategy and workshops to rural small-scale dairy farmers and extension officers and disseminate project information to rural small-scale farming dairy hygiene management. A convergent parallel mixed method approach integrating quantitative and qualitative methods was used to address these challenges.

The first part of this study was to survey traditional milk handling practices used by rural small-scale dairy farmers from production to consumption. Investigate whether the rural small-scale dairy farmer's milk handling and practices affect the quality of milk. Secondly was to assess bacterial contamination of raw milk meant for human consumption. Isolate and characterise particularly common microorganisms contaminating raw milk and finally evaluate different adulterant present in raw milk. The study used descriptive statistics, cross tabulation tests, ANOVA test, total plate count, biochemical identification tests and milk adulteration tests to achieve these objectives.

6.2 Conclusion:

Milk production and marketing is one of the most important farm activities that help generate income for households, maintain household food security in study areas and also contribute to the national economy. The major problems identified in the areas were hygiene practices in milk production such as herd management, milking practices, and chemical adulterants, and their associated risk was human health. A common problem observed in the study area was the presence of poor milk handling practices and the absence of hygiene milk processing system. Among the important determinants of milk contamination in the study area were the unhygienic conditions of milking, unclean handling of milking utensils and the use of contaminated cleaning water. The study revealed the limited involvement of women in milk production in this area, especially youth. This indicated that women in rural areas still lack education, equal rights to property, exclusion in decision-making and limited control of resources. Additionally, the study revealed that the participants were old-age. Despite the fact that most participants were experienced in farming results indicated that some participants had no knowledge in dairy farming. With regard to hygiene practices, most farmers have a limited understanding of the importance of milk handling, such as udder washing, teat towel drying, the source of water, indicating poor milk hygienic practice. It was also found that it takes more than 15 minutes to reach the house or storage site from the milking area and there are no means of preservation, such as a refrigerator, to preserve milk for further use, which can lead to a rapid spoilage of milk due to the hot climate of the area.

The observed poor quality of milk produced by rural small-scale dairy farmers was probably due to the poor hygienic condition of the milking environment, lack of cooling system, poor sanitary condition of the milk containers, poor udder and teats cleaning practice, failure to use separate towels for each cow and poor personal hygiene of the milkers. Cow housing systems could also be an influencing factor for mastitis that causes permanent blockage of teats and leads to less milk production. In addition, very high microbial counts observed in milk samples collected from rural small-scale dairy farmers could be attributed to the absence of cooling systems, the use of plastic containers for milk collection, the mixing of milk obtained from different cows and the presence of further contamination at milk selling sites. The results of milk adulteration tests clearly showed that the milk collected from different villages in Hlabisa had different adulterants and preservatives such as salt, skim milk powder, glucose, urea, neutralisers, detergents, formalin and hydrogen peroxide, which have economic and public health implications because this can cause serious health problems among consumers.

Improving the safety of milk can be achieved through good management practices by rural small-scale dairy farmers, market incentives, and increased efforts by various stakeholders and the adoption of best practices. In this regard, a coordinated action involving all stakeholders is needed to implement preventative/control measures, quality management strategies, and appropriate regulation while supporting and building the capacity of smallholder dairy producers to minimise risks associated with milk production.

6.3 Recommendation:

The following recommendations for rural small-scale dairy farmers were found to improve milk quality:

1. Dairy extension is needed to assist rural small-scale dairy farmers.
2. Visual hands on practice workshops and standard operation procedure to ensure optimisation of milk hygiene conditions from production to utilisation.
3. Dairy farmers need to adopt good farming practices, including good dairy housing, use of clean water, regular veterinary care to maintain animal health, and sanitary milking procedures, including the use of suitable equipment, cleaning, disinfection, and post-rinsing..
4. Rural small-scale dairy farmers must be provided with incentives (premiums) for adopting practices that ensure milk safety in addition to developing a formal milk market.
5. Presentation of this project results to small-scale dairy farmers.

