MICROBIOLOGICAL QUALITY OF GOAT MILK OBTAINED UNDER DIFFERENT PRODUCTION SYSTEMS

by

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to

My husband, John

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SUMMARY

MICROBIOLOGICAL QUALITY OF GOAT MILK OBTAINED UNDER DIFFERENT PRODUCTION SYSTEMS

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Reliability of quality of milk produced by smallholder farmers was assessed by means of a comparative analysis of the microbiological quality and somatic cell counts (SCC) of the raw milk obtained from dairy goats.

Information regarding dairy goat farming and goat milk production in and around Pretoria was initially determined by means of a questionnaire. With this information, dairy goat herds were selected for the study, based on the fact that these farms produced milk for both domestic and commercial consumption. The study was conducted on three commercial dairy goat farms each under a different production system, the extensive, semi-intensive and intensive production systems. The method of milking varied with the type of production system; hand milking, bucket system and pipeline milking respectively.

Udder health under the respective production systems was assessed by means of bacterial analysis of udder half milk samples. Bacteriology of bulk milk samples was also determined in order to assess the level of hygiene in the milking environment. In addition, water samples from the different farms were analysed for their microbial quality.

Results of these parameters were compared between the different production systems using the analysis of variance. Capability of safe raw milk production by smallholder dairy goat farmers was then evaluated from the results obtained.

Reliability of the SCC as a reflection of goat udder health was also evaluated. Further assessment was carried out to determine the relationship between udder conformation and presence of intra-mammary infection and SCC of the raw milk.

Bacteria potentially capable of producing either food poisoning or enhanced spoilage of raw milk were cultured from the goat milk samples. These included pathogens such as *Staphylococcus aureus, Bacillus cereus* and *Enterococcus faecalis,* found associated with use of milking machines as was the case in the intensive and semi-intensive production systems compared to the extensive production system.

The prevalence of intramammary infection was 33.3%. Coagulase negative staphylococci were the most common cause of intramammary infection with a prevalence of 86.6% of the infected udder halves. They included *Staphylococcus epidermidis, Staphylococcus simulans* and *Staphylococcus intermedius.* The remaining 13.4% of the infection was due to *Staphylococcus aureus.* Somatic Cell Counts were not a reflection of udder health status, hence, not reliable in the prediction of goat udder health ($p = 0.2$ Fisher's exact test of association). No significant relationship was proved to exist between the udder conformation and presence of intra-mammary infection or SCC of the milk produced.

Raw milk obtained by the bucket system milking machine had the lowest total bacterial count (TBC) (16 450 Colony Forming Units per millilitre [CFU/m*l*]) as compared to that by pipeline milking machine (36 300 CFU/m*l*) or hand milking (48 000 CFU/m*l*).

In comparison to the other two production systems, it was shown that dairy goat farming under the extensive production system, where hand milking was practised, was adequate for production of safe raw goat milk. Coliforms were found to be the most predominantly isolated organisms from the raw milk obtained under the extensive production system. However, these can be eliminated by pasteurisation of the milk.

The extensive production system, therefore, could be a means to promote dairy farming in developing communities through smallholder farmers. This could be facilitated by extension services aimed at monitoring management on the farms. This would, consequently, help alleviate the problem of food security and low income in these communities.

SAMEVATTING

DIE MIKROBIOLOGIESE KWALITEIT VAN BOKMELK VERKRY ONDER VERSKILLENDE PRODUKSIESISTEME

deur

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Die betroubaarheid van melkproduksie deur boere, wat op klein skaal boer, is bepaal deur middel van ‘n ontleding van die mikrobiologiese kwaliteit en somatiese seltellings (SST) van die melk wat van melkbokke verkry is.

Die inligting aangaande melkbokboerdery en bokmelkproduksie in en om Pretoria is bepaal deur middel van ‘n vraelys. Met hierdie inligting is melkbokkuddes vir die studie geselekteer, gebaseer op die feit dat hierdie boere melk vir beide huis- en kommersiële verbruik geproduseer het. Die studie is op drie kommersiële melkbokplase uitgevoer, elk met ‘n verskillende produksiesisteem - ekstensief, semi-intensief en intensief. Die melkwinningsmetode het gewissel na gelang van die produksiesisteem wat gevolg is – handmelking, emmer- en pyplynsisteem respektiewelik.

Die uiergesondheid met die verskillende produksiesisteme is bepaal met behulp van ‘n bakteriese ontleding van uier halfmelkmonsters. Die bakteriologie van massamelkmonsters is ook bepaal om die vlak van higiëne in die melkomgewing vas te stel.

Die resultate van hierdie parameters is met gebruikmaking van analise van variansie tussen die verskillende produksiesisteme vergelyk. Die vermoë van die melkboere om veilige melk te produseer is met behulp van hierdie resultate geëvalueer. Die betroubaarheid van die SST

as ‘n maatstaf van bokuiergesondheid is ook geëvalueer.
‘n Verdere studie is uitgevoer om die verwantskap tussen uierkonformasie en die teenwoordigheid van binne-uierse infeksie en SST van die melk te bepaal.

Bakterieë wat die potensiaal het om voedselvergiftiging of gevorderde bederf van roumelk te veroorsaak is uit die bokmelkmonsters gekweek. Hierdie het patogene soos *Staphylococcus aureus*, *Bacillus cereus* en *Enterococcus faecalis* ingesluit, geassosieer met die gebruik van melkmasjiene, soos in die geval van die intensiewe en semi-intensiewe produksiesisteme, in vergelyking met die ekstensiewe produksiesisteem.

Die voorkoms van binne-uierse infeksie was 33.3%. Koagulase negatiewe stafilokokke was die mees algemene oorsaak van binne-uierse infeksie met ‘n voorkoms van 86.6% in besmette uierhelftes. Dit het *Staphylococcus epidermidis, Staphylococcus simulans* en *Staphylococcus intermedius* ingesluit. Die oorblywende 13.4% van infeksie was weens *Staphylococcus aureus*. Daar is gevind dat die somatiese seltellings nie as maatstaf vir uiergesondheid gebruik kon word nie en derhalwe was dit nie betroubaar in die voorspelling van bokuiergesondheid nie ($p = 0.2$ Fisher se eksakte toets van assosiasie). Dit is bewys dat daar geen noemenswaardige verband tussen uierkonformasie en die voorkoms van binne-uierse infeksie en SST van die melk wat geproduseer is, was nie.

Melk wat met die emmersisteem gewin is, het die laagste standaard plaattelling (16 450 Kolonievormende-eenhede per milliliter [KVE/m*l*] in vergelyking met die pyplynstelsel (36 300 KVE/m*l*) of handmelking (48 000 KVE/m*l*) gehad. Dit is gevind dat kolivorme bakterieë die mees algemeen geïsoleerde organismes was in melk wat onder die ekstensiewe produksiesisteem waar handmelking gebruik is, verkry is. Hulle kan egter met behulp van pasteurisasie vernietig word.

In vergelyking met die ander twee produksiesisteme is dit aangetoon dat bokboerdery onder ‘n ekstensiewe produksiesisteem voldoende is om veilige bokmelk te produseer. Op hierdie manier kan melkboerdery in ontwikkelende gemeenskappe aangemoedig word. Dit kan aangehelp word deur ‘n voorligtingsdiens wat gemik is op die monitering van bestuur op plase. Dit sal uiteindelik help om die probleem van voedselvoorsiening in hierdie gemeenskappe.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

BACKGROUND

The dairy goat industry is rapidly gaining in importance throughout the world (Boscos *et al.*, 1996). Between 1965 and 1994 the world goat population was estimated to have increased from 373 million to 609 million head, an average increase of eight million head per year (Nu Nu San & De Boer 1996). Goats rank third in terms of global milk production from different animal species after cattle and buffaloes (Klinger & Rosenthal 1997). Goat milk and its products are popular among health conscious consumers and certain ethnic groups (Park 1991). Many people with allergies, including children, are more able to tolerate goat milk than that of cows (Wilson *et al*., 1995).

Goats are reported to play a special role in the life of smallholder farmers. Their small size makes it possible for farmers to keep a large herd in a small area (Boylan *et al.*, 1996). They are known to thrive in virtually any climatic zone and in every imaginable production system (Smith & Sherman 1994). They have also been found to be biologically and economically efficient (Devendra 1982). As a result of their great contribution to the health and nutrition of the landless and rural poor, they have been referred to as the "poor man's cow" (Dresch 1988).

Currently there are approximately 42 registered commercial dairy goat farmers in South Africa, 19 of whom are from the Gauteng Province (ANPI-ARC, 1999). Looking into the future, there will be a need for increased investment in dairy goat schemes to support and expand household milk supply and small-scale dairy enterprises at the village level. This is justified for socio-economic and nutritional reasons, and is complementary to large-scale dairy operations, which supply milk mainly to urban areas. This need was stated by Donkin (1992), whose goal it was to investigate, develop and promote the use of dairy goats as a source of milk for households and smallholder farmers in southern Africa. This would contribute towards providing high quality protein for the children of southern Africa; particularly those who do not have ready access to products from the established dairy (cow) industry.

There is, however, a need to ascertain whether the small-scale dairy enterprises, composed of smallholder farmers, can compete favourably in the production of safe goat milk.

In addition, to ensure continued growth in output of goat milk in an environmentally sustainable manner, a strong research and extension system is essential (Nu Nu San & De Boer 1996). This is particularly so for goats because most production is carried out by diverse groups of smallholders under a wide range of production systems.

Production systems research and extension is one approach that has evolved to address this need. It was, therefore, decided to conduct a farm based research study to assess the microbiological quality of milk harvested under the prevalent dairy goat production systems.

The hypothesis of the study was:

Production systems of smallholder dairy goat farmers are adequate for safe milk production.

The objectives of the study, were to:

1. Establish the safety of goat milk produced under the different production systems with respect to the prevalence of specific pathogens in the milk, viz.: staphylococci; streptococci and *Escherichia coli*.

2. Determine the relationship between somatic cell counts (SCC) and the presence of udder infection in the prediction of udder health under the different production systems.

3 Evaluate procedures employed to ensure hygienic milk harvesting under the different production systems.

1.1 MICROBIOLOGICAL QUALITY OF GOAT MILK

Jaubert & Kalantzopoulos (1996), stated that the quality of goat milk may be considered as its potential to undergo further processing and result in a product which lived up to the consumers' expectations in terms of health (nutritional value), safety (hygienic quality) and satisfaction (sensory attributes). Public Health Authorities responsible for milk supplies in South Africa have had to focus their efforts on safety of milk (Giesecke *et al*., 1994).

Difficulties in managing the safety of milk derive from the various sources of contamination. Undesirable organisms may get into milk either through the body (endogenously) or from some external source (exogenously) after milk has been drawn (Lowenstein & Speck 1983). It has become increasingly clear, internationally, that disease in dairy animals and the production and handling of milk under poor hygienic conditions, can lead to widespread outbreaks of human disease (Giesecke *et al*., 1994).

