THE UNIVERSITY OF ZAMBIA

LEVEL OF BACTERIAL CONTAMINATION OF RAW MILK PRODUCED UNDER DIFFERENT MILKING ENVIRONMENTS IN SMALLHOLDER DAIRIES OF MAGOYE

BY

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DECLARATION

is research project report has been compiled by myself and has not been accepted in any :vious application for a degree. The work in this report has been done by me and all sources of ormation have been acknowledged by means of references.

MATTHEW PELEKAMOYO ZULU

MAY, 2010

DEDICATION

I dedicate this project report to my ever inspiring mother Jenipher Miti and my late father Godfrey "Kambwili" Zulu.

ABSTRACT

he level of bacterial contamination of raw milk produced under different milking environments smallholder dairies of Magoye was studied. The milking environments examined were housed rlours with soil floor, housed milking area with concrete floor, structureless milking area with il floor and structureless milking area with concrete floor. Sixteen (16) smallholder farmers nembers of the Magoye Smallholder Dairy Cooperative) were selected for the study presenting 10% of the farmers delivering milk to the Milk Collection Centre in Magoye at the ne the study was carried out. The results showed a strong negative correlation (r) of -0.587 <0.05) between the milking environment and bacterial contamination. The least level of cteria contamination (44,333 cfu/ml, Grade AA milk) was found among farmers milking their imals in housed parlours with concrete floors whereas farmers producing milk in structureless ilking areas that have soil floors had the highest with 234,583 cfu/ml (Grade C milk). Farmers oducing Grades A and B lose K250 while those producing Grade C lose K450 per litre of ilk. It was concluded that the environment under which milking was done had a significant fect on the level of bacterial contamination of the milk.

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ACRONYMS

DPB	Dairy Produce Board
FAO	Food and Agriculture Organisation
GART	Golden Valley Agricultural Research Trust
HC	Housed milking area with concrete floor
HS	Housed milking area with soil floor
NHC	Structureless milking area with concrete floor
NHS	Structureless milking area with soil floor
TBC	Total Bacterial Count

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 The Dairy Industry in Zambia

Zambia has long been seen to have great potential for an expanded dairy industry both within the country, as well as regionally (Daka, 2006). The dairy industry has also been seen as a strategic means of generating income and employment, reducing poverty, hunger and malnutrition – especially among vulnerable people. The origins of Zambia's commercial dairy sector are traced to a small group of white settler farmers who introduced dairy cows in the 1920s (Kaluba, 1993). However, after independence in 1964 most of the dairy farmers relocated to the then Southern Rhodesia while many of those who remained switched to other agricultural commodities such as poultry which proved more profitable; as a result there was a decline in commercial milk production from the mid-1960s and into the 1970s (Bwalya, 1987; Daka, 2006). This decline in milk production coincided with increase in dairy consumption within Zambia, especially in the expanding urban towns of Lusaka, Livingstone and Copperbelt towns such as Ndola, Chingola and Kitwe (Kenny and Mather, 2008).

Parastatal dairy farms were established on abandoned former white settler owned farms between the late 1960s and late 1970s as a measure to reduce the growing demand for dairy products countrywide (Kaluba, 1993). Production on these farms, which were heavily subsidized by the Zambian government, supplied over 30 percent of processed milk. However, this did not meet demand; thus the increase in dairy consumption was met through imported dairy products (Kenny and Mather, 2008). Daka (2006) points out that although the ratio between local production and imports has varied over time, Zambia has always had to depend on imports to meet consumption demands. Government control of dairy development between 1964 and 1983 through state dairy farms, dairy settlement schemes, rural milk production schemes, parastatal dairy farms and their related smallholder development programs ended in failure, largely due to poor selection of farmers who were not market orientated, unsuitable dairy animals, inadequate dairy extension services, high production costs, high subsidies on inputs by the government, and regulated farm gate prices of milk by the government. The overall involvement of government in milk production and marketing reduced the productivity and growth of the dairy industry in Zambia, (Daka, 2006; Swanson, 2009).

The Dairy Produce Board (DPB) was established to coordinate milk production and processing, and was also tasked with increasing milk production through initiatives that were more in line with the developmental priorities of the Zambian government (Bwalya, 1987; Kenny and Mather, 2008). One of these strategies was the Rural Milk Production Scheme supported by the World Food Programme which involved identifying smallholder farmers who were located outside of the Dairy Produce Board's normal operating area. The beneficiaries of the scheme were provided with cows on loan and the farmers themselves were involved in the marketing of he milk. In order to improve the supply of milk for commercial sale, the DPB was also involved n establishing the Dairy Settlement Scheme (Bwalya, 1987; Daka, 2006; Swanson, 2009).

According to Kenny and Mather (2008), the government identified land near Lusaka, Kabwe, Ndola and Mpika for establishing dairy resettlement schemes and the farmers participating in hese schemes were trained at Palabana Dairy Institute in dairy husbandry and management. Another strategy embarked on by the government for increasing milk production was the Smallholder Dairy Development Project, which received support from the World Bank whose im was to assist about 1800 farmers who would be provided with loans to purchase cattle and other farming equipment and the milk from these farmers would be collected by the Dairy Produce Board and processed for sale in growing urban markets where demand was high Kaluba, 1993).

DPB like many other state controlled companies was hit with financial problems in the late 980s which led to its collapse in the early 1990s (Daka, 2006). At this time Zambia began to nove towards privatization of most parastatals. DPB was privatized in 1996 and the Bonita Group from South Africa (now Parmalat Zambia plc) purchased Lusaka, Mazabuka, and Kitwe rocessing plants while the Chipata plant, Ndola depot, and Chingola depot processing plants vere also sold to the local businesses. Today there are more than twenty privately owned dairy rocessing plants with varying capacities, located in different parts of the country; notable mong these are Kaposhi Dairy Products, Diamondale Dairy, and Cedrics Farms (Valeta, 2004; wanson, 2009).

1.2 Milk Production and Consumption in Zambia

Zambia's dairy sector is experiencing growth as a result of increased population and consumption of dairy products. According to Valeta (2004) and Emongor et al. (2004), dairy production in 2003 increased from 138 million litres to over 190 million litres. Currently, the Golden Valley Agricultural Research Trust (GART) estimates raw milk production to be over 240 million litres as at December 2010. This increase is more impressive considering the dairy sector that experienced stagnating and declining production levels between the 1970s and mid-1990s. A significant proportion of the increase in dairy production is attributable to smallholder farmers who have received extensive support from both non-governmental organizations and private processors, such as Parmalat, Land O' lakes and Zambia Agribusiness Technical Assistance Centre (Mukumbuta and Sherchand, 2006; Kenny and Mather, 2008). In the context of declining numbers of large-scale commercial farmers, small-scale producers are now regarded as the solution to meeting the increasing demand of dairy products in Zambia (Kenny and Mather, 2008; Aregheore, 2009).

Investment in infrastructure has assisted smallholder dairy farmers improve their volumes and quality of raw milk with the support from Parmalat, Land O'Lakes, Golden Valley Agricultural Research Trust and the Zambian government. In addition, it is providing support in terms of transportation and collection of raw milk, which historically has been a serious problem for smallholders (Mukumbuta and Sherchand, 2006; Pandey and Muliokela, 2006; Kenny and Mather, 2008).

With regard to consumption, Emongor et al. (2004) estimated the country's total milk requirement at approximately 253 million litres per year. However the country has generally been facing a shortfall in milk production given that domestic production meets only 75 percent of the demand. This deficit of 25 percent is covered by importing powder milk from New Zealand and long life milk from South Africa and other countries (Emongor et al., 2004; Mukumbuta and Sherchand, 2006; Kenny and Mather, 2008). According to Daka (2006) and Kenny and Mather (2008) about 70 to 80 percent of all milk consumed in Zambia is sold directly to consumers in local open markets and approximately 20 to 30 percent is processed by the commercial dairy processing industry. However, there are no proper statistics available. The increase in the number of processors, has led to significant product differentiation resulting in increase in demand for fresh milk, but while the majority of the nation's milk supply is provided by traditional herds kept by smallholders, little of it enters the formal commercial dairy channels (Mukumbuta and Sherchand, 2006).

Despite the growth, domestic consumption remains relatively low in Zambia. Per capita milk consumption in Zambia is estimated at 15 litres/annum. This is far lower than the FAO recommended per capita consumption of 45 litres/annum (Emongor et al., 2004; Valeta, 2004; Mukumbuta and Sherchand, 2006). Pandey and Muliokela (2006) reported per capita milk consumption at 17 litres/annum. Although there is inconsistence in the reports, it is nonetheless evident that Zambia's consumption of milk is still very low. Despite the domestic demand not being satisfied fully, Zambia exports milk to its neighbours, primarily the Democratic Republic of Congo (Valeta, 2004; Daka, 2006).

1.3 Importance of Raw Milk

Animal milk is known to have been used first as human food during the Secondary Products Revolution, around 5000 BC (Mc Gee, 1984); it is presumed that when animals such as cattle were first domesticated, it was only for purposes of meat. However, dairy products obtained from the animals proved to be a more efficient way of turning uncultivated grasslands into sustenance. Milk by-products found inside Stone Age pottery from Turkey indicate processed milk was consumed in 6500 BC, some thousands of years before it is thought that adult humans had evolved the ability to digest raw milk (Mc Gee, 1984; Microsoft Encarta, 2009).

Most milk is composed of 80 to 90 percent water and the remaining 10 percent consists of an abundance of the major nutrients needed by the body for good health, including fats, carbohydrates, proteins, minerals, and vitamins. Alvaro (2008) reports that, cow milk typically contains about 3.5 to 5 percent fat, which is dispersed throughout the milk in globules. In addition to providing milk's characteristic taste and texture, fat supplies vitamins A, D, E, and K, as well as certain fatty acids that the body cannot produce on its own. Lactose is a carbohydrate found only in milk; it gives milk its sweet taste, makes up about 5 percent of milk's content (Simbaya and Yambayamba, 2008). Lactose is broken down easily by infants to supply the body with energy.