6.4 Recommendations for Policy, Rural Development and Practice:

1. The government and non-governmental organisation (NGO's) should consider equipping rural small-scale dairy farmers with entrepreneurial skills in order to successfully benefit from the enterprise. Furthermore, assuming that rural small-scale dairy farmers are striving to commercialise their business, it is recommended that they should be capacitated with skills that will give them a comparative advantage over their counterparts (commercial farmers) in order for them to fully participate in South African dairy industry.
2. Commercial dairy feeds and other inputs should be subsidised to encourage rural small-scale dairy farmers to supplement cattles according to weight and level of production using a dairy meal. This will increase milk production and reduce the cost of milk production. Also, the government and the stakeholders in the dairy industry should sensitise rural small-scale dairy farmers through extension staff on the importance of livestock insurance and create subsidised livestock insurance schemes.

3. More farmer-to-farmer visits should be encouraged to enable peer motivation in the application of acquired knowledge into practice. This will play a role in bridging the gap between knowledge acquisition and its application.

6.5 Recommendations for Future Research:

There is limited information or knowledge regarding effective cattle mastitis management. Organised problem-oriented research is needed to monitor udder health and milk quality of cows. Cow herds should be carefully monitored for a range of quality and disease parameters throughout lactation to establish baseline values and infection information. Both formal and informal methods should be employed to strengthen the understanding and reliability of data collected and to achieve analytical quality. This kind of a research must fulfil the needs of the rural small-scale dairy farmer owners and the consumers. The cost benefit relationship of mastitis control measures in cows needs to be examined in detail.

6.6 REFERENCES

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APPENDICES

Appendix A: Research Questionnaire:

SECTION A: SOCIO-ECONOMIC DEMOGRAPHICS

Code	1	2	3	4	5
1. Age (years)	15-20	21-30	31-40	41-50	>50
2. Gender	Female	Male			
3. Level of education	No formal education	Primary	Secondary	Tertiary	
4. Size of your land (hectare)	0.5-1.5 h	1.6-2.5 h	2.6-3.5 h	3.6-4.5 h	> 4.5
5. Household size	1	2-3	4-7	>7	
6. Sources of income	Dairy	Other agricultural activities	Off farm employment	Remittances	Pension
7. Dairy herd size	<5	5-10	>10		
8. Do you sell milk to the community?	Yes	No			
9. Farming Experience (years)	<5	5-10	>10		
10. Have ever you participated in any dairy production training	Yes	No			
11. If yes, specify the type of training	General farm management	Record keeping	Milk marketing	Pasture establishment & management	Proper milking & clean milk handling

SECTION B: MILKING PRACTICES

Code	1	2	3	4	5
12. Who is responsible for milking the cows?	Owner	Family member	Employee	Other	
13. Do you have milking overalls/cloths?	Yes	No	If yes, how many times do you wash them?		

14. **Do you tie the back legs of the cow when milking?**	Yes	No			
15. **Which milking system do you use?**	Manual	Portable Milking parlour	Fixed Dairy Parlour		
16. **Do you always wash your hands before milking?**	Yes	No			
17. **If yes, when do you wash your hands for milking?**	Before milking	After milking	During milking	Before and after	
18. **What does use to wash your hands with?**	Cold water only	Warm water only	Warm water with detergent	Cold water with detergent	
19. **What type of container do you use during milking?**	Stainless-steel	Plastic	Clay Pots	Calabash	Wooden container
20. **When do you wash the milking container?**	Before milking only	After milking only	Before and after milking		
21. **Cleaning agent for milking utensils and collecting tanks?**	Cold water only	Warm water only	Warm water with detergent	Cold water with detergent	
22. **Source of water to clean milk handling Utensils?**	Tap	Wells	Boreholes	Water streams	
23. **Is the milking container used for other use?**	Yes	No			
24. **Do you practice the washing o the udder and teats before milking?**	Yes	No			
25. **Surface type of the milking area**	Concrete surface	Earthed surface	Cow dung surface		
26. **Use of towel for drying udder**	Common towel	Individual towel for each cow	No use of a towel		
27. **The practice of teats dipping and dry cow therapy**	Yes	No	If yes, how		