Some of the diseases that can be transmitted to humans from milk include salmonellosis, tuberculosis, brucellosis, listeriosis, Q fever, toxoplasmosis, streptococcal infections, staphylococcal infections and Campylobacter infections (Devendra & Burns 1983; Mowlem 1988). Appropriate epidemiological statistics on milk-borne diseases in South Africa are not readily available (Giesecke *et al*., 1994). An efficient surveillance system for the regular monitoring and further epidemiological investigation of such diseases is, therefore, necessary. It has, however, been, reported that goat milk contains significantly lower bacterial counts than cow or buffalo milk, and that a variety of microbial organisms can be present in goat milk without being pathogenic to humans (Haenlein 1992). This can be explained by the pathogenicity of bacteria not only being dependent on the type of organism, but also on the quantity of those organisms present in any vehicle.

1.1.1 Udder Health

The most prevalent mastitis agents in goats have been found to include *Streptococcus agalactiae, Streptococcus pyogenes, Streptococcus dysgalactiae, Streptococcus zooepidemicus, Staphylococcus aureus, Staphylococcus epidermidis, Staphylococcus pyogenes, Yersinia pseudo-tuberculosis, Enterobacter cloacae, Pseudomonas aeruginosa, Clostridium perfringens* type C, *Corynebacterium ovis, Bacillus cereus, Klebsiella pneumoniae* and *Mycoplasma putrifaciens* (Ryan & Greenwood 1990; Dunn 1994).

Non-haemolytic staphylococcus species that originate from the skin of the teat, the streak canal or milkers' hands have also been isolated from goat milk (Ryan & Greenwood 1990). While some may consider non-haemolytic staphylococcus intramammary infections co-incidental in goats, others contend that these infections may become chronic and lead to sore udders, elevated SCC and decreased milk production (White & Hinckley 1999).

Maisi & Riipinen (1991) reported that nearly all the staphylococci that have been isolated from drawn milk in subclinical cases of mastitis. *S. aureus* has been reported to be the most pathogenic staphylococcal infection both in its subclinical and clinical form in the caprine udder. *S. aureus* is a Gram-positive coccus that is non-spore forming and facultatively anaerobic, which grows rapidly in raw milk. It can cause food poisoning by the production of enterotoxins. The optimum temperature for the production of enterotoxins is 35 - 40°C. There are five serologically distinct enterotoxins recognised (A - E), with enterotoxin A most frequently involved in food poisoning outbreaks. Presence of other bacteria often affects production of enterotoxin by *S. aureus*, apparently by limiting the multiplication of the staphylococci. *S. aureus* itself is destroyed by pasteurisation and cooking, but enterotoxin A is destroyed only partially at 100ºC for 30 minutes and can survive short or light cooking.

As little as 1.0 µg of enterotoxin A can be sufficient to produce food poisoning. As staphylococcal food poisoning is an intoxication, the onset is rapid and the incubation period can be as short as two hours, but is usually four - six hours. The enterotoxin may be regarded as a neurotoxin, as vomiting is initiated by its action on the emetic centre. The signs include severe vomiting that can mimic seasickness. There can be abdominal pain and diarrhoea, sometimes followed by dehydration and collapse. Recovery is rapid, usually within 24 hours. Bramley & McKinnon (1990) are of the opinion that udder disease remains widespread and so consumers of raw milk still risk food poisoning.

1.1.2 Somatic Cell Counts

Somatic cell counts have been accepted as a quantitative index for mastitic conditions in cow milk or for a degree of glandular irritation in bovine mammary glands (Park & Humphrey 1986). When the udder is injured or becomes infected, significant numbers of white blood cells are recovered from the milk. The SCC of an infected quarter can reach millions of cells per millilitre of milk (Poutrel & Rainard 1982).

Somatic cells are body cells of tissue or blood origin that are passed into milk through the mammary system (Ryan *et al.*, 1996). The somatic cells found in milk are:

- epithelial cells from the lining of the udder which have been discarded into the milk;
- macrophages which scavenge dead cells and abnormal milk components;
- neutrophils which are important for fighting infection; and

- lymphocytes that assist in immunity.

Increase in SCC has been reported to correspond to increase in the lactation stage and lactation number of does in milk (Wilson *et al*., 1995). According to Kapture (1980), it is also common to find high SCC in goat milk when actual leucocytic counts are low. As opposed to the situation in cows, many authors have stated that the total SCC does not correlate with leucocyte counts in goat milk (White and Hinckley, 1999, Dulin *et al*., 1982). This has been attributed to the difference in the milk secretory systems of the two species**:** cow (merocrine) and that of the goat (apocrine).

In the apocrine secretory process, milk secretory products become concentrated at the free end of the secreting cell and are dispersed from the cell surface along with a portion of the cell and its accompanying cytoplasm into the milk (Kapture 1980). The resulting cytoplasmic particles are similar in size to milk leucocytes ranging from 5 – 30 nm. They contain protein, lipid and casein micelles, but lack nuclei and hence do not contain deoxyribonucleic acid (DNA). These particles are not cells, but are a product of the normal milk secretory process of the goat (Park & Humphrey 1986). Their presence in milk, therefore, masks and makes difficult the interpretation of the leucocytic response to mammary infection (Zeng *et al*., 1999).

Methods specific for DNA detection have been shown to give significantly lower results than Coulter electronic cell counts or direct microscopic SCC using a non-specific stain (Dulin *et al*., 1982). Only counting methods specific for DNA should be employed for estimating SCC in goat milk (Park & Humphrey 1986). Among these methods is the use of the Fossomatic machine. The Fossomatic machine has been used to determine the SCC for a large number of goat milk samples on a daily basis (Zeng *et al*., 1999).

The biggest disadvantage of the Fossomatic machine, however, is its inability to distinguish leucocytes from epithelial cells that also contain DNA (Park & Humphrey 1986). Consequently, different authors (Kapture 1980; Poultrel & Lerondelle 1983), have suggested that since the SCC alone does not reveal mastitis in goat milk, it is necessary to compare or correlate it with the number of bacterial cells present, such as total bacterial counts (TBC),

staphylococcal counts (STC), or coliform counts (CC). The number of pathogenic organisms in milk can then be the quantitative index of inflammation of the mammary gland.

1.1.3 Teat and Udder Conformation

As is the case in cows, goats have udders suspended in a natural udder shelter. Giesecke *et al*., 1994 describe this natural udder shelter as the area bordered by the abdominal wall and the median aspect of the two tarsal joints. It stretches up to the umbilicus and vertically up to where the two hind legs join. The shelter is raised off the ground level by the legs. With the protection afforded by the udder shelter against adverse environmental conditions, risk of the udder to lesions, infections and mastitis is reduced (Giesecke *et al*., 1994).

From the point of view of udder health and milking, one should realise that the more the dimensions of the udder and its teats exceed the dimensions of the natural udder shelter, the greater the exposure to harmful environmental conditions. Depending on its development during maturation, the udder may remain within the functional boundaries of the udder shelter or it may outgrow it (Giesecke *et al*., 1994).

Suspension of the udder is another important factor, which determines the position of the teats above the ground. In cases where the position of the teats is so low that they almost touch the ground, it becomes impossible to carry out hygienic milking (Giesecke *et al*., 1994). This is because a teat cup cluster cannot be attached to the teats without parts of it touching the ground.

Similar to the udder, the characteristics of the teat (shape, size) and teat end (orifice) are also important from the point of view of udder health and control of mastitis (Giesecke *et al*., 1994). The University of Vermont Teat End (orifice) Evaluation System evaluates teat end condition by the following scores (1 - 5) (Goldberg *et al*., 1994):

SCORE	TEAT CONDITION
1.	Teat end sphincter is smooth with no evidence of irritation.
2.	Teat end has a raised ring.
3.	Teat end sphincter is roughened with slight cracks, but no redness is present.
4.	Teat end sphincter is inverted with severe radial cracking, giving a flowered appearance.

5. Teat end is severely damaged and ulcerative with scabs or open lesions. Large or numerous warts present that interfere with teat end function.

1.1.4 Milk Hygiene

Milk within a healthy udder contains no bacteria (Sandholm *et al*., 1995a). Contamination takes place during milking, when various bacteria enter the milk from the teat canal, milking equipment and environment (Sandholm *et al*., 1995a). There are activities during milk harvesting, which have a marked influence on the microbiological quality of milk (Giesecke *et al*., 1994). These include:

- Fore-milking, if it is inadequate will fail to eliminate bacterial content of the teat canal (especially its opening), and result in contamination of the milk.
- Drying of the skin of the udder during udder preparation, if it is incomplete may be a source of contamination.
- Milk surging or flooding of the teat liners during milking will wash contaminants off the teat surface into the milk.
- Milk contact with milkers' hands and surfaces of the milking equipment during its passage through the milking system (teat liners, pipelines, buckets, etc.).

Zeng & Escobar (1996) reported a significant difference in the bacterial counts determined in milk obtained by different milking methods. Milk from does milked by hand showed the highest TBC at various stages of lactation, while milk from does milked by the bucket system milking machine had the lowest throughout lactation.

Hand milking

Mowlem (1988), described hand milking in goats. Goats can be hand milked anywhere, but in the interests of good hygiene, should always be milked well away from any bedding, hay or dusty straw. Setting aside a clean area where goats can be tethered and milked is all that is required. In hand milking, the base of the teat is compressed between the forefinger and the thumb thus trapping the milk in the teat cistern. The milk is then expelled from the cistern by applying positive pressure with the remaining fingers in sequence, thus forcing the milk out of the teat.

This system is refined a little by having the goats on a simple raised stand, with something to hold the milking bucket in place. It is quite convenient to use a wooden standing platform

into which a hole can be cut to hold the bucket (which is preferably stainless steel). The wood may be covered with polythene for ease of cleaning as it can be hosed down (Hetherington & Matthews 1994).

While it is not essential to give the goats their ration of concentrate feed during milking, it encourages them to stand still. Feeding during milking is known to induce defaecation. However, unlike cows, goats cause minimal environmental contamination as their faeces are consistently in pellet form when passed (Mowlem 1988). To be able to feed the goats, some form of bucket or feed hopper system will be required and this can be attached to a simple yoke system that will hold the goats in position while they are being milked (Mowlem 1988).

Cleanliness of the udder, milking facilities, milking utensils, milkers clothing and hands cannot be emphasised enough in the harvesting of quality milk (Giesecke *et al*., 1994).

Machine milking

Hand milking depends on creating a pressure inside the teat greater than the atmospheric pressure outside, causing the milk to eject. The milking machine works on the principle of causing milk to flow by reducing the pressure outside the teat to about half atmospheric pressure. Milking is achieved by means of the cluster and the pulsator mechanism. The milking cluster is the unit attached to the udder and consists of 2 teat cups, cup liners, a claw piece, a pulsator tube and a milk tube. The pulsator mechanism supplies atmospheric air and vacuum alternatively to the cavity between the rubber liner and metal teat cup, thus causing the liner to collapse and open at regular intervals. This is responsible for maintaining blood circulation around the teat, providing the necessary relief for the teats. During milking vacuum is constantly applied to the base of the teat. The rest phase is when atmospheric air enters the pulsation chamber, forcing the liner to collapse around the teat, stopping milk flow and allowing blood to circulate around the teat. When the atmospheric air pressure is replaced with vacuum, the liner opens under its own elasticity in the milking phase. The liner is attached to rubber pipes that take the milk away to a collecting vessel (Mowlem 1988).

There are three main layouts or systems used. The first is a layout using a bucket to collect milk and it is the simplest and cheapest particularly when all of the equipment is mounted on a trolley as a self-contained unit that can be wheeled to where the goats are standing.