The most important protein in milk is casein, accounting for 80 percent of milk protein. Casein is a complete protein, meaning that it contains all of the essential amino acids, which the body cannot manufacture on its own. The casein molecules and globules of fat deflect light rays passing through milk, giving milk its opalescent appearance. Other proteins present in milk include albumin and globulin.

Milk contains many minerals, the most abundant of which are calcium and phosphorus, as well as smaller amounts of potassium, sodium, sulphur, aluminium, copper, iodine, manganese, and zinc. Milk is perhaps the best dietary source of calcium: one litre of milk supplies as much calcium as 21 eggs, 12 kg of lean beef, or 2.2 kg of whole wheat bread (Ogola et al., 2007; Microsoft Encarta, 2009). Milk is an excellent source of vitamins A and B_2. All other vitamins are present also, but in lower doses. Vitamin D is typically added to commercially sold milk. Vitamin A, which is found in the globules of fat, is removed when fat is skimmed away to make low-fat or skim milk. Generally, vitamin A is replaced during the production of commercially sold low-fat milk.

A number of products are made from whole milk such as skim milk, cheese, butter, ice cream, yoghurt, condensed milk and dry milk. The quality of these products is greatly affected by the quality of milk used to manufacture them, hence, the use of hygienic methods in the milking parlour, the maintenance of clean stalls and surroundings are important if quality milk is to be produced. Dairy hygiene in the production and marketing of milk means marketing milk that is fresh and free of contamination from disease transmitting germs and foreign materials (Simbaya and Yambayamba, 2008; Microsoft Encarta, 2009).

1.4 Objectives

The main objective of this study was to investigate the level of bacterial contamination of raw milk produced under varying smallholder dairy set ups in the Magoye area. The specific objectives were:

1. To measure the total bacterial load of milk; and
2. To estimate the financial loss experienced by the smallholder dairy farmers

CHAPTER TWO

LITERATURE REVIEW

2.1 Milk Bacteria

Microorganisms in milk contribute greatly to the variations in the quality of milk (Charles, 1998). It must be appreciated that nearly all the changes which take place in taste, odour or appearance of the milk after milking are as a result of microorganisms, especially bacteria. These organisms are widely distributed in nature. Contamination generally occurs from three main sources (Bramley and McKinnon, 1990): from within the udder, from the exterior of the udder, and from the surface of milk handling and storage equipment. The health and hygiene of the cow, the environment in which the cow is housed and milked, and the procedures used in cleaning before milking are all key in influencing the level of microbial contamination of raw milk. Equally important are the temperature and length of time of storage, which allow microbial contaminants to multiply and increase in numbers.

Milk handling practices from the point of milking up to marketing of the milk have a greater influence on the physical and microbiological contamination of the milk and subsequently on the microbial quality of the raw milk. Gran et al. (2002) who studied the hygiene practices during milking and the bacteriological quality of milk at the farm and on delivery, found that the increase in the number of bacteria in the milk was correlated with factors which would increase delivery time.

The improvement of the hygienic quality of milk and the ability to identify the associated risks of contamination from production, transportation, processing and the preservation of dairy products is critical to ensure a sustainable dairy industry (Faye and Loiseau, 2002). Sebastien et al. (2010) reported that good hygienic practices during storage, transport, and handling are of major importance to preserve original bacteriological quality of milk before treatment. Microbiological quality of milk is a well documented public health issue except in low-income countries such as those located in sub-Saharan Africa (Bonfoh et al., 2003). It should also be noted that bacteria, mainly of species of *Salmonella*, *Aspergillus*, *Fusarium*, *E. Coli* and *Penicillium* can grow in milk and dairy products and if the conditions permit, these organisms may produce mycotoxins which can be a health hazard (Alvaro, 2008). Further, the status of milk borne zoonoses such as brucellosis and Tuberculosis with special reference to mycobacterium is of special interest because of the public health associated with the consumption of raw and naturally fermented milk (Mdegela et al., 2000).

Vissers (2007) demonstrated the use of quantitative methods for the improvement of the control of the microbial ecology at dairy farms. Through a better control of the microbial ecology, animal diseases can be reduced and the microbial quality of the raw milk improved. Also developed quantitative tools can be used in decision support systems for individual farms assisting the farmer in taking the best decision when subject to changing environmental circumstances.

2.2 Sources of Milk Contamination

Milk is synthesized in specialized cells of the mammary gland and is virtually sterile when secreted into the alveoli of the udder. Beyond this stage, microbial contamination of the milk can occur (Adam and Moss, 2002). From the time the milk leaves the udder, until it is dispensed into containers, everything with which it comes into contact is a potential source of microorganisms. Milking performed under hygienic conditions, with strict attention to sanitary practices, will reduce the entry of microorganisms into the milk; however, it may become contaminated with bacteria during or after milking. Milk drawn from a healthy milk animal already contains some bacteria, thus, very high numbers of bacteria present can be in the udder and in the milk (Gonzalo et al., 2006). Some disease causing organisms (pathogens) can be shed through cow faeces and may contaminate the outside of the udder and teats, the farm environment (for example, milking parlour floor) and the milking equipment. Murphy and Boor (2009) reported that although optimal growth conditions for bacteria are different for different organisms, milk contains important nutritional components for mammal growth, and, therefore, it is also an ideal medium for the growth of many different bacteria.

According to Sinha (2000) three principal sources of milk bacteria are: from within the udder, from the exterior of the udder, and from the surface of milk handling and storage equipment. The health and hygiene of the cow, the environment in which the cow is housed and milked, and the procedures used in cleaning and sanitizing the milking and storage equipment are all important in influencing the level of microbial contamination of raw milk. Equally important are the temperature and length of time of storage, which allow microbial contaminants to multiply and increase in numbers. All these factors will influence the total bacteria count or Standard Plate Count (SPC) and the types of bacteria present in bulk raw milk (Murphy and Boor, 2009).

2.2.1 The producing animal

The dairy animal is one of the most significant sources of contamination. Care and management of the animal and its health is therefore the starting point for clean milk production (Sinha, 2000). Diseased animals especially those with contagious diseases, including mastitis should be kept separate from the healthy ones and their milk disposed of safely to avoid contamination. Milk from a cow with an infected udder is likely to contain a large number of organisms thus the probability of diseases of the udder contaminating the milk is very high. The skin of the animal provides a large surface for possible contamination; thus it is important that the flanks, udder and teats are given special sanitary care just before milking (FAO, 2000)

2.2.2 Utensils and equipment

Utensils and equipments are known to be the greatest sources of contamination. They may account for as much as 100, 000 to a billion organisms per millilitre (Alvaro, 2008). Pails, strainers, milking machines, cans, pipes, bottles, and other equipment used for the handling of milk are sometimes not properly washed and sanitized. Rajah (2001) observed that organisms survive in the cracks, corners, crevices, dents, scratches, and other irregularities of the utensils. These factors provide ideal conditions for the growth of microorganisms before the utensils are used again. Suitable washing procedures are facilitated by using warm water, a brush, and a detergent satisfactory to the hardness of the local water used for cleaning. Subsequent sanitizing treatments may utilize hot air, hot water, steam, chlorine or quaternary ammonium compounds.

2.2.3 The Personnel

In the case of hand milking, the danger of contamination coming from the milker is higher compared with machine milking. Therefore, the milker should be free from contagious diseases (Sinha, 2000). Persons involved in the milking process must be in good health and must be careful in their personal cleanliness. Although workers may not contribute a large number of organisms, these are of considerable importance since they may well be human pathogens (Adam and Moss, 2002). Probably the majority of milk borne epidemics of disease was started by workers who were carriers, or who had mild cases, or who were in close contact with others so affected (Cohen, 1998). The importance of contamination contributed by the workers is simply that it is the most dangerous.

2.2.4 Water

Water is continuously required for cleaning and processing operations in a dairy. Rajah (2001) reported that water quality varied with the source of supply. Water from surface supplies is contaminated by dust, animals, plants, people, and other agents. The microbiological quality of water to be used in dairy hygiene practices is very important. The most common test for water destined for domestic or industrial use, is the presumptive coliform test. This test reveals faecal or sewage contamination. Chlorination of water is commonly practiced to assure reduced microbial load.

2.2.5 Milking environment and surface

The environment in which milking of the animals is done is of paramount importance to the overall sanitary quality of the milk produced by a farmer. In a study by Cempirkova (2007), farmers who milked their animals in milking parlours had a lower microbial contamination of milk compared to farms that used the in-stall milking pipeline system but the difference was statistically significant only in Total Bacterial Count. Gonzalo et al. (2006) compared the use of loose slatted-floor litter less, loose cubicle littered and stanchion littered milking parlour housing on microbial contamination; the researchers found that loose slatted-floor litter less was connected with insufficient environmental hygiene and with the subsequent higher fouling of dairy cows, which was reflected in the highest milk contamination by all groups of the investigated microorganisms. But the results could not be generalized because this technology was used on one farm only. However, these results showed the need to investigate the effect of milking environment on microbial quality of milk as practiced by different farmers.

The type of surface in the milking parlour has a major bearing on the hygiene quality of milk as it is one of the major sources of physical as well as microbial contamination of milk. Effective cleaning of the environment under which milking is done is greatly influenced by the kind of floor. Concrete floors are easy to clean compared to compacted gravel or straw covered surfaces. Dirty cow sheds and milking parlours may be infested with flies and other disease transmitting pathogens (Simbaya and Yambayamba, 2008).