28. **How do you practice teats dipping?**	Wash the udder and use of udder towels	Teat dipping	Wash and use of milking salve	Treat clinical cases	
29. **Do you think the milk will be bad when your cow is ill?**	Yes	No			
30. **Do you milk the cattle yourself when you are ill?**	Yes	No			
31. **Milking frequency per day?**	Once	Twice	Thrice	No regular schedule	
32. **Do you think there are bacteria's in milk?**	Yes	No	Do not know		
33. **Do you cover the container when you take the milk to the storage?**	Yes	No			
34. **Distance from milking area to storage? (meters)**					
35. **How many litres you milk in a day**	1-5 litres	6-10 litres	11-15 litres	>15 litres	
36. **How many times in a day is the milking area cleaned?**	Once	Twice	Sometimes	Never	
37. **Are records for milk production kept?**	Yes	No			

SECTION C: MILK HANDLING

Code	1	2	3	4	5
38. **Do you take milk to the store room immediately after milking?**	Yes	No			
39. **Storage method after milking**	Use of refrigerator	Room temperature	Traditionally stored		
40. **If traditionally stored, what type of traditional storage method is used?**	Washing and smoking milk vessel	Keeping in a cold place	Souring	Boiling	Other (specify)

41. **Do you transfer the milk to a different container for household use?**	Yes	No			
42. **Do you use a third container to transfer milk to a different container?**	Yes	No			
43. **Do you mix fresh milk with the left-over milk?**	Yes	No	If yes, why?		
44. **Do you boil the raw milk before consuming it?**	Yes	No	If no, why?		
45. **How do you consume the milk?**	Raw milk	Fermented	Processed	Other	
46. **What are the indicators you use to determine that the milk is bad?**	It has become sour and thick	Signs of dirt or foreign matters	Mould growth in or on the milk	Blood in the milk	Other (specify)
47. **What are the cows fed on?**	Napier grass	Maize stover	Concentrate	Other (specify)	
48. **Which farming system does the household practice?**	Zero-grazing	Open grazing	Both	Zero-grazing	

SECTION D: ANIMAL HEALTH-ANTIBIOTICS

Code	1	2	3	4	5
49. **Do you ever give your cows any antibiotics for the treatment of diseases?**	Yes	No	If yes, what is the name of the antibiotics?		
50. **What do use antibiotics for?**	Treatment	Prevention	Growth promoter		
51. **Who administer antibiotics**	Veterinarian	Village extension officer	Animal health worker	The owner	Worker
52. **Are you treating any of your cows wit h antibiotics currently?**	Yes	No			
53. **How do you use the antibiotics?**	Symptomatic	Empirical	Overuse	Underuse	
54. **Have you heard about antibiotic resistance?**	Yes	No	If yes, explain		
55. **If you are treating a cow/s with antibi otics, do you sell/consume the milk fro m that cow at the same time?**	Yes	No	If no, how long do you wait?		
56. **If you do not sell the milk (from the treated cow), what do you do with it?**	Feed calves	Feed cat/dogs	Drink it	Discard it	
57. **Once antibiotic treatment is over, how do you check antibiotic remains in the milk?**					

58. What do you do to your milk immediately after milking?

____

____

____

____

59. Do you consume raw milk with your family? **Why?**

60. Do you consume the fermented milk? **Why?**

61. Do you think personal hygiene is important for milking**? Why?**

62. What do you perceived as quality & safety **(define it, attributes used to assess quality &safety and its importance?)**