The second system is a direct to line system where the milk goes directly through a pipeline to the bulk tank or other storage vessel, without going through any kind of recording system.

Lastly, a similar system to the latter incorporates recording jars that allow the milk produced by each goat to be measured before it is transferred along the pipes to the bulk tank.

During machine milking the milk is continuously in contact with the teat skin and teat liners, hence microbe transfer into milk is likely to occur (Giesecke *et al*., 1994). Inadequately cleaned and disinfected milking installations are the most frequent reasons for initial bacterial contamination of milk. It is estimated that as much as 90% of the total bacterial contamination of the raw milk produced freshly on farms originates from milking installations (Giesecke *et al*., 1994). Therefore, regular correct cleaning and disinfection of milking equipment is necessary to ensure satisfactory milk quality and also reduce the risk of mastitis.

Components of the milking machine requiring particularly regular and careful attention are (Giesecke *et al*., 1994):

- milking cluster unit, milk tube connections on the milk pipeline;
- connections in the milk pipeline and in-line filters;
- receiving jar, milk pump and sanitary trap;
- vacuum control valve and dosing devices for cleaning and disinfecting agents; and
- dead ends in pipelines.

A cleaning process for the milking machine can always be adapted to individual needs, but normally consists of the following basic steps (Reybroek 1997):

1. a preliminary rinse with lukewarm water to remove most of the milk residues (soil);
2. a warm wash with alkaline detergent solutions;
3. one or more rinses with clean potable water to remove the chemicals; and
4. an acid rinse once or twice a week depending on the hardness of the water.

It is good practice to check the effectiveness of the cleaning system regularly (Mowlem 1988). This is reflected by the microbiological quality of the milk.

Even if good cleaning procedures are used for the udders and the equipment, the washed surfaces will become re-contaminated if they are rinsed with poor quality water. It is,

therefore, vital to investigate the water source, e.g. borehole water. Laboratory tests should be conducted to establish whether the water is potable or not (Giesecke *et al*., 1994).

1.1.5 Water Quality

Water used in the process of milk production should be of bacteriologically potable quality (Bramley & McKinnon 1990). The purity of properly treated supplies direct from the mains is assured, but bacterial contamination can be introduced from storage tanks which are not properly protected from rodents, birds, insects and dust (Bramley & McKinnon 1990). If untreated water gains access to milk or is used for rinsing equipment and containers, any micro-organisms present in the water will contaminate the milk. Although the numbers of micro-organisms added, even from relatively heavily contaminated water, may be insignificant in terms of colony forming units per millilitre (CFU/m*l*) of milk, their multiplication in any residual water in the equipment will result in more serious contamination.

This may lead to establishment of some undesirable types of micro-organisms, e.g. psychrothrophic Gram-negative rods, in the milking equipment (Bramley & McKinnon 1990). For these reasons in countries where farm water supplies are known to be bacteriologically unsatisfactory, chlorination of the water, by dosing with hypochlorite is recommended. This helps to reduce the risk of bacterial multiplication in residual water left in milking machines that are cleaned and sanitised in one operation (Bramley & McKinnon 1990).

An alternative method is to delay chemical disinfection of milking equipment until just before the next milking. The disinfectant solution is merely drained from the equipment before it is used for milking (Bramley & McKinnon 1990).

Udder washing water contaminated with bacteria such as *Pseudomonas* spp. or coliforms, is believed to have been responsible for outbreaks of mastitis caused by these organisms. The risk can be reduced by venturi mixing a disinfectant, e.g. hypochlorite or iodophor, into the water. The contact time of this mixture with the udder also determines the level of bacterial reduction on the teats after udder washing (Bramley & McKinnon 1990).

It is important to know that most water contains substances that can interfere with cleaning schemes, a condition termed as water hardness (Zall 1990). Hardness may be classified as either temporary or permanent. Temporary hardness is caused by calcium or magnesium bicarbonate, and these can be precipitated by heat. These impurities can also be precipitated by many alkaline materials and are often left behind on equipment surfaces as "scum". Sulphates and chlorides of calcium and magnesium mostly cause permanent hardness. It is the deposition of these salts upon equipment surfaces during rinsing operations that causes water spots upon which micro-organisms establish themselves. Hard water requires conditioning by ion exchange systems and final rinse waters may need acid treatment.

1.1.6 Legislation

The Foodstuffs, Cosmetics and Disinfectant Act (54/1972) states *inter alia* that "no person shall use or sell any raw milk intended for further processing which:

i) contains pathogenic organisms, extraneous matter or any inflammatory product or other substance that for any reason whatsoever may render the milk unfit for human consumption;

ii) exceeds the most probable number (MPN) of 10.0 coliform bacteria per 1.0 m*l* of milk; or if the number exceeds 20.0 coliform per m*l* of milk using the dry rehydrated film method for coliform and *E. coli* counts;

(iii) on application of modified Eijkman test, the Violet red bile 4-methylumbelliferyl B-D-glucuronide (VRB MUG) agar method or the dry rehydrated film method, the milk is found to contain *E. coli* in 0.01 m*l* of milk;

(iv) gives a standard plate count of more than 50 000 CFU per 1.0 m*l* of milk when subject to the dry rehydrated film method for standard colony count test; and

(v) contains 750 000 or more somatic cells per 1.0 m*l* of milk after three successive readings at intervals of at least seven days during the test period, or which shows any other signs of abnormal secretory activity of the mammary gland(s)."

1.2 PRODUCTION SYSTEMS

In order for milk goat development to be successful, socio-economic constraints in production must be accorded at least the same importance as the technical constraints. The type of production system is determined by environmental and socio-economic conditions present (Aich *et al*., 1995).

Information was obtained on the structure of the herds and flocks of a sample of 41 households on three Masai Group Ranches in Kenya. From 2 730 sheep and 2 300 goat producers, it was realised that poor households preferred goats, while rich households preferred sheep (King *et al*., 1984).

The reason as to why this is so can only be speculated upon based on the fact that goats are generally more hardy than sheep and, therefore, much easier to rear. The author did not, however, elaborate on this point.

Aich *et al*., (1995) attempted to classify the different production systems into three categories based on a study carried out in the Mediterranean region; viz.:

a) *Range goat production system (Extensive)*

In this system, range and vegetation represent the main feed resources for goats. Goats are systematically herded and brought back to their pens in the evening to protect them from predators. Concentration of the herds in pens also facilitates manure collection for the arable land. Only in particular situations (few predators, feed in excess on range) are goats shepherded. Such goat flocks are mainly orientated towards meat production. Occasionally milk from these goats is used for home consumption. This is often processed into cheese and sold directly from the farm. However, due to constant exposure to low levels of nutrition and disease there is low productivity (Egwu *et al*., 1988).

This system is, therefore, described as a low input – low output system in which high productivity cannot be expected (Devendra & Burns 1983). The basis for this farming

system is to maximise utilisation of vegetation per animal. Therefore, the herds are usually large in size and composed of goats of local breeds. It has been referred to as the "collecting goat production system" (Aich *et al*., 1995).

b) *Mixed range and concentrate feeding system (Semi-intensive)*

In these systems the natural vegetation of rangelands is regarded as one of the feeds. In addition to exploiting range land the farmer may supply grain, concentrate or even hay to the animals.

The basis of this feeding allowance is for the fulfilment of the nutritional needs of the animal, to achieve a pre-determined performance regarded as best economically.

The grazing of range will be considered a satisfactory practice when there is no negative impact on milk production. Therefore, the strategy adopted is to have goats graze the pasture only when nutritional needs are low.

The advantage of permitting some grazing is that it gives the goats a chance to use their selective feeding habits to overcome any dietary deficiencies (Devendra & Burns 1983). Goats graze pasture enriched with legumes for one or two hours at the end of the grazing day. In order to improve the digestibility of the range forage, feed supplements such as molasses with urea are provided. This system, therefore, is referred to as the "milk production oriented" goat farming system, with the feeding system targeting milk yield (Aich *et al*., 1995).

c) *Intensive goat farming system*

This is applied where free-range grazing does not achieve production objectives. Goat feeding in this case turns to zero grazing. In some instances, the goats graze on either cultivated pastures or crops in a fenced up area at very high stocking density (Devendra & Burns 1983). The system is suited to high producing animals and exotic, particularly

temperate breeds. Stocked animals are bred or cross-bred with the objective of maximising milk production per animal. This system is ideal for heavily populated areas. However, it is quite expensive to run in view of the feed costs, establishment of farm infrastructure and the labour required for successful management.

1.3 RESEARCH AND EXTENSION

Goat producers are often among the poorer, less educated and marginal society. Therefore, generating relevant results and delivering these results to the targeted audience is very difficult, relative to research extension programmes working with commercial producers (Nu Nu San & De Boer 1996).

Therefore, Nu Nu San & De Boer (1996) suggest that in such cases an effective research extension programme should comprise of the following elements:

- A farmer-based approach where practitioners pay close attention to farming conditions, and where they integrate farmers' ideas into the research and development.

- A comprehensive study approach where all farm activities are included in the search for improvement in the farm family's welfare and productivity.

- A problem-solving process that seeks opportunities to develop and guide research and identify ways to make local services and national policies more focussed on needs of the smallholder.

The term "smallholder farmer" has often been difficult to define. It cannot exclusively refer to the total number of animals possessed, or the total area of land owned. Often undefined parameters are used with the emphasis on the fact that a smallholder farmer is a farmer who possesses little or no capital and other means of production, with the exception of labour (Van den Berg 1990).

CHAPTER TWO

MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Questionnaire

A questionnaire was used to obtain information regarding dairy goat farming and goat milk production from farmers (Appendix 1). Six farmers were identified in the study area; they were located in Winterveldt, Oskraal and Ga-Rankuwa (north west of Pretoria); Skeerpoort (south west of Pretoria); Lynnwood and Garsfontein (east of Pretoria). The researcher completed the questionnaire during the farm visits. Information obtained from the questionnaire was consequently used to select farmers representative of the target area.

2.1.2 Goat herds

Four dairy goat herds were selected, the criteria for selection being based on their capacity to produce goat milk for human consumption for domestic and/or commercial purposes. These herds were considered representative of the three different production systems under analysis and were classified in groups as follows:

Group A: Extensive production system (two goat herds).

Group B: Semi-intensive production system.

Group C: Intensive production system.

2.1.3 Milk Samples

Ninety (15 x 2 x 3) udder half milk samples were obtained from each farm. A total number of 270 udder half milk samples were analysed from the first three commercial herds studied. The origin of the udder half milk samples is illustrated in Table 1.

Table 1: Origin: Udder Half Milk Samples

PRODUCTION SYSTEM	HERD SIZE	NUMBER OF GOATS SAMPLED	NUMBER OF UDDER HALVES	TOTAL UDDER HALF SAMPLES (X 3 VISITS)
Extensive	66	15	30	90
Semi-intensive	45	15	30	90
Intensive	66	15	30	90
Total number of udder half milk samples				**270**

One bulk milk sample was also obtained from each farm every visit. This resulted in a total of nine (3 x 3) bulk milk samples obtained over the entire study period.

2.1.4 Water Samples

One water sample was taken from the water source on each farm, on each visit. This also resulted in nine (3 x 3) water samples altogether during the study.