2.3 Recommended milking practices

The efficient production of milk under good hygienic conditions is the key to successful dairying. The principal constraints in smallholder systems are inadequate feeding, low genetic potential in animals and high levels of bacterial contamination leading to spoilage before reaching the market (FAO, 2011).

2.3.1 Health and Cleanliness of Cows

It must be ensured that cows are thoroughly cleaned before milking to prevent physical contamination of the milk. Furthermore, the flanks, udder and teats should be given special sanitary care just before milking. Washing and massaging the cow's udder with clean warm water and detergent or sanitizer solution such as chlorine before milking eliminates possibilities of contamination by the animal. The health status of milking animals should be of good condition as it affects the quality of milk the cow produces. According to Sinha (2000) long hairs on the flanks, hind legs, tail and udder should be clipped at frequent intervals because the hair of all animals harbours organisms. If washing of animals is not practiced regularly as is observed in smallholder dairy production, at least grooming of the animals should be done to keep the hair and dust away from milk.

2.3.2 Water

The water given to animals for drinking and that used for cleaning animals, utensils and surroundings should be clean. Preferably water fit for human drinking as it reduces microbial contamination (Rajah, 2001). Thus, the use of water sanitizers such as chlorine helps to improve water quality especially in areas where there is no pipe water.

2.3.3 Milking environment

The animal shed is one of the main sources of contamination. At the same time, a good shed protects against micro-organisms as it keeps out other animals, people, wind, rain and excessive heat, all increasing the danger of contamination (Sinha, 2000). Mud, urine, faeces, and feed residues should regularly be removed from the shed. The shed should have proper drainage, sufficient light and ventilation. In very wet areas, sprinkling slaked lime over the surface will help to dry it out quickly.

The milking area of the shed needs special hygienic attention. The floor of the milking area should be swept with clean water, and disinfected with 1 percent bleaching powder solution.

Facilities should be provided for a sufficient supply of safe and potable water for drinking, washing udders and flanks of the animals, utensils and milkers hands (MALDM, 2000).

2.3.4 Milking personnel

Persons involved in the milking process must be in good health and must be careful in their personal cleanliness. They should wash their hands, clean and rinse them with soap, and dry them with a clean towel or mutton cloth before starting to milk (MALDM, 2000). They should keep finger nails free of dirt and each person must always carry a clean handkerchief and use it to prevent the spraying of nasal and oral discharges into the atmosphere, equipment or products (Rajah, 2001). They should wear a neat and clean uniform. A surgical mask where possible is an effective addition to the uniform. Small scale farmers should ensure that the milkers are clean and of good health (Simbaya and Yambayamba, 2008).

2.3.5 Utensils and storage equipment

Suitable washing procedures are facilitated by using clean warm water, a brush, and a detergent (Sinha, 2000). This is because dirty milking equipment is one of the main sources of infection of milk. In commercial production, subsequent sanitizing treatments may utilize hot air, hot water, steam, chlorine or quaternary ammonium compounds for cleaning milk handling equipment. The utensils should be allowed to dry after washing and before adding milk. This ensures that odours of the detergents used are not transferred to the milk.

Sinha, (2000) further states that milking equipment should also be thoroughly cleaned after use because any milk residues in the equipment will allow microorganisms to grow rapidly. The utensils and equipment used during milking should be of standard quality. They should be made up of acceptable, non-absorbent, corrosion-resistant material and should be easy to clean. The milking utensils and equipment should be thoroughly cleaned and sanitised after each milking and where possible non-corrosive cleaning and bactericidal agent should be used for cleaning and sanitation (Sinha, 2000; Rajah, 2001).

After cleaning and sanitation, the utensils and equipment should be stored in such a manner and location to prevent contamination from flies, insects dust, dirt and rodents. They should preferably be stored in an inverted position off the ground to facilitate drainage of wash water (Rajah, 2001).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of Study

The study was carried out in Magoye, Mazabuka District (Southern Province) involving sixteen (16) smallholder farmers who were members of the Magoye Smallholder Dairy Cooperative. The selected farmers were 10% of the farmers delivering milk to the Milk Collection Centre in Magoye at the time the study was carried out.

3.2 Data collection

3.2.1 Sample collection

Stratified random sampling was used in the study. Oral interviews were used to identify the Smallholder farmers and pooled them into two strata: those with milking areas without structures (structureless) and milking areas with a structure (housing). Further, floor type was the basis for the distinction of the observation variables in each stratum; thus two observation variables in each stratum namely Concrete floor and Compact soil (gravel) floor were considered. Farmers were then categorized into four (4) distinct groups: structureless milking area with concrete floor (Figure 1), structureless milking area with soil floor (Figure 2), housed milking area with concrete floor (Figure 3) and housed milking area with soil floor (Figure 4). Each of these groups represented 2.5% of the sample, thus, four (4) farmers were selected from each category using simple random draws.

Three 4 ml milk samples were collected from each farmer, bringing the total to 48. Sterilized sampling equipment was used to collect aseptic sample by cleaning the dip stick with tap water, swabbed with 99% ethanol and rinsed with distilled water. The stainless steel dip stick was later flamed with a lighter so as to ensure the milk sample was not contaminated with microorganisms from the sampling equipment.