63. How do you ensure the general hygiene of yourself before handling the milk?

64. What informs your daily milking and hygiene practices, **elaborate**?

65. What methods of milk preservation do you use? (**Techniques, methods, reasons**).

Appendix B: Representative of Cross Tabulation:

Age * Tying_of_hindlengs

		Yes	No	Total
Age	15-20	1	0	1
	21-30	2	1	3
	31-40	3	0	3
	41-50	14	1	15
	>50	28	3	31
Total		48	5	53

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.559[a]	4	.634
Likelihood Ratio	2.242	4	.691
Linear-by-Linear Association	.150	1	.699
N of Valid Cases	53		

Age * Milking techniques

		Manual milking	Total

Age	15-20	1	1
	21-30	3	3
	31-40	3	3
	41-50	15	15
	>50	31	31
Total		53	53

Age * Handwash before milking

		Handwash_before_milking	
		Yes	Total
Age	15-20	1	1
	21-30	3	3
	31-40	3	3
	41-50	15	15
	>50	31	31
Total		53	53

Age * Period of handwash

		Period_of_handwash			
		Before milking	During milking	Before and after milking	Total
Age	15-20	0	0	1	1
	21-30	0	0	3	3
	31-40	0	1	2	3
	41-50	2	1	12	15
	>50	4	1	26	31
Total		6	3	44	53

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.806[a]	8	.669
Livelihood ratio	4.703	8	.789
Linear-by-linear association	.443	1	.506
N of Valid Cases	53		

a. 13 cells (86,7%) have expected count less than 5. The minimum expected count is,06.

Age * Hand washing before milking

		Cold water only	Warm water only	Warm water with detergent	Cold water with detergent	Total
Age	15-20	0	0	1	0	1
	21-30	3	0	0	0	3
	31-40	1	0	0	2	3
	41-50	13	0	1	1	15
	>50	25	2	0	4	31
Total		42	2	2	7	53

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	37.059[a]	12	.000
Likelihood Ratio	17.626	12	.128
Linear-by-Linear Association	1.074	1	.300
N of Valid Cases	53		

Age * Type of milking equipment

Crosstab

Count

		Type of milking equipment			
		Stainless-steel	Plastic	Wooden container	Total
Age	15-20	0	0	1	1
	21-30	0	3	0	3
	31-40	0	3	0	3
	41-50	0	12	3	15
	>50	1	24	6	31
Total		1	42	10	53

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.477[a]	8	.594
Likelihood Ratio	6.963	8	.541
Linear-by-Linear Association	.104	1	.748
N of Valid Cases	53		

Age * Washing of milking container

Crosstab

	Washing of milking container		
	Before milking only	Before and after milking	Total

Age	15-20	0	1	1
	21-30	0	3	3
	31-40	0	3	3
	41-50	3	12	15
	>50	2	29	31
Total		5	48	53

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.012[a]	4	.556
Likelihood Ratio	3.278	4	.512
Linear-by-Linear Association	.010	1	.919
N of Valid Cases	53		

a. 8 cells (80,0%) have expected count less than 5. The minimum expected count is,09

Appendix C: Approved Ethical Clearance:

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

08 September 2016

Mr Nkosinathi Humphrey Xulu (210505224)
School of Agriculture, Earth & Environmental Sciences
Pietermaritzburg Campus

Dear Mr Xulu,

Protocol reference number: HSS/1072/016M
Project title: Evaluating milk handling amongst small-scale's dairy farmers: A case study of dairy farmers in Groblersdal, Limpopo

Full Approval – Expedited Application

In response to your application received on 14 July 2016, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL.**

THE APPLICATION WAS SEEN BY AREC (REF: AREC/060/016M) AND THERE WAS NO ETHICAL ISSUES.

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 Shamila Naidoo (Deputy Chair)

/ms

Cc Supervisor: Dr Sumaiya Jamal-Ally and Dr Denver Naidoo
Cc Dean of Research: Professor O Mutanga
Cc School Administrator: Ms Marsha Manjoo

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