2.1.5 Swab Samples

Sterile surface swabs were used to sample the milk contact surfaces of the milking equipment. The number of sites swabbed varied with type of milking used.

2.2 METHODS

2.2.1. Field Study

The field study occurred in two phases. The first phase involved sampling of milk for qualitative analysis, observation of the milk harvesting processes and study of the factors that contribute to milk hygiene. This was done on the three commercial dairy farms, each under a different production system. Sampling was carried out during the first stage of (early) lactation of the goats on all the farms. This is the period immediately after parturition, which ranges from two to four weeks postpartum. This lactation period varied within and among the different production systems, and so did the sampling regimes. Visits were made to each farm once a week for three consecutive weeks. The seven-day interval was chosen based on the stipulation made in the legislation regarding the period required for the detection of udder disease using SCC. This was done as follows:

PRODUCTION SYSTEM		WEEK 1	WEEK 2	WEEK 3
Group A:	Extensive	17 August	24 August	31 August
Group B:	Semi-intensive	16 August	23 August	30 August
Group C:	Intensive	7 June	14 June	21 June

2.2.2 Comparative Study

Phase two of the study involved a follow-up study on one of the farms that altered the method of milking under the extensive production system (A). The farmer initially milked by hand, but five months after the initial study, he acquired the bucket system milking machine. Milk samples were analysed during both regimes in the same format as in the previous cases, and a comparative study carried out.

PRODUCTION SYSTEM A	WEEK 1	WEEK 2	WEEK 3
Milking by hand	8 June	16 June	22 June
Milking by machine	9 November	17 November	24 November

The difference in the lactation period is attributed mainly to the type of breeding and management systems exercised on the farm under the respective production system.

2.2.3 On-Farm Activities

The following activities were carried out on each farm during the study:

- Swab samples were taken from milk contact surfaces of the milking equipment just before use.
- Aseptic sampling from the source of water used on individual farms, for the assessment of its bacteriological quality was done.
- Water hardness testing was done at the farm using test strips.
- The udder was examined to assess variation in teat and udder conformation.
- Milk sampling was done during the evening milking.
- Two foremilk samples were taken from each udder (one from each half) after the pre-milking regime used on the individual farm.
- One bulk milk sample was taken from the bulk milk-collecting vessel.
- Temperature of the bulk milk at sampling was determined.
- All samples collected were transported on ice (4°C) to the laboratory.

2.2.4 Sampling procedures

A. Udder half milk sampling

Sampling was done aseptically as follows:

The teat orifice was wiped with cotton wool moistened with methylated spirits, and then examined for any lesions. The first two to three jets of milk were discarded into a strip cup to rinse the teat canal and to test for any abnormalities in the milk, which were then recorded.

Approximately five ml of milk from each half was taken in sterile sample containers, which were then labelled and placed upright in a cool box with ice. The samples were kept at a temperature of approximately 4°C after collection until arrival at the laboratory, where they were held at the same temperature in a refrigerator. The milk was then analysed the following morning after 13 to 14 hours post-sampling.

B. Bulk milk sampling

Milk in a bulk tank was allowed to mix for approximately five minutes before sampling. In the case of plastic buckets, milk was mixed using a plastic paddle that was sterilised, as required in boiling water. Gentle agitation was done to avoid rupture of the milk fat globule membrane that becomes brittle under cooling and, therefore, sensitive to damage.

In cases where milk was stored in a frozen state, bulk samples were taken just after the milk was harvested. A sample of 100 ml of milk was sampled into a wide mouth sterile container that was labelled and placed into the cool box with ice.

Temperature of the bulk milk was determined after the milking process by use of individual sterile thermometers. This was done to avoid cross-contamination.

C. Equipment surface sampling

Swab samples were taken from the following potential problem areas of the milking machine:

- inner aspect of teat liners (lower third portion),
- milk pipeline and in-line filters, and
- in-line filter surface.

In the case of hand milking, swabs were taken of milk contact surfaces of the collecting containers after they had been cleaned and were ready for use.

D. Water sampling

Water samples were collected in sterile 250 ml bottles, which were labelled with the farm address and type of water source. In order to sample from a tap, cold water was allowed to flow for two to three minutes to flush the pipe supplying the tap.

E. Water hardness testing

This was carried out using water hardness testing strips, which contain Titriplex III (ethylenedinitrilotetra-acetic di-sodium salt). The test strips measured the chemical hardness of water, which is dependent on the quantity of calcium and magnesium salts present in water. The strips were dipped in a coldwater sample (not running water) for one second to make sure that they were fully wet. Surplus water was shaken off and colouration of the test zones assessed after one minute. The intensity of the different zone colours on each test strip was indicative of the extent of the complex forming reaction between calcium and magnesium ions in the water and Titriplex III present in the test strip. The resultant colour pattern on the test strip was then used to determine the level of water hardness.

2.2.5 Sampling Charts

The following charts were used for documentation of results:

A. Farm records

Group (Production system)

A.1 Farm details

FARM/ OWNER	NO. OF DOES SAMPLED	BULK MILK VESSEL	BULK MILK TEMPERATURE	WATER SOURCE	WATER HARDNESS SCORE

A.2 Individual Goat Chart

DOE ID	LACTATION NUMBER	UDDER SYMMETRY	UDDER ATTACH-MENT	TEAT SHAPE	TEAT ORIFICE	FOREMILK APPEAR-ANCE

Legend: Interpretation of Individual Goat Chart

PARAMETER	CODE	INTERPRETATION
1. Doe identification	Doe ID	- Name or Number of the doe
2. Lactation number	1- 5	- Number of lactation periods or parity
3. Udder Symmetry	S AS	- Udder halves display symmetry - Udder lacks symmetry.
4. Udder attachment	1 – 3	- Attachment of udder ranging from *firm attachment* (1) to *loose attachment* (3).
5. Teat shape	N CD GD	- Normal - Conically dilated - Generally dilated.
6. Teat orifice *	1 – 5	1. Teat end sphincter is smooth with no evidence of irritation 2. Teat end has a raised ring 3. Teat end sphincter is roughened with slight cracks, but no redness is present.

* Teat orifice scores may go up to 5. The highest score encountered in this study was 3.

B. Laboratory records

B.1 Bulk milk, water and swab samples

SAMPLE TYPE	PETRIFILM AEROBIC COUNT	PETRIFILM		SCC	PSEUDOMONAS
		CFC	*E. coli* Type 1		
Bulk milk					
Water source					
Swab	Teat liner				
	Milk pipe line connections				
	Receiving jar				
	Collecting container				

Key: CFC Coliform Counts

B.2 Udder-half milk samples

Group (Production system) _____

Sampling date _____

Number of samples _____

FARM	GT	MP	HALF	KOH	CTL	STE	ASC	CMP	ORG	SCC

Key:

GT Goat identity

MP Milk production

KOH Potassium hydroxide test

CTL Catalase test

STE Staphylase test

ASC Aesculin test

CMP CAMP test

ORG Organisms

2.2.6 Sample analysis

The following tests were carried out on the respective samples taken at the farms:

SAMPLE	TESTS	RELEVANCE
Aseptic udder half milk samples	Somatic cell count Bacterial culturing Bacterial identification	Udder health
Bulk milk samples	Temperature Bacterial identification Coliform and *E. coli* type 1 counts Standard colony count Somatic cell count	Temperature control Environmental and milking hygiene. Level of udder inflammation
Equipment swab samples	Bacterial identification Coliform and *E. coli* type 1 counts Standard colony count	Milking hygiene & cleaning efficiency.
Water samples	Hardness test Standard colony count Coliform and *E. coli* type 1 counts	Effect on cleaning efficiency Bacteriological quality of the water

A. Milk Sample Analysis

Bacteriological tests carried out on both the bulk milk samples and udder half samples were as stated in the Foodstuffs, Cosmetics and Disinfectants Act, 1972, (Act No. 54 of 1972).

These included the following**:**

A.1 Udder half sample analysis

The following tests were carried out on udder half milk samples:

A.1.1 Blood Tryptose Agar Culturing

An amount of 0.01 ml of milk from each half milk sample was streaked onto blood tryptose agar plates (petri dishes) and incubated for 48 hours at 37°C.

Each petri dish was clearly identified with the goat number or name. Two zones were marked on the back of each petri dish to indicate the left and right halves of the udder.

With an inoculation loop, 0.01 ml of milk sample from the test tube was streaked onto the agar. The agar plates were then incubated in an inverted position to prevent condensing of gases released from bacteria on the inside of the lids of the petri dishes.

Colony characterisation after incubation of the culture was then done in which the colour, shape, texture and the presence of haemolysis of the colonies were used to identify the organism. Quantitative identification of the colonies was also done. Further testing followed to confirm identity of the organisms, this being carried out at the Onderstepoort Veterinary Institute (Henton 1999).

A.1.2 Potassium Hydroxide Test

This was carried out to differentiate between bacteria with sturdy and thin cell walls, i.e. Gram positive and Gram negative bacteria respectively. Using a heat sterilised loop a sample of the test colony was mixed in a drop of potassium hydroxide on a clean glass slide. If the mixture thickened and formed mucoid gels and threads, it was positive, indicating presence of Gram-negative organisms. An unchanged mixture was a negative test indicating Gram-positive organisms.

A.1.3 Catalase Test

A loop of the test colony was mixed in a drop of hydrogen peroxide placed on a clean glass slide and a positive test was identified by immediate effervescence. Staphylococci are catalase positive as opposed to streptococci that display delayed, or showed no, effervescence.

A.1.4 Staphylase Test

This differentiates between S. *aureus* and other staphylococci that are coagulase negative, by testing for the presence or absence of the coagulase enzyme. Presence of coagulase is visualised through the clumping of fibrinogen – sensitised and colour reagent-bound, sheep red blood cells.

A drop of the staphylase test reagent was spread out into a thin film to cover the circle on the reaction card. A loop of the catalase positive, KOH negative, test colonies was then mixed with the reagent and observed for any agglutination reaction. All positive reactions were confirmed by repeating the same procedure, but with the staphylase control reagent.

A.2 Bulk sample analysis

Bulk sample milk analysis tests included the following:

A.2.1 Standard colony count with the dry re-hydrated film method

A milk dilution of 1:10 was prepared by adding 1 m*l* of milk to 9 m*l* of sterile phosphate buffer then mixed well. A 1:100 dilution was prepared by adding 1 m*l* of the 1:10 dilution to 9 m*l* of sterile phosphate buffer. After mixing well, a dilution of 1:1 000 was prepared in a similar manner. Using labelled films, 1 m*l* of the 1:1 000 dilution was transferred to the centre of the bottom film.

The top film was then released to drop onto the sample. The process was repeated with the 1:100 milk dilutions. Pressure was applied onto the films with the help of a spreader to distribute the samples evenly. The films were then stacked in a pile with the clear sides up and incubated at 32°C for 48 hours. Un-inoculated media plates were included as controls to eliminate the possibility of media contamination, which would give false results.

After incubation, the number of colony forming units (CFU) was determined. The figure obtained gave the estimated total bacterial count in 0.001 and 0.01 millilitre of milk. The value obtained was multiplied by the factor of three and two respectively, and the average value recorded. This then gave an estimation of the total number of colony forming units in 1 ml of milk. Only plates with between 10 and 300 CFU were counted, as counts beyond these margins would not be accurate.