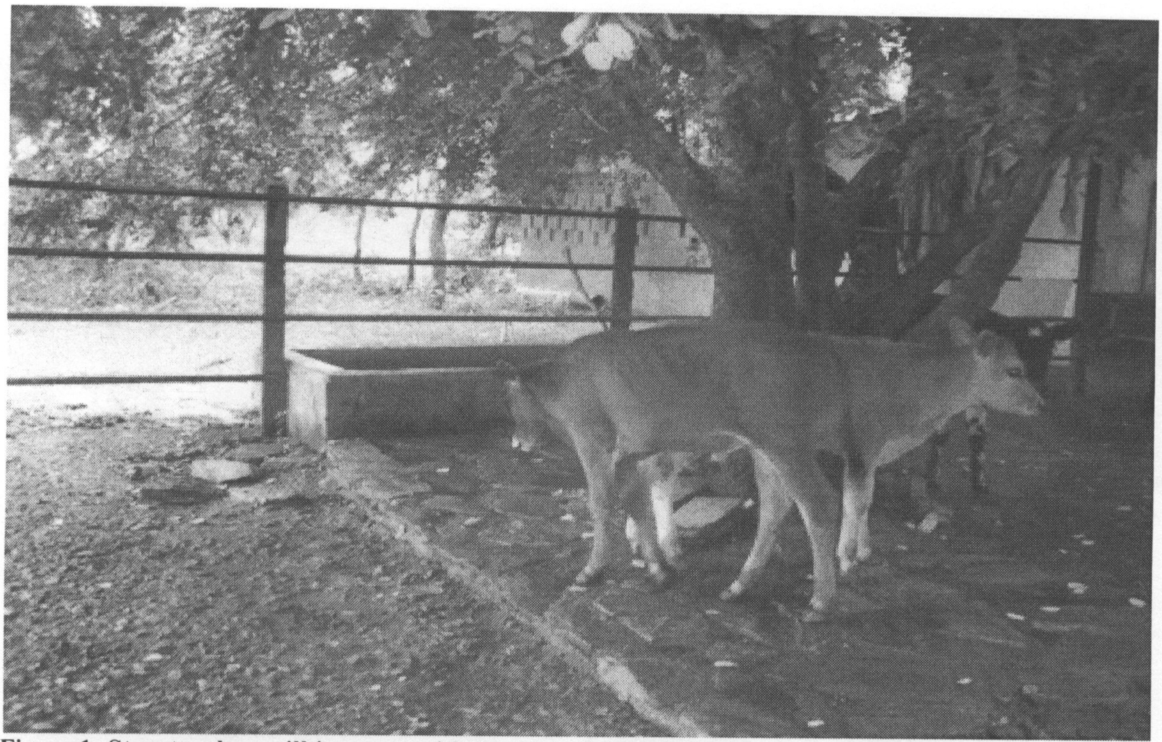

Figure 1: Structureless milking area with concrete floor

Figure 2: Structureless milking area with soil floor

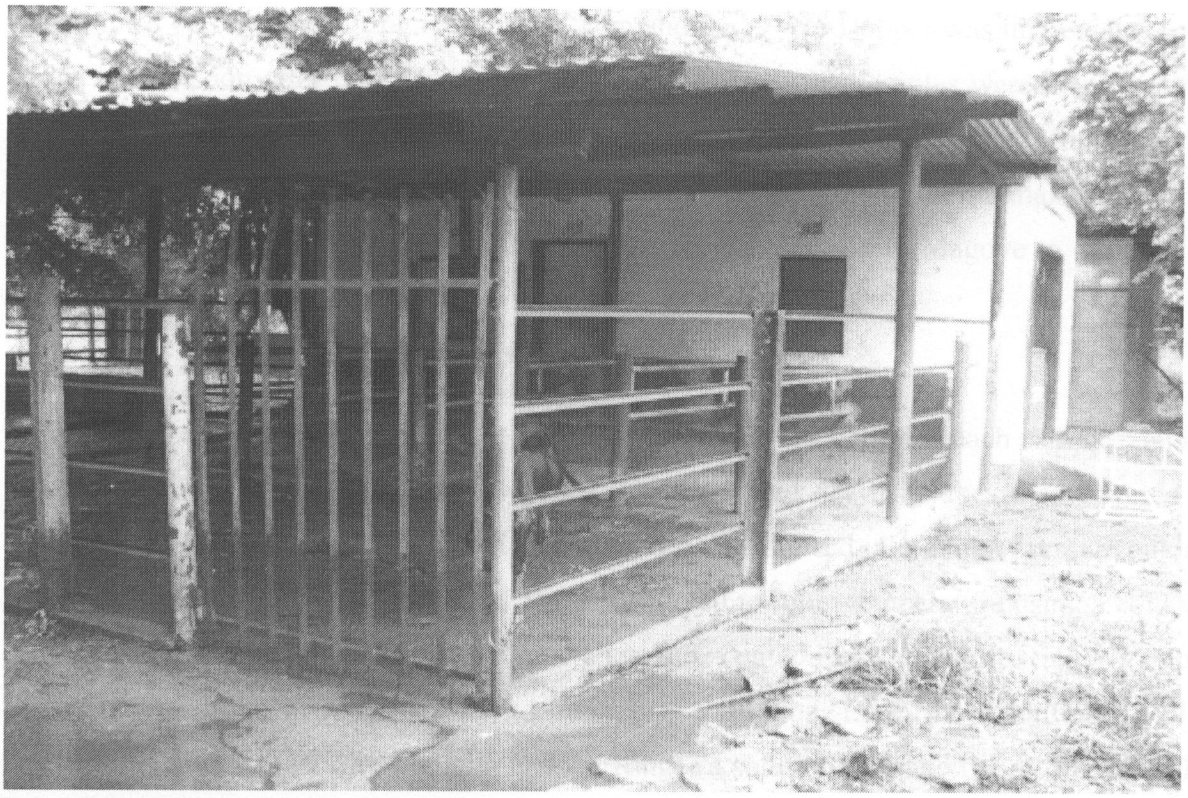

Figure 3: housed parlour with concrete floor

Figure 4: housed parlour with soil floor

Sterile 4 ml plastic bottles were used to collect the samples. The opening of the sample bottles were flamed before transferring the milk in them and the rubber stopper was immediately placed on the bottles soon after transferring the milk sample. The milk samples were then placed in a chiller box containing ice blocks to keep the samples cool and fresh as well as reduce microbial proliferation (Figure 5). The samples were immediately transported to the Parmalat laboratory in Lusaka for analysis. Transportation of the samples took 2 hours from Magoye to the laboratory and analysis was done immediately.

3.2.2 Sample dilution and preparation

Three dilutions (-1or 1/10, -2 or 1/100 and -3 or 1/1000) were done for each sample. Nine (9) millilitres of Ringers solution was dispensed into clean and dry test tubes then covered with aluminium foil (Figure 6). The covered test tubes were transferred into a high pressure autoclave and autoclaved for 15 minutes at 121^0C and later cooled to room temperature using a cold water bath. One millilitre of milk was pipetted into a test tube containing 9 ml sterile Ringer's solution, using a micropipette with sterile tips, to make the -1 dilution. From the -1 dilution, 1ml was pipetted into another test tube containing 9 ml Ringer's solution to make the -2 dilution. The -3 dilution was made by transferring 1 ml of the -2 dilution in a test tube containing 9 ml Ringer's solution.

One millilitre of the -3 dilution was pipetted into clean, dry and sterile Petri dishes on which the Plate Count Agar was previously poured and was left to solidify. The Petri dishes were then placed in a Labcon incubator (Figure 7) and incubated for 48 hours at 31^0C.

In order to avoid cross contamination of samples during dilutions, new micropipette tips were used for each sample. The tips were flamed to sterilize them. Likewise, during dilutions the test tubes remained covered with aluminium foil and were only opened when a sample or diluents was transferred in them. The micropipette was cleaned with 99% ethanol and rinsed with distilled water before use.

3.2.3 Plate Count Agar preparation

Exactly 11.5 g of agar powder was weighed and placed into a 500 ml volumetric flask. Distilled water was added to fill the flask to the mark and was shaken until the powder dissolved. The opening of the volumetric flask was covered with aluminium foil and placed into a High pressure autoclave and autoclaving was done at $121^{0}C$ for 15 minutes. The Plate Count Agar (PCA) was placed in a cold water bath and cooled to $44^{0}C$, then poured on Petri dishes containing 1ml of the -3 dilution (Figure 8).

3.2.4 Enumeration of Total bacteria

After 48 hours of incubation, the Petri dishes were removed from the incubator and each dish or plate was placed on the Colony counter (Figure 9) and the number of colonies enumerated. Only colonies with a diameter of 2 mm or more were counted (Figure 10). The number of colonies counted was multiplied by 1000 and the results expressed as Colony Forming Units per millilitre of milk (CFU/ml). This represented the total bacteria in the 1 ml milk sample, consequently, indicating the level of bacterial contamination in the milk. After enumerating, the Petri dishes were disinfected by pouring 99% Ethanol (Figure 11) on them then covered. They were then placed in a clean sterile polythene bag which was sealed (Figure 12) and disposed off in a trash bin. The results obtained were used to grade the milk according to the standards as prescribed the by Food and Drugs Act number 22 of 1972 as indicated in Table 1.

Table 1: Zambian Standards for grading raw milk

RANGE	GRADE
<50,000 cfu/ml	AA
≥50,000cfu/ml to ≤100,000 cfu/ml	A
>100,000 cfu/ml to <200,000cfu/ml	B
≥200,000 cfu/ml	C

Source: Regulation 154 of the Food and Drug Act 22 of 1972 of the Laws of Zambia

For purposes of this study, Grade C milk ranged from 200,000 cfu/ml to 500,000 cfu/ml. Above 500,000 cfu/ml the milk was regarded Too Numerous to Count (TNTC). This was, however, still considered as a proportion of Grade C.