A.2.2 Coliform and *E. coli count* with the dry rehydrated film method

Commercially available films (3M Microbiological Products, USA) labelled for the test were used. One ml of bulk milk was transferred to the centre of the bottom film. The top film was then slowly rolled onto the sample to prevent air bubbles being trapped under the top film.

Using a spreader, pressure was applied onto the films to spread the sample evenly. The films were left for one minute undisturbed in order for them to solidify. Piled in a stack, the films were incubated at 32°C for 24 hours.

Red colonies associated with gas were indicative of coliform colonies, but colonies identified by their blue colour and associated with gas, were considered positive for *E. coli*. Colonies not associated with gas, were not counted.

A.3 Somatic cell counting

Milk SCC of udder half samples and bulk milk samples were determined using the Fossomatic-90 cell counter. After culturing milk for bacterial identification, milk from the bulk sample and udder half samples was preserved using potassium dichromate crystals. Approximately 0.06gm of the $K_2Cr_2O_7$ was mixed thoroughly in 5mls of udder milk samples by inverting each test tube five times. The following day, the milk samples with dichromate were warmed up in a 40°C water bath and mixed for standardisation according to the instruction manual. One µl of the milk sample was then drawn from the milk sample for analysis.

2.2.7 Swab sample analysis

The swab samples were left to soak in phosphate buffer for approximately 30 minutes and a 1 ml sample from this dilution was plated out by streaking onto blood agar. The plates were incubated for 24 hours at 37°C. Identification of the resulting colonies was then done. The format followed was as described by Zall (1990). Identification of quantitatively dominant colonies was carried out, which often were *Pseudomonas*. Further testing for *Pseudomonas* was done. Bacterial enrichment was done on the Methyl Red Voges Proskauer (MRVP) broth as stated by Clemons & Gadberry (1982).

2.2.8 Data Analysis

Analysis of variance, calculations of the mean difference between production systems and correlation among different parameters were done to determine the following aspects:

1. Correlation between udder depth and symmetry with udder health;
2. Relationship between SCC and udder health in individual goats under the different production systems;
3. Variation in the TBC of bulk milk samples between individual systems;
4. Comparison of individual bacteria obtained from swabs of milking equipment and their presence in bulk milk samples under the different systems, e.g. *Pseudomonas aeruginosa* and *Enterobacter*
5. Correlation between the quality of water used and the bacterial content of goat milk produced.

CHAPTER THREE

RESULTS

3.1 Questionnaire

Information obtained from the questionnaire revealed the following facts about dairy goat farming in this part of the country.

3.1.1 Production Systems

Despite the fact that there were few farmers identified within the study area, the three different production systems were represented. The extensive system was the most commonly practised production system (four of the six farmers), while one farmer only implemented each of the intensive and semi-intensive systems.

The different dairy goat herds were obtained through purchase of animals with only one farmer acquiring his herd through settlement of debt owing to him. Some goats were bought with the initial intention of keeping them as pets in the home, while others as a consequence of allergic response of a family member to cow's milk. Most, however, bought goats with the sole intention of establishing a dairy goat herd.

The most predominant breed was the Saanen. Herd sizes varied between and within the production groups. In the extensive system, herd sizes for the four farms were 10, 19, 23 and 66 does. Dairy goat farming on these farms had occurred for a period ranging from seven months to eight years.

In the single semi-intensive system of production, the herd size was 45 does and dairy goat farming had been carried out for four years. The intensive production system farm was established for research purposes in 1988, and its herd size was 66 does.

3.1.2 Management

In the extensive production system, goats were kept on free range. In all these cases the land utilised was privately owned. Goats were let out on range in the late hours of the morning (10:00 - 11:00) and they returned in the evening (16:00 - 17:00). Shelter was provided at night. Two of the four farmers used a kraal, one used a structure built with iron sheets and the other used a concrete building for shelter at night.

Only water and mineral lick were regularly provided at night. One of the farmers provided supplementary feeding just before milking, while another farmer supplemented his animals only during winter with hay.

In the semi-intensive production system goats were allowed to graze on privately owned land and were supplemented with feed during the day until milking time. Supplementary feeding was with both dairy meal and hay placed in feeders found within the grazing area. Water and mineral lick were provided *ad libitum*.

In the intensive production system, the goats were housed in concrete buildings. They were released only at milking time. The system practised zero grazing and food was provided within the building. Feeds were composed mainly of dairy meal, lucerne and hay.

3.1.3 Feed Source

Feeds for supplementation under the semi-intensive and extensive production systems were obtained from shops. In the intensive system, feeds were locally produced.

3.1.4 Water Source

Three of the farmers under the extensive system obtained water from boreholes, whilst the fourth farmer purchased his from the main municipal supply and kept the water in a tank. The farmer using the semi-intensive system used water from a borehole, channelled into a concealed plastic water tank. Water used in the intensive system was reticulated municipal tap water.

3.1.5 Milking Methods

Extensive production system

On all the farms under the extensive production system milking was done by hand.

This was, in some cases, attributed to low income, in other instances due to the small volume of milk produced by the goats, which made machine milking a non-viable proposition. On two of the farms there was no milking parlour and milking was done outside in the kraal where the goats rested after grazing. In each of the other two cases an abreast milking parlour was used. Milking on the two latter farms was done twice a day, while in the former cases only once, i.e. in the morning. Lactation periods varied from as short as three months to as long as ten months. The amount of milk produced per goat also varied from one to six litres of milk per goat per day.

Two of the farmers produced milk for both commercial and domestic use, but the other two produced enough milk for domestic use only. On two of the farms, the workers milked the goats; whilst in the other case, the farmer or his children did it.

The farm with the largest herd size (66), with milking done by hand in a parlour, was selected for the research project. Milk obtained was used for both domestic consumption and for commercial purposes. Random selection among the lactating does was done to make the study sample.

On this farm, the following procedure was applied during milking:

- Teats were cleaned with a wet cloth dipped in warm water;
- milking was into a small 2 litres plastic bucket;
- teats were then dipped into a disinfectant post-milking; and
- bulk milk was collected in a bigger (20 litres) plastic bucket.

Unhygienic procedures practised during the milking process were as follows:

- The same cloth was used for all the goats during the milking process making cross-contamination between udders possible; and
- Water used for udder preparation did not contain any detergent or disinfectant, hence a possible source of infection.

Semi-intensive production system

Workers used the bucket type of milking machine for milking under the semi-intensive production system. Milking was done twice a day and the amount of milk produced ranged between three to eight litres of milk per goat per day. Milking was carried out in an abreast design milking parlour with a two-animal capacity. Lactation period was as long as eight months before the goats were dried off. Milk produced was used for both commercial and domestic consumption.

The procedure used was as follows:

- Dry teats were wiped clean with disposable paper towels;
- Clusters were attached onto the teats and then milking began;
- After milking the teats were sprayed with a disinfectant; and
- Milk from the metallic milking bucket was collected in a plastic bucket.

Foremilk stripping was not carried out, making it difficult for macroscopic screening for mastitis.

Intensive production system

In the intensive production system, milking was done twice a day using the line milking machine. The milking parlour was the abreast design with a capacity of six goats. Milk production ranged from 1.2 to 4.0 litres per goat per day. The lactation period was nine months before drying off. Milk production was entirely commercial.

The milking process under this system was as follows:

- The teats were washed with cold water using a hosepipe;
- they were then wiped dry with disposable paper towels;
- clusters were attached and milking began; and
- after milking the teats were dipped in disinfectant.

The following practices were noticed during the milking process:

- Foremilk stripping and teat dipping were not regularly done;
- prolonged attachment of the milking clusters often occurred after the udder was dry, this may have resulted into over-milking of the goat udders; and
- some of the goats lacked identification features so milk records were unreliable.

3.1.6 Milk and Milk Products

Two of the farmers produced and sold raw milk, while the rest (four) pasteurised the milk. The sale of raw milk was due to customer preference. Often milk was preserved in a frozen state (67%). Further processing of milk included preparation of yoghurt, feta cheese and ice cream.

3.1.7 Constraints

Some of the diseases and conditions reported in the farm records included heartwater disease, coccidiosis, mastitis, udder papillomatosis, pulpy kidney, corynebacteriosis, acidosis and fungal infections.

Major problems that were encountered in management by the different farmers included the following:

- Unavailability of water (this was in an extensive production system);
- Predation of the kids by jackals as the goats went out to graze on the range; and
- A limited market for goat milk for the commercial farmers.

3.2 Udder Conformation

Morphological analysis of the udders of the study goats under the different production systems revealed the following as shown in Table 2 below.

Table 2: Summary of a Comparison of Udder Conformation of Goats Under the Different Production Systems

PARAMETER		EXTENSIVE (A)	SEMI-INTENSIVE (B)	INTENSIVE (C)
1. Udder Symmetry	S	12 (80%)	12 (80%)	6 (40%)
	AS	3 (20%)	3 (20%)	9 (60%)
2. Udder Attachment	1	9 (60%)	12 (80%)	7 (46%)
	2	3 (20%)	2 (13%)	4 (27%)
	≥ 3	3 (20%)	1 (7%)	4 (27%)
3. Teat Shape	N	11 (73%)	9 (60%)	6 (40%)
	CD	3 (20%)	4 (27%)	5 (33%)
	GD	1 (7%)	2 (13%)	4 (27%)
4. Teat Orifice	1	14 (93%)	10 (67%)	10 (67%)
	2	1 (7%)	4 (27%)	4 (27%)
	3	0	1 (6%)	1 (6%)
5. Lactation Number	1	No Records	1 (6.7%)	5 (33%)
	2		3 (20%)	2 (13%)
	3		5 (33.3%)	4 (27%)
	≥4		6 (40%)	4 (27%)

Legend: Interpretation of Individual Goat Chart

- Udder Symmetry: S = symmetrical AS = asymmetrical
- Udder attachment: 1 – 3 = Firm attachment (1) to loose attachment (3)
- Teat shape: N = normal; CD = conically dilated; GD = generally dilated.
- Teat orifice: 1 – 3
  - ə 1 = teat end sphincter is smooth with no evidence of irritation
  - ə 2 = teat end has a raised ring
  - ə 3 = teat end sphincter is roughened with slight cracks, but no redness is present.

Details of these results are in Appendix 2 on pages 63-65 and analysed, reveal the following:

- Does under the extensive production system displayed better udder conformation compared to those reared under either the intensive or the semi-intensive systems. Most notable was that there were very few animals with teat orifice scale > 1 (7%).
- More than half the herd reared under the intensive system had an asymmetrical udder conformation. This impaired proper attachment of the cluster cups during milking.
- "Firm" udder attachment was noted among goats under the semi-intensive system with 80% of the udders falling in scale 1. It can be inferred from the lactation number and/or parity that most of these goats were mature animals.

3.3 Udder Health

Coagulase negative staphylococci (CNS) were the most commonly isolated organisms accounting for 86.6% of the infected udder halves. They included *Staphylococcus epidermidis* and *S. intermedius. Staphylococcus aureus* was the other pathogen isolated from the udder halves. The percentage infection rate was 13.4% of infected udders. It was only isolated from the herds implementing the intensive and semi-intensive production systems as shown in Table 3 below.

Table 3: Bacterial Infection Rates in Udder Halves of Goats within the Three Production Systems

NUMBER OF HALVES EXAMINED	DAIRY GOAT HERDS			ALL HERDS	
	A EXTENSIVE	B SEMI-INTENSIVE	C INTENSIVE		
	30	30	30	90	%
Infection status					
Negative	26	16	18	60	66.7
Positive				30	33.3
CNS	4	12	10	26	86.6
Staphyloccus aureus	0	2	2	4	13.4
Streptococci	0	0	0	0	0
Coliforms	0	0	0	0	0
Total halves infected	**4**	**14**	**12**	**30**	
Percentage infected	**(13.3%)**	**(46.7%)**	**(40.0%)**	**(100%)**	

Analysis was done to determine correlation between udder conformation and presence of infection in the udders. There was no significant correlation, which could be attributed to the limited number of goats available for the study.

3.4 Somatic Cell Counts

Somatic cell counts of individual udder halves were carried out for each goat under the three production systems. Presence of infection in the milk was assessed in these milk samples. The relationship between the two variables was consequently determined and the results are tabulated below (Table 4).

According to the Foodstuffs, Cosmetics and Disinfectants Act, 1972, (Act No. 54 of 1972), SCC higher than 750 000 cells/m*l* in goat milk, indicates that the milk is not fit for human consumption. The same cut off value was used as indicative of mastitis in this study.

Table 4: Relationship Between Udder Half Infection Status and SCC Under The Different Production Systems

SCC CELLS/m*l* x 10^3	UDDER HALVES					
	EXTENSIVE PRODUCTION SYSTEM		SEMI-INTENSIVE PRODUCTION SYSTEM		INTENSIVE PRODUCTION SYSTEM	
	Number of halves	Positive Cases	Number of halves	Positive Cases	Number of halves	Positive Cases
0 – 125	12	-	13	3	7	3
126 – 250	4	1	7	4	8	2
251 – 375	1	-	5	5	2	-
376 – 500	3	-	1	-	2	-
501 – 625	2	1	1	1	3	1
626 – 750	3	1	2	1	1	-
751 – 875	1	1	1	-	1	1
876 – 1 000	-	-	-	-	1	-
1 001 – 1 125	1	-	-	-	3	3
1 126 – 1 250	-	-	-	-	1	1
1 251 – 1 500	-	-	-	-	-	-
1 500+	3	-	-	-	1	1

On this basis, correlation between SCC equal to or >750 000 cells per m*l* of milk, and the presence of infection in goat milk was determined using the Fisher Exact test for association ($p = 0.2$) under the different production systems. Infection status of the udder was based on growth of bacteria on cultured udder milk samples, where presence of bacterial growth referred to positive infection status.

There was no statistically significant association between the two variables as shown below. The resultant p-values were 0.282, 1.000 and 1.000 for the intensive, semi-intensive and extensive respectively ($p = 0.2$).

Table 5: Somatic Cell Counts of Bulk Milk Under Different Production Systems

DAIRY GOAT HERD GROUP	PRODUCTION SYSTEM	MEAN BULK SCC (Standard <750 000 cells/m*l* milk)
A	Extensive system	518 000
B	Semi-intensive system	210 000
C	Intensive system	872 000

3.5 Milk Production

The amount of milk produced by the test animals during the study was determined. The highest and lowest values of milk volume produced during the evening milking for the different groups were as follows:

Table 6: Volume of Milk (*l*) Produced per Goat per Milking in each Group

DAIRY GOAT HERD GROUP	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Extensive	0.10	1.70	1.07	± 0.49
Semi-intensive	0.30	2.90	1.25	± 0.56
Intensive	0.20	2.00	1.17	± 0.46

Table 7: Variation in Lactation Number and Amount of Milk Produced Under the Semi-intensive Production System

AMOUNT OF MILK PRODUCED PER GOAT PER MILKING (*l*)					
LACTATION NUMBER	NUMBER OF DOES	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1	1	1.08	± 0.10	1.00	1.20
2	3	1.43	± 0.50	0.50	1.80
3	5	1.55	± 0.26	1.00	2.00
4	4	1.37	± 0.61	0.30	2.19
5	2	2.26	± 0.39	1.70	2.90

Table 8: Variation in Lactation Number and Amount of Milk Produced Under the Intensive Production System

AMOUNT OF MILK PRODUCED PER GOAT PER MILKING (*l*)					
LACTATION NUMBER	NUMBER OF DOES	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1	5	1.10	± 0.42	0.60	1.80
2	2	0.80	± 0.58	0.20	1.60
3	4	1.43	± 0.36	0.40	2.00
5	2	1.05	± 0.10	1.00	1.20
6	2	1.38	± 0.39	1.20	1.50

An analysis was carried out to determine whether there was any significant correlation between increase in the amount of milk produced and an increase in the lactation number (parity) under the semi-intensive system. Spearman's correlation value was 0.421, showing correlation between increase in parity and amount of milk produced (p = >0.0061). A similar analysis under the extensive system could not be done due to lack of relevant records from the farmer. In the process of random sampling of goats under the intensive system, does of lactation number four were missed out. As a result of this void created in the records, the analysis could not be carried out.

3.6 Milk Hygiene

Qualitative and quantitative microbial analysis of the bulk milk samples was done to assess the level of milking hygiene. Aerobic culturing of the milk samples was carried out. The organisms isolated were recorded, ranging from the most common to the least. Mean bacterial counts of the bulk milk samples are also reported and the results are shown in Table 9.

Table 9: Organisms Isolated and Bacterial counts determined from Bulk Milk Samples Under the Different Production Systems

GROUP	BULK MILK VESSEL	MEAN BULK MILK TEM-PERATURE	ORGANISMS ISOLATED	MEAN CC/m*l* (STANDARD <20)	MEAN TBC/m*l* (STANDARD 50 000 CFU/m*l*)
A	Bulk tank	4°C	Enterobacter *Escherichia coli* (rough)	22	36 300 CFU/m*l*
B	Plastic bucket	*27°C	*Enterococcus* spp. *Staph. epidermidis* *Staph..intermedius* Enterobacter	7	16 450 CFU/m*l*
C	Bulk tank	3°C	*Enterococcus faecalis* *Staph. epidermidis* *Bacillus* spp. *Pseudomonas* spp. *Aureobacterium* spp.	15	48 000 CFU/m*l*

* The temperature was taken from the bulk milk in a plastic bucket after the milking process, hence the higher value.

Legend:

TBC	Total Bacterial Count	**A**	Extensive Production System
CC	Coliform Counts	**B**	Semi-intensive Production System
CFU	Colony Forming Units	**C**	Intensive Production System

Based on the TBC, it can be deduced that the lowest environmental contamination occurred in the semi-intensive production system in comparison to the other two systems. Swabs were taken of the milk contact surfaces of the milking equipment and these were suspended in

phosphate buffer to dissolve any organisms and then cultured on blood agar. The organisms that were isolated under the different production systems are shown in Table 10 below.

Table 10: Organisms Isolated from the Inner Surfaces of Milking Utensils Under the Different Production Systems

GROUP	ORGANISMS ISOLATED	SOURCE
Intensive (line milking machine)	*Aureobacterium* spp. *Staphylococcus epidermidis*	Filter Pipeline
	Pseudomonas aeroginosa *Aureobacterium* *Staphylococcus* spp.	Milk line (rubber)
	Staphylococcus spp. *Pseudomonas* spp	Teat cup rim
Semi-intensive (bucket-milking machine)	*Klebsiella oxytoca* *Chryseobacterium meningosepticum*	Metallic bucket (inner surface)
	Acinetobacter lwofii *Enterobacter*	Milk line (silicon)
Extensive (hand milking)	*Enterococcus* spp. Non-haemolytic *Staphylococcus* spp.	Plastic milking bucket (inner surface)

3.7 Water Quality

Water hardness scores and microbial quality tests were done under the different production systems and the results obtained are as shown in Table 11.

Table 11: Water Hardness and Microbial Quality Under the Different Production Systems

GROUP	WATER SOURCE	WATER HARDNESS SCORE	TBC (CFU/m*l*)	*E. coli* TYPE 1
Standard	**Potable**	**<250 mg/*l* $CaCO_3$**	**<100 CFU/m*l***	**Negative**
Extensive	Bore-hole	70 - 125 mg/*l* $CaCO_3$	523	Negative
Semi-intensive	Bore-hole	70 - 125 mg/*l* $CaCO_3$	85	Negative
Intensive	Municipal tap water	70 - 125 mg/*l* $CaCO_3$	No growth	Negative

3.8 Comparative (follow-up) study

One small-holder farmer with 19 does was involved in the study to assess the effect that change in milking methods has on the microbial quality of milk produced. The dairy farm had been established for seven months, and at the beginning of the study, the production system used was extensive type. Goats were let out to graze on range and then supplemented at milking time with dairy concentrates in pellet form and lucerne in their shelter. The farmer initially milked by hand, but five months after the initial study, he acquired the bucket system milking machine. Milking was done in an abreast design milking parlour. Results of the analysis are illustrated in Table 12.

Table 12: Bacterial Infections in Udders of Goats from the Smallholder Dairy Farm

	MILKING METHODS	
	HAND MILKING	**BUCKET SYSTEM**
Number of halves examined	12	33
Infection status of halves		
Negative	8 (66.7%)	28 (84.8%)
Coagulase negative staphylococci	4 (33.3%)	4 (12.2%)
Staphylococcus aureus	0	1 (3.0%)
Streptocci	0	0
Coliforms	0	0

Coagulase negative staphylococci isolated from udder halves were non-haemolytic staphylococcus and *Staphylococcus simulans.* From these results it can be noted that *Staphylococcus aureus* was obtained from the milk harvested using the milking machine, which is not the case with hand milking.

Milking procedures followed during both regimes are outlined below:

1. Hand milking

- Teats were wiped clean using a wet cloth dipped in warm water with detergent;
- Foremilk stripping was then done;
- Milking was done into a small plastic bucket; and
- The teats were then dipped in a disinfectant.

The unhygienic practice, noticed during the milking process, was the use of the same cloth for the entire herd, making cross-contamination possible.

2. Bucket system

- Teats were wiped clean with a cloth soaked in warm water containing a detergent;
- Disinfectant was sprayed onto the teats and left to take effect for about 15 seconds;
- Foremilk stripping then followed;
- Clusters were then attached and milking began; and
- Teats were eventually dipped into disinfectant after milking.

Quality analysis of the microbiological state of bulk milk during both the hand milking and machine milking regimes was also done and a comparison made. Results are illustrated in Table 13 below. Temperature of the bulk milk was also determined at the time of sampling.

Table 13 Microbial Quality of Bulk Milk under the Extensive System Using Two Different Milking Methods

MILKING METHOD	BULK MILK TEMPERATURE	MEAN TBC /ml OF MILK CFU/ml	ORGANISMS ISOLATED	*E. coli* TYPE 1	MEAN BULK MILK SCC
Hand milking	10°C	58 000	*Enterococcus* spp. Aeromonas, Myroides, Acinetobacter	Negative	1 274 000
Bucket system	10°C	750	*Bacillus cereus*	Negative	131 000

There appeared to be, on the basis of the number of samples taken, a major difference in milk hygiene between the two different milking regimes, as indicated by the TBC. More environmental contamination is seen when hand milking was used as compared to the bucket type of machine milking. The water used on the farm was from a borehole. It was tested to assess its hardness level and microbial quality. The results obtained are as shown in Table 14 below.