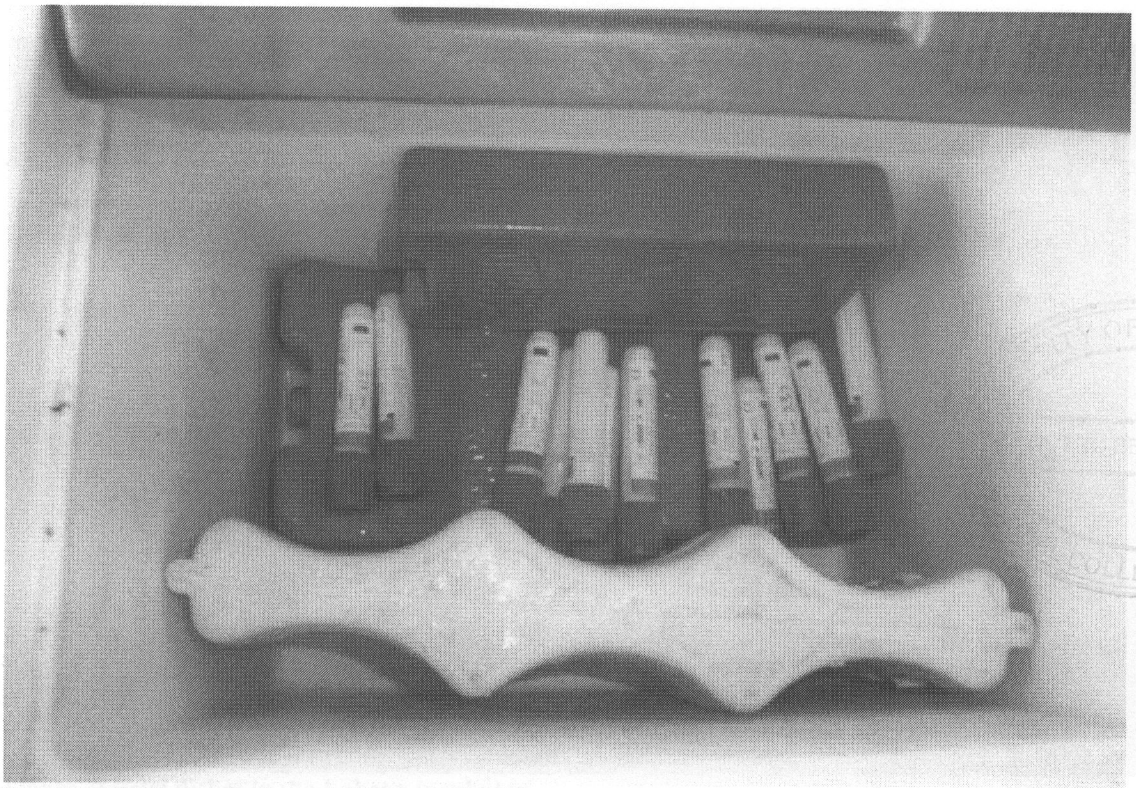

Figure 5: Milk samples in a chiller box with ice packs

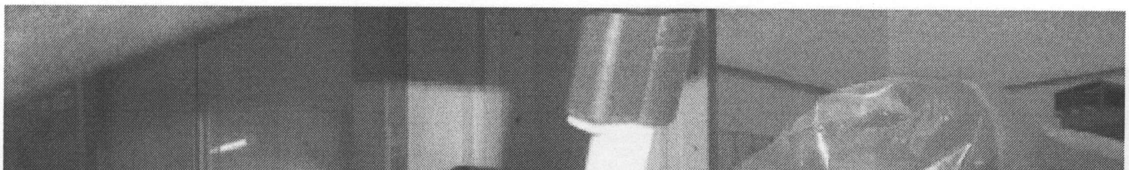

Figure 6: Dispensing Ringers solution

Figure 7: Petri dishes in the Labcon incubator

Figure 8: Pouring plate count agar on Petri dishes

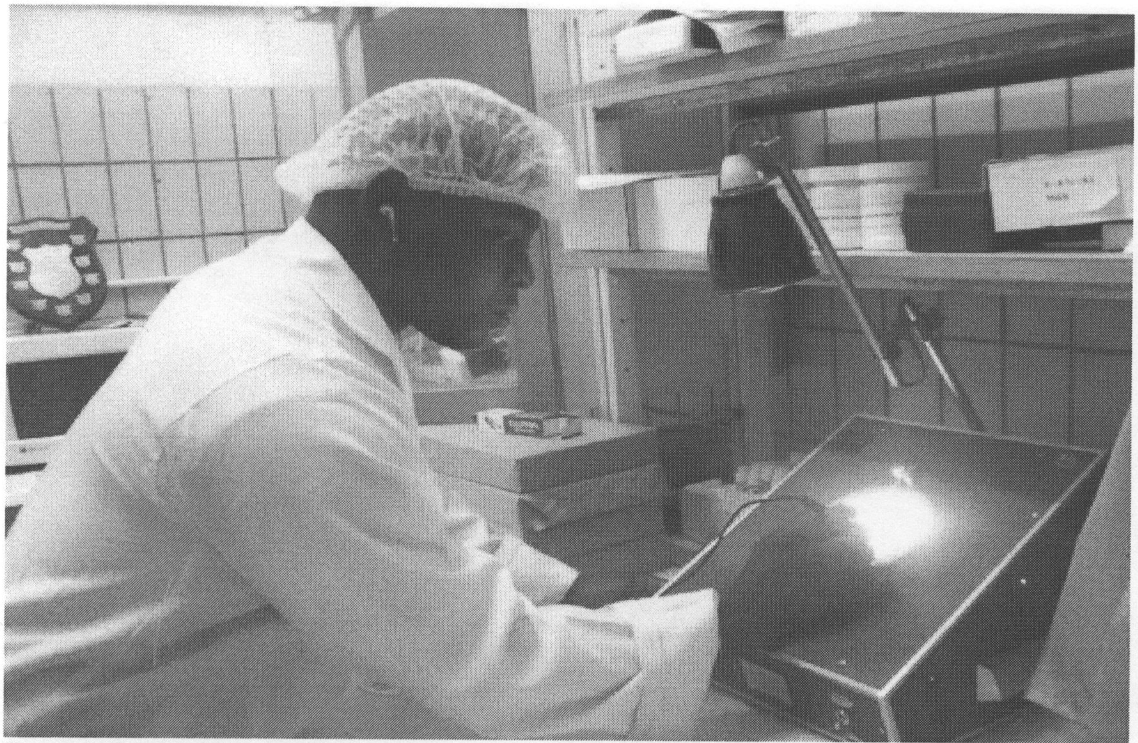

Figure 9: Enumerating bacteria

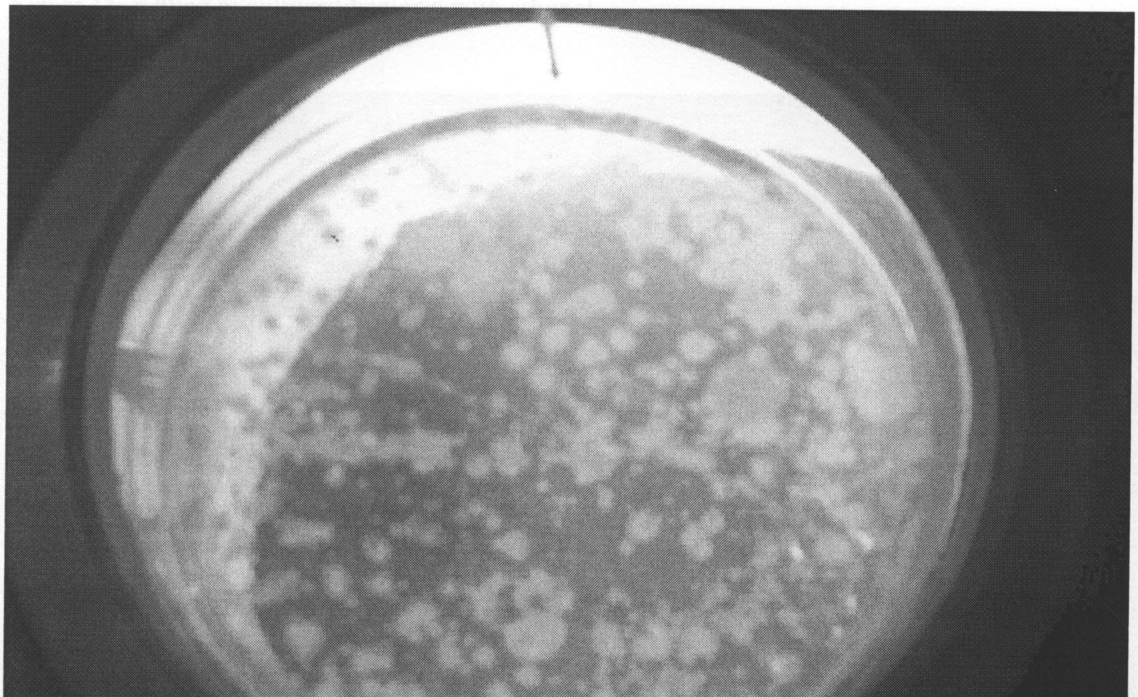

Figure 10: Bacteria colonies as seen on a counter


Figure 11: Killing of cultured bacteria with ethanol

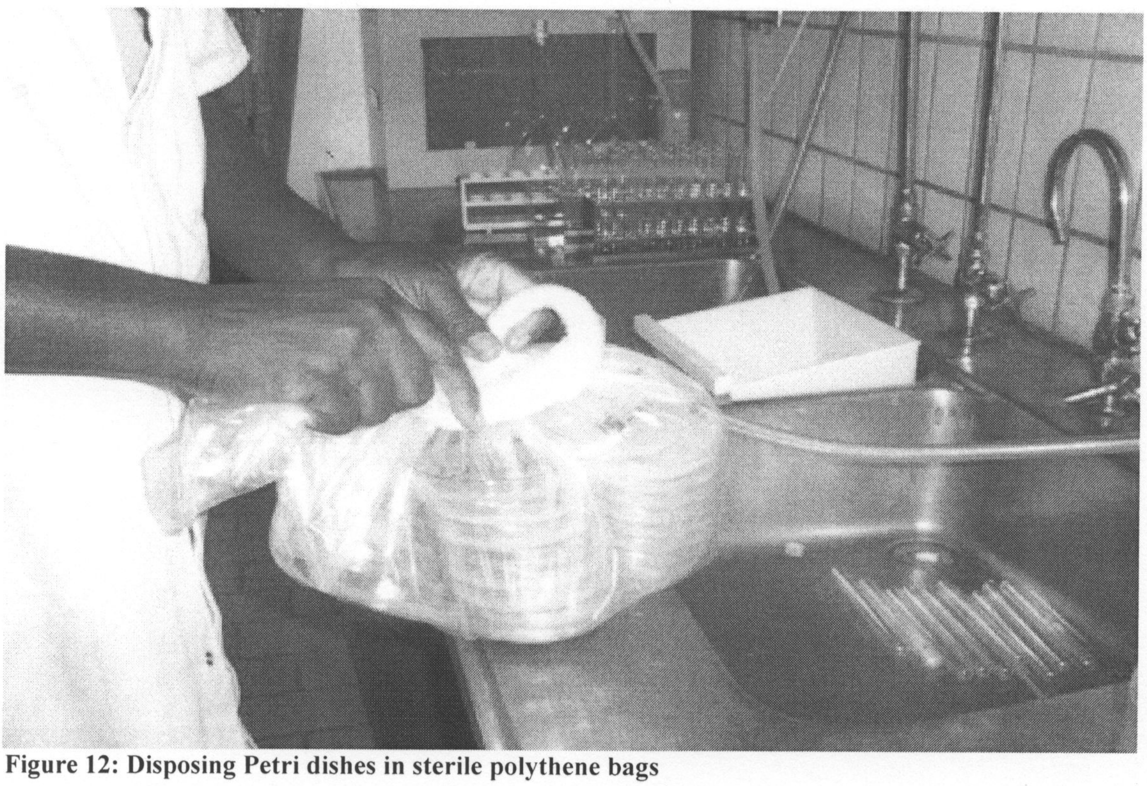
Figure 12: Disposing Petri dishes in sterile polythene bags

3.2.5 Estimation of income loss

The income from the milk per litre according to the milk grade of a farmer was then compared to the income that would be obtained if the farmers were producing Grade AA milk. The difference of these income levels were the estimated income losses that farmers were currently experiencing.

3.2 Statistical analysis of data

The data were pooled for each type of milking environment, and analyzed using SPSS version 16. The type of milking environment was the source of error. Analysis was done by computing means, frequencies and percentages. The paired Students T-test was used to compare means.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The milking environment and milk quality

4.1.1 Bulk milk quality

There was a strong negative correlation (r) of -0.587 ($p<0.05$) between the milking environment and bacterial contamination (Table 2). This means that improving the conditions of the milking environment tremendously reduces the level of bacteria in the milk, thus, improves milk quality provided the milk is cooled to 4^0C within 2 hours of milking (Gran et al., 2002). Sebastien et al. (2010) concluded that strict adherence to practices of dairy hygiene in the milking area as well as during storage is important in maintaining a low level of bacteria contamination, consequently, preserving of the original bacteriological quality of raw milk before treatment.

The mean bulk bacterial load was 113,021 cfu/ml representing Grade B milk. This conforms to the current production records of the Magoye Smallholder Dairy Cooperative (2010) which indicate that the cooperatives bulk milk grade has been Grade B since 2007. However, as shown in Table 2, individual farmer grading revealed that 41.67% and 31.25% of the sampled farmers produced Grade AA and A respectively. Twelve and half (12.5%) per cent of the farmers produced Grade B while 14.58% produced Grade C.

Table 2: Bacterial counts and grades of milk produced by smallholder farmers in Magoye

MEAN BULK TBC	BULK MILK GRADE		MILK GRADES				
			AA	**A**	**B**	**C**	**TNTC**
		Frequency	20	15	6	7	5
113,021 cfu/ml	B	Percentage	41.67 %	31.25 %	12.5 %	14.58 %	10.42%

TBC= Total Bacterial Count

Over 72% of the farmers produced milk containing less than 100,000 cfu/ml. Thus one would expect the bulk milk grade to be at least Grade A but this was not the case. This could be attributed to the fact that 71.47% of Grade C milk was regarded TNTC milk with more than 500,000 cfu/ml which contributed significantly to the reduction of the bulk milk grade produced by the smallholder farmers in Magoye. Therefore, the results indicate that the proportion of milk considered TNTC in Grade C milk and the bulk sample has a profound influence on the overall quality of raw milk in bulk samples.

4.1.2 Milking area structure and milk quality

Farmers milking their animals in a structure or housed parlours produced Grade A milk with average of 79,125 cfu/ml. Likewise, the farmers that milked their animals in the open or structureless environments produced Grade B milk containing 146,917 cfu/ml (Table 3). The paired T-test indicated a significant difference ($p<0.05$) in the quality of milk produced under housed and non housed conditions. These differences in the quality of milk would arise from differences in sanitary conditions in the milking areas between farmers with housed and those with non housed milking areas (Faye and Loiseau, 2002).

The coefficient of variation for milking areas with a structure was 1.19 while that for milking areas without a structure was 1.28. This shows that here is less variation in the bacterial counts in milk among farmers milking under housed conditions than those with milking areas that are not housed. Vissers (2007) reported that farmers are faced with changing environmental circumstances during the course of production, therefore, housing helps to control the environmental conditions as a result fluctuations in the bacterial counts among farmers with housed parlours. Most of the farmers milking in non housed conditions in Magoye milked their animal in kraals; thus the animals were usually dirty and covered with mud, hence, their milk was of low quality due to increased risk of physical contamination of the milk as ascertained in studies by Cempirkova (2007) and FAO (2000).

Figures 13 (a) and 13 (b), indicate that 25% of the farmers milking their animals in areas without a structure produced Grade C milk as compared to 4% of the farmers using housed milking areas when milking their animals. Milk produced under housed conditions had a higher proportion of Grades AA and A which in total accounted for 83% of the production unlike 66.67% for milk produced under structureless milking areas. Grades AA and A accounted for the largest share in both housed and non housed environments, though, there was a higher proportion of farmers with housed milking areas who had Grade AA milk (48%) compared to 37.5% of the farmers milking in areas that were not housed.

The proportion of Grade C milk among the farmers milking animals in structureless milking areas was a major factor that influenced the lower milk grade compared to farmers milking animals in housed areas. This is because 66.67% of Grade C milk produced by farmers milking animals in structureless areas as compared to 4.16% for those milking in housed milking areas was considered TNTC. The high proportion of Grades AA and A milk coupled with a low proportion of Grade C milk was a major contributor to the average Grade A milk produced by farmers using housed milking areas.

Table 3: Bacterial counts and grades of milk produced on different housing environments

	STRUCTURELESS	HOUSED
Mean TBC	146,917 cfu/ml	79,125 cfu/ml
Milk grade	B	A
Coefficient of Variation	1.28	1.19