Table 14: Microbial quality of water obtained under the extensive system

	TBC/ml OF WATER	COLIFORMS	*E. coli* TYPE 1	WATER HARDNESS
Standards	**< 100 CFU/ml**	**None**	**None**	**< 250 mg/l $CaCO_3$**
Test Results	240 CFU/ml	Negative	Negative	70-125 mg/l $CaCO_3$

CHAPTER FOUR

DISCUSSION

4.1 Production Systems

Reasons why many countries are trying to initiate or stimulate dairy husbandry (Van den Berg 1990) are:

- to increase milk availability per capita;
- to increase the standard of life in the rural areas, and
- to become self-supporting in milk.

Van den Berg (1990), did a study on the conditions required for a successful dairy development programme. Results obtained from the questionnaire regarding different production systems were discussed with respect to these conditions studied.

Van den Berg (1990), was of the opinion that dairy development programmes will succeed better when the position of smallholder farmers is also taken into consideration. This requires an understanding of the smallholder farmers, characteristics of their enterprises and the resources available (Devendra & Burns 1983). Based on the definition that a smallholder farmer is a farmer who possesses little or no capital and other means of production with the exception of labour (Van den Berg 1990), three of the farmers encountered in the study could be categorised as smallholder farmers. They all used the extensive management system of production, milking was done by hand, they kept their goats in kraals and depended on their family for labour.

Initial planning and organisation for the promotion of dairy farming should be directed towards what is thought to be the optimal situation easily achieved (Van den Berg 1990). Often drastic changes with high demands requiring infrastructural improvements will impede progress since most farmers are unable financially, and therefore unwilling, to pay for such alterations. Among the farmers encountered in this study it was revealed that the extensive production system was the system most commonly practised with four of the six farmers identified. This could be ascribed to the ease found in its implementation compared to the other two systems. This could be a suitable system to begin with in order to facilitate smallholder dairy goat farming.

A comparative study of the quantity and quality of milk obtained under the different production systems was done to ascertain whether this was indeed possible.

4.2 Udder Health and Conformation

Udder health is essential to optimise both quantity and quality of milk produced (Giesecke *et al*., 1994). In this study the prevalence of intramammary infection in goats was 33.3% (Table 3). This reflects a similar prevalence reported by Contreras *et al*., (1999), who measured an intramammary infection prevalence of 34%. The highest intra-mammary infection was recorded under the semi-intensive system with 46.7% udder infection rate as compared to 40% and 13.3% infection rates under the intensive and extensive production systems respectively, as shown in Table 4.

The majority of the bacterial infections found in this study were due to coagulase negative staphylococci with a prevalence of 86.7% of the infected udder halves. This agreed with results reported by other authors (Ryan & Greenwood 1990). The coagulase negative organisms consisted of *S. epidermidis, S. simulans* and *S. intermedius.* The remaining 13.3% of the infected udder halves was due to *Staphylococcus aureus.* This observation is in agreement with what Maisi & Riipinen (1991) found. In addition, *Staphylococcus hyicus* was isolated in their research. This indicates that *Staphylococcus hyicus* may also be associated with intramammary infections. Though tests were conducted for the presence of streptococcal organisms, only *Streptococcus faecalis* (more commonly known as *Enterococcus faecalis*) was isolated from a single bulk milk sample obtained from the intensive production system.

Staphylococcus epidermidis was the most commonly isolated coagulase negative organism. *S. epidermidis* is a commonly found inhabitant of the teat canal, and may be referred to as normal flora of the teat canal. It is reported to cause opportunistic infections in man, and very occasionally in animals (Quinn *et al*., 1994), although it is often regarded as non-pathogenic. Intramammary infections are closely related to the number of micro-organisms present on the teat end. The sequence of infection is usually one of progression from teat skin to teat canal to within the udder (Giesecke *et al*., 1994).

Any factor that promotes the frequency, duration or number of dangerous organisms on and around the teat tip, may also increase the prevalence of udder infections (Giesecke *et al*., 1994).

Staphylococci readily colonise the teat canal and normal skin particularly damp areas, e.g. in the region of the teat orifice (Quinn *et al*., 1994). Non-septic lesions of the skin can harbour more than usual numbers of the organisms, while septic lesions can release very large numbers of staphylococci. Colonisation of the teat canal is said to persist for many weeks, without bacteria penetrating to the teat sinus and producing mastitis. It has been shown that, under certain conditions, the action of the milking machine can be responsible for propelling bacteria through the teat duct (Quinn *et al*., 1994). This may explain why *S. aureus* was isolated only in cases where milking machines were used as shown in Table 3. Testing of the functioning of the milking machines would have verified this assumption, but was not considered in the experimental design.

From the follow-up study carried out under the extensive production system, the farmer initially milked by hand, but five months later he acquired the bucket system milking machine. *Staphylococcus aureus* was only isolated from milk during the latter regime, an observation similar to the situation under the systems where machines were used for milking. This observation could indicate that the method of milking does influence udder health as seen in cows, further study with larger study sample will help to test this observation.

Results of the teat orifice conformation as shown in Table 2 indicate a predisposition of teat ends to damage under machine milking as compared to hand milking. Over 90% of the does in the latter category had their teats in scale = 1, where the teat orifices were smooth with no evidence of irritation. In comparison, results obtained under the semi-intensive and intensive systems showed that 27% of the teat orifices had a raised ring and 6% bore slight cracks. Under the intensive production system, it was also observed that prolonged attachment of the teat cups onto the udder often occurred during milking after the udder was empty. This may have resulted in over-milking of the udder that could have caused trauma to the teat ends rendering them susceptible to infection.

Correlation between SCC equal to or greater than 750 000 cells per m*l* of milk and presence of infection in goat milk was determined using the Fisher Exact Test for association ($p = 0.2$), under the different production systems. Infection status of the udder was based on growth of bacteria on cultured milk, where presence of growth referred to positive infection status. There was no statistically significant association between the two variables. These results agree with what was observed by previous researchers (Kapture 1980; Poultrel & Lerondelle 1983) that SCC alone could not be relied upon for the prediction of goat udder health.

More than half the does displayed asymmetry of their udder halves, under the intensive system. It is postulated that the asymmetry may have been a result of clinical mastitis in one of the udder halves destroying part of the mammary tissue. A history of frequent cases of clinical mastitis on the farm was revealed from the farm records. It is also postulated that asymmetry can be a genetic udder characteristic in the herd. This could be relevant in future work, as such postulation is not currently supported in either bovine or caprine literature.

In addition, less than half (40%) of the sample doe population under this system had their udders with teat shapes classified as normal, as compared to those under the semi-intensive (60%) or the extensive system (73%). Such features often lead to poor cluster attachment, predisposing the udder to infection. This may occur during milking when one of the teat cups slips off the udder resulting in a sudden break in the vacuum. Milk under high pressure is flushed back onto the teat surface of the other udder half propelling bacteria present on the teat surface up the open teat canal into the teat cistern.

"Firm" udder attachment was noted among goats under the semi-intensive system with 80% of the udders falling in scale 1. With reference to the lactation number and/or parity, it can be stated that most of these goats were mature animals. This exhibits the genetic make-up of the goats as ideal for firm udders consequently reducing susceptibility to trauma and disease.

4.3 Milk Hygiene

Milk hygiene under the different production systems varied greatly. Total bacterial counts (TBC) of raw bulk milk revealed gross contamination of milk produced under the intensive and extensive production systems. The mean TBC were 16 450 CFU/m*l* in the semi-intensive system; 36 300 CFU/m*l* in the intensive system and 48 000 CFU/m*l* in the extensive production system. According to the International Dairy Federation, 1974, milk having TBC values <20 000 CFU/m*l* reflects good hygienic practices (Bramley & McKinnon 1990), implying that proper hygiene was observed in the semi-intensive production system.

From Tables 9 and 10 it can be seen that most of the organisms that were isolated from the bulk milk under the intensive system were the same organisms isolated from milk contact surface swab samples. These were *Pseudomonas aeroginosa, Staphylococcus epidermidis*, and *Aureobacterium* spp. This shows that the machine was a major source of contamination under this system.

This outcome agrees with the statement made by Giesecke *et al*., (1994), that as much as 90% of the total bacterial contamination of the raw bulk milk produced freshly on a farm, often originates from milking installations. This further stresses the value of effective machine cleaning as stated by Giesecke *et al*., (1994). An assessment of the efficiency of the cleaning of the milking machine would enhance future work of this nature.

Under the extensive system coliforms were the most commonly isolated bacteria from the bulk milk. The highest number of coliform population in the study was encountered in this system with an average number of 22 coliform counts per ml of milk. This is in comparison with the situation under the intensive system (15 coliform counts per ml) and the semi-intensive system (7 coliform counts per ml) as shown in Table 9. Since most coliforms are obtained from water as stated by previous authors (Gilmour & Rowe 1981; Sandholm *et al*., 1995b), this variation could be attributed to the quality of water that was from a borehole under the extensive system.

This suggestion is supported by the bacterial quality of the water used under the extensive system that revealed a TBC of 523 CFU/m*l* (legislation standard: 100 CFU/m*l* - Foodstuffs, Cosmetics and Disinfectants Act, 1972). This shows how this farm, like most of the smallholder farms, rely on untreated water supplies from boreholes. Some of these may be contaminated at the source with a wide variety of saprophytic organisms derived from soil and vegetation present. This appears to have been the situation under the extensive production system.

In spite of water used under the semi-intensive being obtained from a borehole with a TBC count of 85 CFU/m*l*, there was less coliform contamination of the raw milk. This may be due to the type of udder preparation carried out which involved dry wiping of the udders with disposable paper. The machine used was also rinsed with water containing a disinfectant. These two factors may explain why there were coliform counts within the safe levels (<20 CC/m*l*). Most bacterial contamination under the semi-intensive system may have been as a result of intramammary infection. On the other hand, udder preparation under the extensive production system was carried out using water without a detergent or a disinfectant. The same quality of water was used to rinse milking equipment after washing. This practice may have contributed to the bacterial load in the raw milk produced. These results clarify the value of potable water in the production of safe milk.

Pseudomonas aeroginosa was isolated only from the pipeline milking machine used under the intensive system. Pseudomonas bacteria are known to be among the most common and widely distributed microbes (Giesecke *et al*., 1994). In the presence of some moisture the pseudomonas bacteria can proliferate under a wide range of conditions. *Pseudomonas aeroginosa* is a Gram-negative rod that is saprophytic and found naturally in soil, water and faeces. In the dairy the most common sources of infection are likely to be contaminated water, soiled milking equipment and unhygienic cleaning and storage facilities for milking utensils (Giesecke *et al*., 1994). *Pseudomonas aeroginosa* can cause severe endotoxaemia and infection may result in a subclinical mastitis with the pathogen persisting in the mammary gland (Sandholm *et al*., 1995b).