TBC= Total Bacterial Count

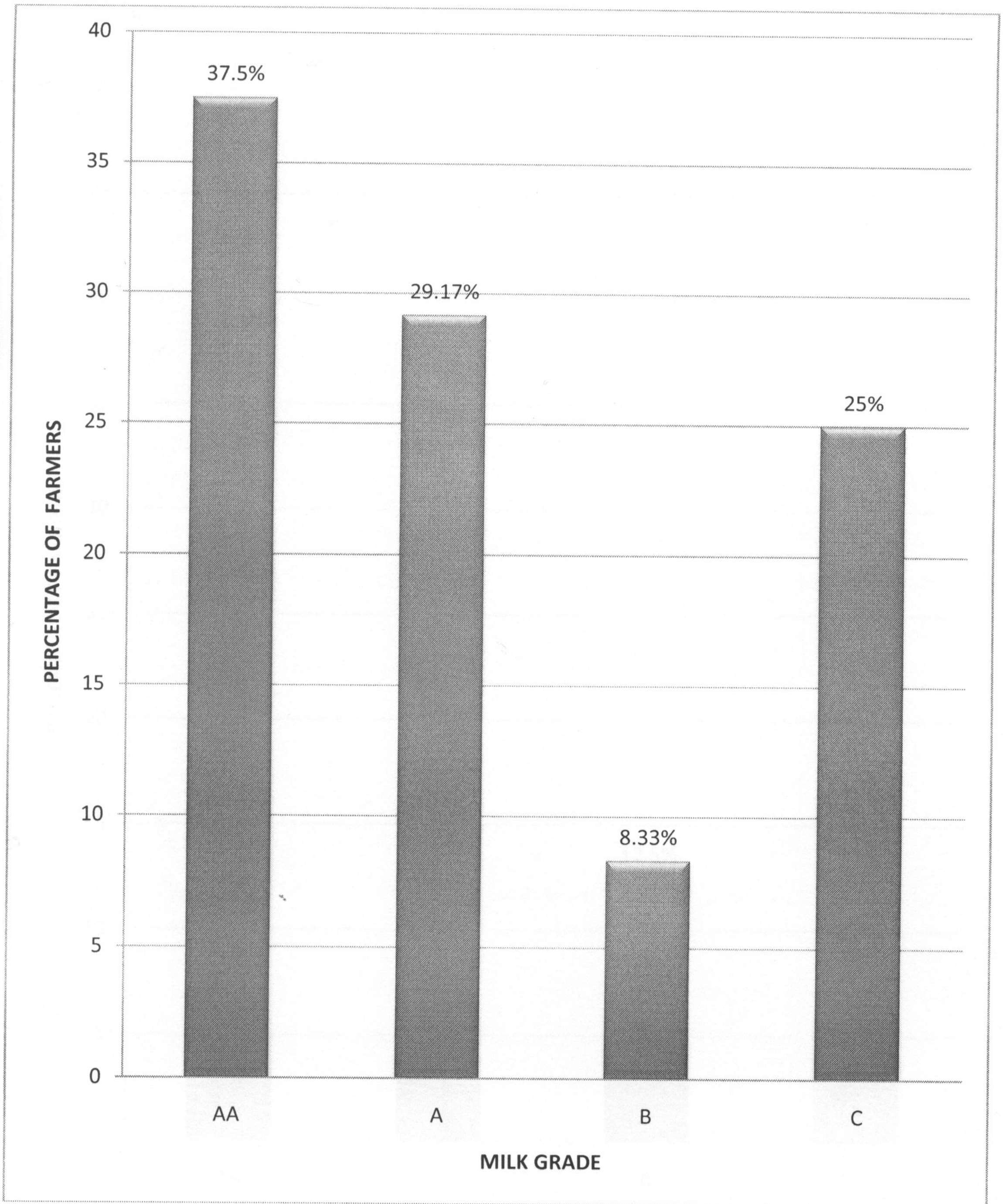

Figure 13 (a): Grades of milk produced under Structureless conditions

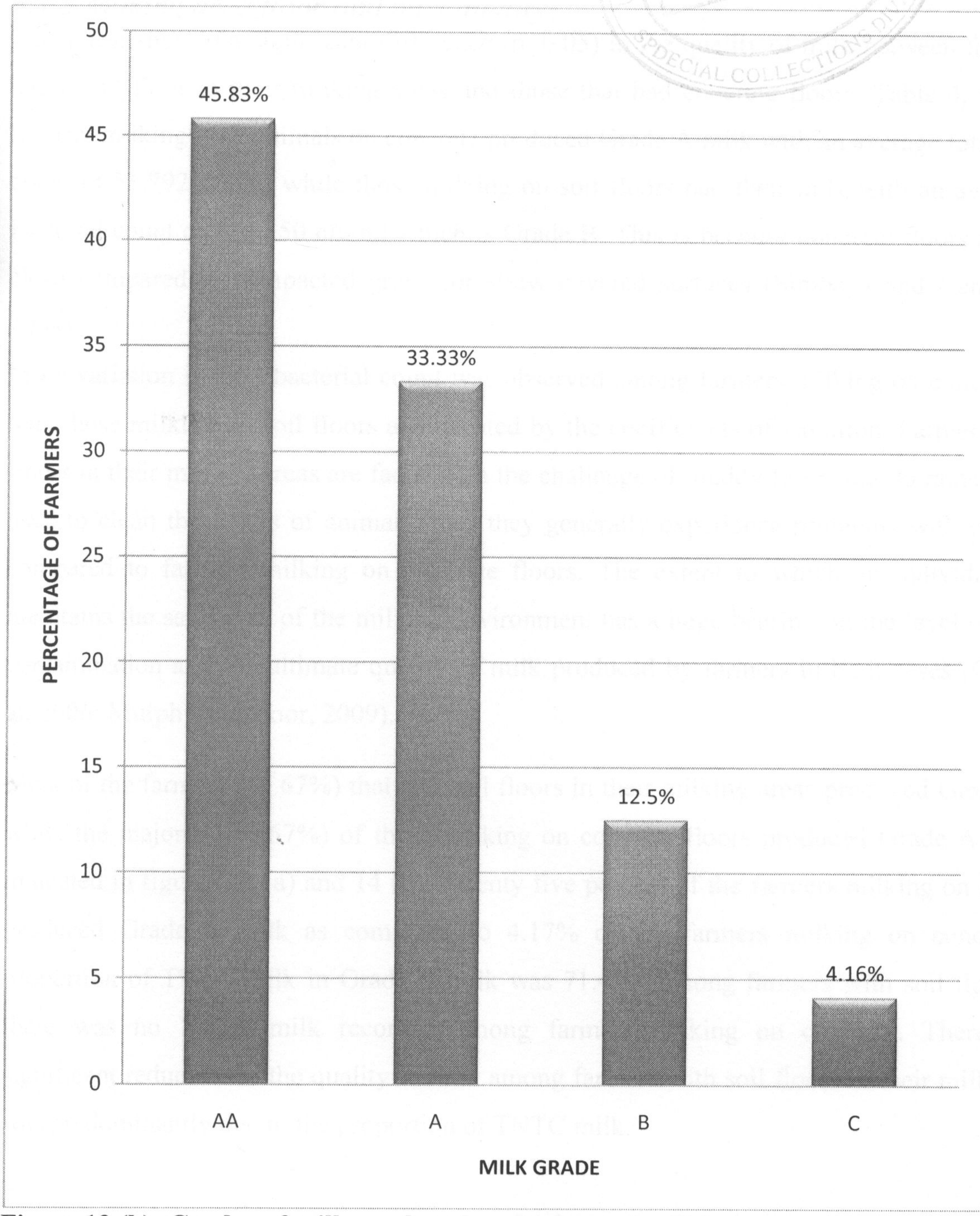

Figure 13 (b): Grades of milk produced under housed milking areas

4.1.3 Milking area floor and milk quality

The T-test showed a significant difference ($p<0.05$) in the quality of milk between farmers that had a soil floor in their milking areas and those that had concrete floors. Table 4, shows that farmers milking their animals on concrete produced Grade A milk with an average total bacterial count of 51,792 cfu/ml while those milking on soil floors had their milk with an average total bacterial count of 174,250 cfu/ml which is Grade B. This is because concrete floors are easy to clean compared to compacted gravel or straw covered surfaces (Simbaya and Yambayamba, 2008).

More variation in total bacterial count was observed among farmers milking on concrete floors than those milking on soil floors as indicated by the coefficients of variation. Farmers with soil floors in their milking areas are faced with the challenge of muddy floors due to rains and water used to clean the flanks of animals; thus they generally experience problems with cleaning as compared to farmers milking on concrete floors. The extent to which an individual farmer maintains the sanitation of the milking environment has a huge bearing on the level of bacterial contamination and the ultimate quality of milk produced by farmers in both cases (Gonzalo et al.,2006; Murphy and Boor, 2009).

Most of the farmers (41.67%) that had soil floors in their milking areas produced Grade A milk while the majority (66.67%) of those milking on concrete floors produced Grade AA milk as indicated in figures 14 (a) and 14 (b). Twenty five percent of the farmers milking on soil floors produced Grade C milk as compared to 4.17% of the farmers milking on concrete. The proportion of TNTC milk in Grade C milk was 71.43% among farmers with soil floors while there was no TNTC milk recorded among farmers milking on concrete. Therefore, the significant reduction in the quality of milk among farmers with soil floors in their milking areas was predominantly due to the proportion of TNTC milk.

Table 4: Bacterial counts and grades of milk produced on different floor types

	SOIL FLOOR	CONCRETE
Mean TBC	174250 cfu/ml	51,792 cfu/ml
Milk grade	B	A
Coefficient of Variation	1.03	1.12

TBC= Total Bacterial Count

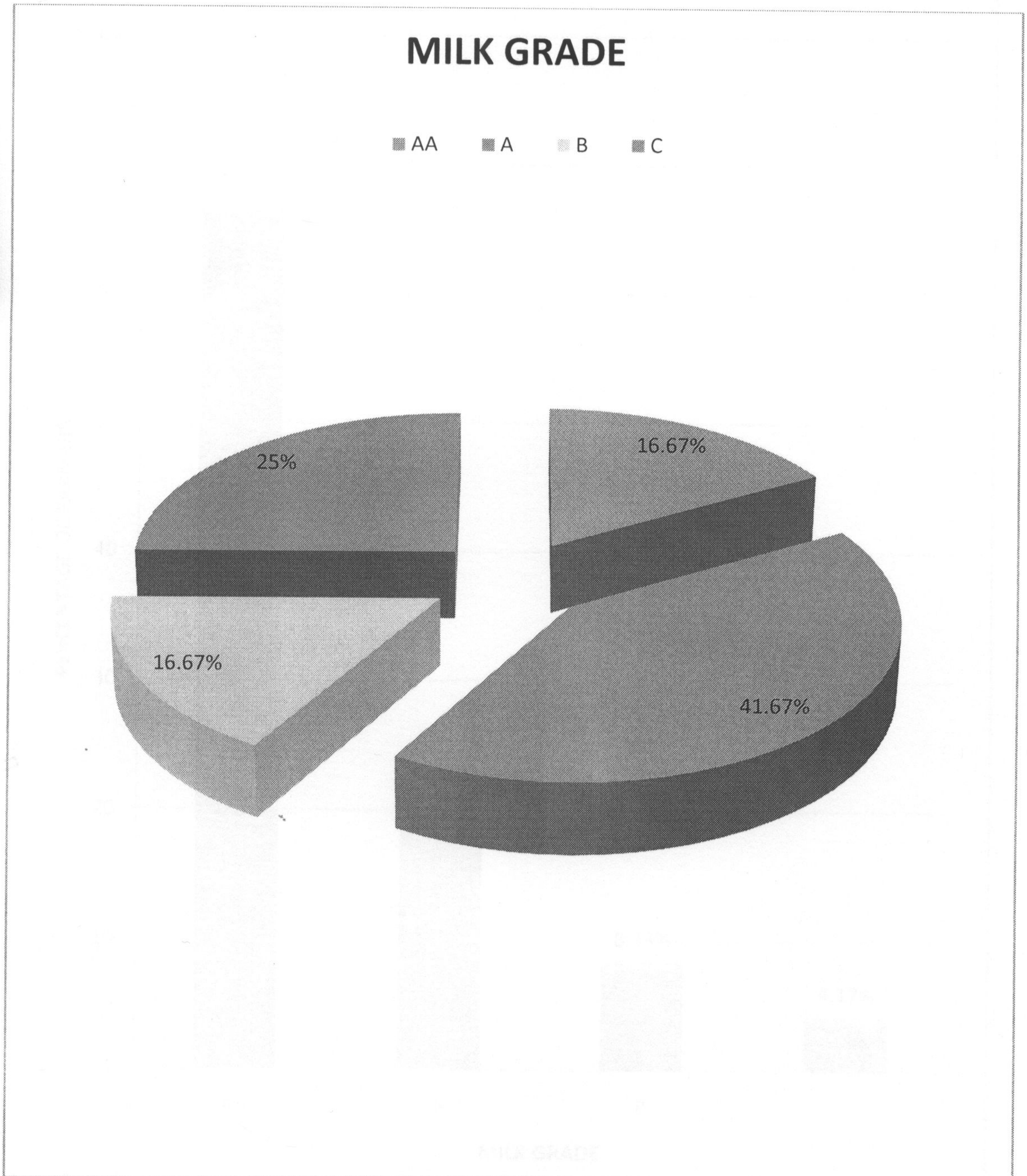

Figure 14 (a) Grades of milk produced on soil floors

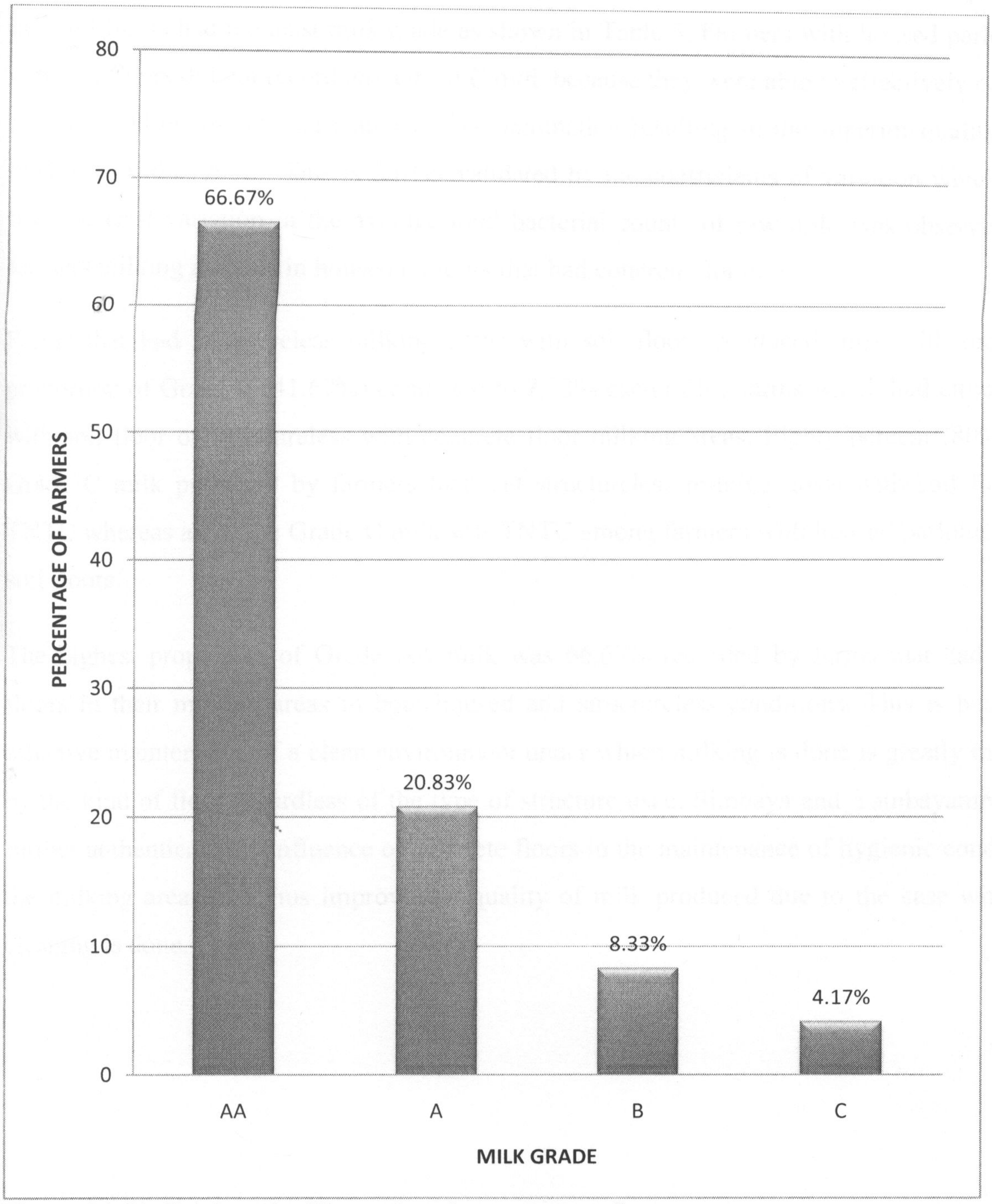

Figure 14 (b) Grades of milk produced on concrete floors

4.1.4 Comparison of different milking environments

The best quality milk (Grade AA) was produced by farmers milking their animals in housed parlours with concrete floors whereas farmers producing milk in structureless milking areas that had soil floors had the least milk grade as shown in Table 5. Farmers with housed parlours with concrete floors did not record any Grade C milk because they were able to effectively control the physical and environmental sources of contamination resulting in the superior quality of milk obtained (Sinha, 2000). This is further validated by the coefficients of variation which showed that the least variation in the average total bacterial counts of raw milk was observed among farmers milking animals in housed parlours that had concrete floors.

Farms that had structureless milking areas with soil floors produced milk with the highest proportion of Grade C (41.67%) compared to 8.33% each of the farms which had either housed with soil floor or structureless with concrete floor milking areas. Eighty percent (80%) of the Grade C milk produced by farmers that had structureless milking areas with soil floors was TNTC whereas all of the Grade C milk was TNTC among farmers with housed parlours that had soil floors.

The highest proportion of Grade AA milk was 66.67% recorded by farms that had concrete floors in their milking areas in both housed and structureless conditions. This is because the effective maintenance of a clean environment under which milking is done is greatly influenced by the kind of floor regardless of the type of structure used. Simbaya and Yambayamba (2008) further authenticate the influence of concrete floors in the maintenance of hygienic conditions in the milking areas and thus improve the quality of milk produced due to the ease with which cleaning is done.

Table 5: Bacterial counts and grades of milk produced under different milking environments

		HS	HC	NHS	NHC
Mean		113,917 cfu/ml	44,333 cfu/ml	234,583 cfu/ml	59,167 cfu/ml
Bulk Milk grade		B	AA	C	A
Coefficient of variation		1.15	0.85	0.88	1.25
	AA	25%	66.67%	8.33%	66.67%
% of milk	A	41.67%	25%	41.67%	16.67%
grades	B	25%	8.33%	8.33%	8.33%
	C	8.33%	0%	41.67%	8.33%

HC= Housed milking area with concrete floor
HS= Housed milking area with soil floor
NHC=Structureless milking area with concrete floor
NHS=Structureless milking area with soil floor

4.2 Income loss

Farmers producing Grades A and B lose K250 while those producing Grade C lose K450 per litre of milk as indicated in Table 6. It was observed that there was no price differential between Grades A and B milk. According to Pandey (2011) the lack of price differential was due to differences in the milk grading system used by processors when buying milk and the official standards as outlined in Regulation 154 of the Food and Drug Act 22 of 1972 of the Laws of Zambia (Table 1). In the standards that are used by most processors, milk with total bacterial count less than 50,000 cfu/ml is considered Grade A, Grade B is milk with total bacterial count between 50,001 cfu/ml and 200,000cfu/ml while milk with above 200,000 cfu/ml is regarded Grade C milk.

According to Table 2, farmers from Magoye Smallholder Dairy Cooperative produce Grade B milk, thus, lose K250 per litre of milk. The Cooperative's production records indicate that 912,500 litres of milk were sold to Parmalat in the year 2010 at 1.8 billion Kwacha (K

1,825,000,000). However, the total income lost by the cooperative amounted to K 228,125,000 which represents 12.5% loss in revenue solely due to the quality of milk produced by the farmers.

Forty one percent (41.67%) of the farmers in Magoye (Table 2) were paid K250 less per litre of milk produced based on the current grading system used whereas 14.58% of the farmers received K 200 per litre of milk. Only 12.5% of the farmers are paid for quality of milk they rightfully deliver. The farmers producing Grade A were paid less than what they deserve; however, the actual loss of income could not be computed using the method employed in the study considering that there was no price differential for this milk grade.

Only farmers producing milk using housed parlours with soil floors were paid the right price for the quality of milk delivered. Those milking in parlours that are housed and not housed with concrete floors are paid a lesser premium for their milk quality. The farmers in Magoye milking their animals in structureless and soil floored milking were paid K200 more per litre of milk for producing low grade milk (Grade C). However, the proportion of these farmers among the members of the cooperative is not known as the cooperative does not keep records of the type of milking area and conditions under which the members milk their animals.

Table 6: Price of raw milk for different milk grades

Milk Grade	**AA**	**A**	**B**	**C**
Price per litre	K2,250	K2,000	K2,000	K1,800
Income lost per litre	K0	K250	K250	K450

Source: Pandey G, Golden Valley Agricultural Research Trust, 2011.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study findings revealed significant differences in the level of bacterial contamination of raw milk produced under different milking environments among smallholder farmers in Magoye. The average total bacterial count for the different milking areas was 44,333 cfu/ml for housed with concrete floor, 113,917 cfu/ml for housed parlours with soil floors, 234,583 cfu/ml for structureless with soil floors and 59,167 cfu/ml for structureless milking areas with concrete floors. The difference in the quality of milk in the different milking environments was mainly due to the ability of the farmers to control the various sources of contamination and ensuring sanitary conditions in the milking areas.

Two hundred and fifty kwacha (K250) per litre of milk was lost by farmers producing Grades A and B milk whereas those producing Grade C milk lost K450 per litre of milk. It was noted that farmers were not aware of the extent of lost income they experience due to the quality of their milk produced.

5.2 Recommendations

In view of the results obtained and the observations made during the study, the following have been recommended:

- Further studies with a larger sample size should be done to investigate the level of bacterial contamination of raw milk produced under varying smallholder dairy set ups in different parts of the country. This would enable to generalize the results for all the Dairy Cooperatives in Zambia as results obtained in this study are only specific to the Magoye Smallholder Dairy Cooperative.
- The cooperative should keep records of the kind of environment and conditions under which the members are milking their animals. This would assist in quality control and assurance of the milk produced. In addition, it would make it easier to conduct extension

programmes in the quest to improving the quality of the milk produced by the farmers as well as improving income obtained from the milk produced.

- Farmers should be encouraged to construct milking parlours as housing significantly improves quality of milk by reducing the level of bacterial contamination. Furthermore, farmers should at least have concrete floors in their milking areas as this would not only improve the quality of milk produced but also make it easier for them to clean their milking areas in the different weather conditions.
- The cooperative should sensitize the farmers on the income losses they experience due to the quality of milk produced.
- Milk price standards should be harmonized as this will help improve the quality of milk produced when farmers receive milk premiums according to the quality of milk produced.
- The cooperative should introduce milk quality bonus premiums to the farmers that produce high grade milk as this will compel most farmers to produce good quality milk thus improve the bulk milk quality as well as minimise income losses.

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APPENDIX ONE

Oral interview questions

1. Name of farmer: ....
2. Area: ....
3. Production system used
   (a) Small scale ☐
   (b) Commercial ☐
4. What milking method do you use
   (a) Hand milking ☐
   (b) Machine milking ☐
   (c) Both ☐
5. Where do you milk your animals from
   (a) Enclosed milking parlour ☐
   (b) Open area ☐
6. If an enclosed parlour is used what kind of enclosure is it?
7. What king of floor does your milking area have
   (a) Cement concrete floor ☐
   (b) Compact soil/gravel floor ☐
8. Do you clean your animals before milking?
   (a) Always ☐
   (b) Sometimes ☐
   (c) Never ☐
9. How do you handle you milk from milking to the collection centre?

APPENDIX TWO

Correlation of milking area and average bacterial load

		milking area	average bacteria
milking area	Pearson Correlation	1	-.587*
	Sig. (2-tailed)		.017
	N	16	16
average bacteria	Pearson Correlation	-.587*	1
	Sig. (2-tailed)	.017	
	N	16	16

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX THREE

Paired T-test for means of soil and concrete floors

	SOIL	*CONCRETE*
Mean	174250	51791.66667
Variance	32193326087	3336780797
Observations	24	24
Pearson Correlation	-0.145873676	
df	23	
t Stat	3.055341392	
P(T<=t) one-tail	0.002804912	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.005609823	
t Critical two-tail	2.068657599	

APPENDIX FOUR

Paired T-test for means of housed and structureless milking areas

	HOUSED	*NOT HOUSED*
Mean	79125	146916.6667
Variance	10182201087	30774166667
Observations	24	24
Pearson Correlation	-0.081310848	
df	23	
t Stat	-1.586248485	
P(T<=t) one-tail	0.063168524	
t Critical one-tail	1.713871517	
P(T<=t) two-tail	0.126337047	
t Critical two-tail	2.068657599	