Since water examination under the intensive system revealed potable quality, the possible source of *P. aeroginosa* may have been the machine. This is supported by the fact that the organism was only isolated from the pipeline milking machine and not from the bucket type of milking machine. The possibility that the design of the machine provided sufficient moisture for the multiplication of the organism was higher than with the bucket type machine. This is further emphasised by the fact that *P. aeroginosa* was isolated from the pipeline milk surface only as compared to other milk surfaces. The importance of an effective cleaning process need not be further emphasized. Since goats are normally milked twice a day, there is therefore, need for immediate cleaning of the machine after milking so as to provide sufficient time for drying before the next milking. Presence of moisture promotes growth of most microbes.

Enterococcus faecalis (*Streptococcus faecalis)* was another organism isolated from milk obtained under the intensive production system. There is some evidence that alpha haemolytic streptococci, such as *E. faecalis* can cause outbreaks of gastro-enteritis if present in large numbers in a food. Its presence in food and water is associated with faecal contamination (Gilmour & Rowe 1981). A possible source of contamination could be the people's hands, and an assessment of the understanding and application of personal hygiene of the people milking the goats should not be overlooked in future work of this nature.

Raw milk among other foods has been incriminated as a source of infection. Enterotoxins that give clinical signs similar to those seen in staphylococcal food poisoning are thought to be involved. Vomiting, abdominal pain and/or diarrhoea are the signs seen. In most cases, similar strains of streptococci to those isolated from patients have been isolated from food-handlers. It is thought that a food-handler with a streptococcal throat infection may be the reservoir of infection (Quinn *et al*., 1994). This may include milkers.

Since this organism was isolated from milk obtained under the intensive production system, where milking is by machine, contamination could have occurred during the process of udder preparation. Preparation involved washing the teats with cold water using a hosepipe and then drying them with disposable paper towels. The hand held hosepipes could have been a potential source of contamination to the milk. Hand held hosepipes must not touch the floor (Giesecke *et al*., 1994), and they should be handled in such a way that they hang clear of the floor. They should be fitted with a suspension hook or ring at the hand-held end or be on a retractable spring coil. This unfortunately was not the case, as the hosepipe was left on the floor in between use.

Milk hygiene was monitored on the smallholder farm, under the extensive production system, where the method of milking was changed from milking by hand to the use of the bucket form milking machine. There was higher environmental contamination observed during the hand milking regime (58 000 CFU/m*l*) as opposed to the situation when the bucket form milking machine was in use (750 CFU/m*l*). These results support the observation reported by Zeng & Escobar (1995) that with hand milking, the chances of environmental contamination are higher than in the case of machine milking.

Coliforms made up the bulk of bacterial contamination of the milk obtained using hand milking. As was discussed earlier, this could be attributed to the water that was also obtained from the borehole with a total bacterial count of 240 CFU/m*l*.

In addition, it was noticed that, unlike the situation under the hand-milking regime, udder preparation involved use of water containing a disinfectant to clean the udder before attaching the milking machine. This may further explain why environmental contamination reduced remarkably.

Though coliform tests were performed on bulk milk as recommended by legislature, they are of limited value in raw milk (Gilmour & Rowe 1981). No coliforms are particularly heat resistant, and thus, all are easily eliminated from milk by pasteurisation. Coliform tests are henceforth, of more value when carried out on pasteurised milk and other milk products to assess the level of post-pasteurisation contamination, or inadequate pasteurisation. Recommendation is made by Williams & Nottingham (1990), to modify the phosphate test commonly used for post-pasteurisation contamination of cow milk to suit goat milk. This was modified to the Aschaffenburg and Mullen alkaline phosphatase test for goats' milk.

However, due to the ability of coliforms to ferment lactose within 48 hours at 37°C, they are accused of causing spoilage of raw milk. Their reduction in raw milk is, therefore, highly recommended. Chlorination by dosing with hypochlorite is frequently recommended for water of unsatisfactory bacteriological quality used for final rinsing of equipment, to reduce bacterial multiplication.

Bacillus cereus was isolated from milk obtained during the use of the bucket type milking machine. *Bacillus cereus* is a large Gram-positive, spore-forming rod that is facultatively anaerobic. It grows within a temperature range of 10 - 48°C with an optimum range between 28 - 35°C. The endospores are formed freely under conditions favourable for growth. These endospores are widespread in the environment, found in the soil, dust and water. They can be responsible for spoilage of milk and milk products. *Bacillus cereus* can cause two forms of food poisoning, the diarrhoeal syndrome caused by a heat labile enterotoxin and an emetic syndrome involving a very heat stable enterotoxin that is not destroyed until after 90 minutes at 121°C. However, no records could be found of *Bacillus cereus* causing mastitis in goats.

4.4 Milk Production

The ability of a dairy animal breed to produce under conditions that are less favourable than its optimal production conditions should be determined (Van den Berg 1990). The questionnaire revealed that the Saanen was the main dairy goat breed reared. Performance of the Saanen reported under the extensive production system varied from a lactation period of three months (small-holder farms) to ten months (commercial farm). This latter duration was in agreement with what Gall (1997) reported, i.e. a lactation period of 270 days.

A similar performance was reported under the intensive and semi-intensive production systems with lactation periods of nine months (270 days) in both cases. This variation could be attributed to the difference in management that depended on the resources available to the farmer.

In this study it was shown that farmers under the extensive production system grazed their animals on privately owned land. Since goats are small, it is possible for farmers to keep a large herd in a small area (Boylan *et al*., 1996).

In addition, the feeding habits of goats as excellent converters of roughage and agricultural or crop by-products, are particularly significant in areas where quantity and quality of feeds are low. Consequently, they give value to land not fit for arable farming (Devendra & Burns 1983; Van den Berg 1990). They are less demanding in their feed supply compared to other dairy animals (Devendra & Burns 1983).

However, goats will not be able to produce to their full potential from forage alone (Mowlem 1988). This was illustrated by the results obtained in the study showing the difference in milk yield and lactation period recorded for the same breed of animal. Goats that relied solely on range had a lactation period of three months (smallholder farms) and a maximum milk production of 1.5 kg per day per goat. This was as opposed to the situation where supplementation occurred (commercial farm), peak milk yield of 6 kg per day per goat was reported.

This was further illustrated under the semi-intensive system where supplements were provided in addition to grazing and a daily peak yield per goat attainable was reported by the farmer to be as high as 9 kg. There is, therefore, need for supplement feeding of lactating goats in order to optimise milk yield.

The amount of water consumed will affect the amount of milk produced. A goat can drink from 4 - 18 litres of water a day (Mowlem 1988). A lactating goat requires 1.43 litres of water per one kg of milk produced. Water shortage was reported as one of the problems encountered under the extensive system in the developing areas. This more than likely contributed to the lower milk yields observed.

Another factor that contributed to the amount of milk produced was the parity of the animal. A significant relationship was noted between the increase in parity (lactation number) and increase in the amount of milk produced by the Saanen goats in the study (Spearmans correlation = 0.421p>0.0061). These results are similar to what other authors (Dulin *et al.*, 1983; Randy *et al*., 1988), reported. They also observed that first lactation Alpine does reached peak yield 8 days post-partum at lower levels (3.32 kg) than older does (5.36 kg) with a peak yield 31 days post-partum.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the research area which was in and around Pretoria, located in the Gauteng Province, it was revealed that there were three types of dairy goat production systems just like was described by Aich *et al*., (1995). These are the extensive, semi-intensive and intensive production systems.

The Saanen breed is the most commonly reared dairy goat breed. Performance of the Saanen does with regard to the amount of milk produced and duration of the lactation period of individual goats varied under the different production systems. The amount of milk and consequent lactation period was dependent on whether the goats had supplemented feed or not. A significant correlation between increase in the amount of milk produced and high lactation number (parity) was observed.

Study of udder health revealed intramammary infection prevalence of 33.3%. The lowest intra-mammary infection was found among goats under the extensive system with 13.3% udder infection rate, as compared to 40% and 46.7% infection rates under the intensive and semi-intensive production systems respectively.

Coagulase negative staphylococci were the main cause of bacterial udder infection with a prevalence of 86.6% of the infected udder halves. These consisted of *Staph. epidermidis, Staph. simulans* and *Staph. intermidius.* The remaining 13.4% of the udder half infection was due to *Staph. aureus.* Pathogens such as *Staphylococcus aureus, Bacillus cereus* and *Enterococcus faecalis,* were associated with use of milking machines.

Within the study period of early lactation, it was observed that somatic cell counts alone could not be relied upon for the prediction of goat udder health. More reliable was the isolation of bacteria from udder milk samples. This research showed that there was no statistically significant association between SCC equal to or greater than 750 000 cells per ml of milk and the presence of infection in goat milk obtained from individual goat halves under the different

production systems. Of the goats evaluated, 26% that had infected udders revealed infection in both halves of the udder.

Good udder conformation was found associated with hand milking as opposed to machine milking. Most notable was the difference in the lower degree of teat damage, a feature that might be related to the lower rate of udder infection. Fewer cases of teat damage were found associated with hand milking, compared to the situation where machines were in use. Only 7% of the does under the extensive system had teat orifices with a raised ring, compared to does under the semi-intensive and intensive systems (27%). Whereas no cracks in teat orifices were observed on the does under the extensive system, 6% of the teat ends were identified, with slight cracks among the does milked using machines.

Environmental contamination varied between the different production systems that implemented different milking methods. Milking was done by hand under the extensive system, the bucket form milking machine was used under the semi-intensive system while the pipeline machine was used in the intensive system. Total bacterial counts of the raw bulk milk revealed higher environmental contamination of milk produced under the extensive (48 000 CFU/m*l*) and intensive (36 300 CFU/m*l*) production systems, compared to the situation under the semi-intensive system (16 450 CFU/m*l*).

A transition from milking by hand to the use of the bucket type of milking machine was monitored on a smallholder farm under the extensive production system to determine the difference in milking hygiene. A higher level of bacterial concentration in the bulk milk, an indication of the level of environmental contamination during milk harvesting, was realised in the case where milk was harvested by hand (58 000 CFU/ml), compared to the situation when the bucket type milking machine was used (750 CFU/ml). This supports the report made by Zeng & Escobar (1995), that, with hand milking, the chances of environmental contamination are higher than in the case of machine milking.

In addition, the bacterial load present in the bulk milk obtained from the extensive production system consisted of coliforms. This was attributed to the water used on the farm obtained from a borehole that was not potable in quality. Spoilage of raw milk is often attributed to coliforms, because of their ability to ferment lactose within 48 hours at 37°C. Their presence in raw milk should be significantly reduced by the use of potable water. This was achieved

on one of the farms by adding disinfectant to the water used to clean the udder during udder preparation, and also to the water used for the final rinse of milking equipment.

5.2 Recommendations

The conclusions above show that fundamental principles of producing safe and clean milk under the extensive production system, where milking was done by hand, were identical to those under the intensive and semi-intensive production systems where machines were used. However, the implementation of basic principles of public health practice in dairy routines encountered certain obstacles in the former situation.

Demonstration of hygienic principles and practices may overcome these obstacles that would otherwise be detrimental to the safety of milk. The emerging smallholder farmer needs to be trained in good agricultural procedures (GAP) with an emphasis on the role of good hygiene management. Central to this task, however, is an understanding by the extension officer of the characteristics of the farmer's enterprise and the resources available.

In order to illustrate this, from the questionnaire it was discovered that most of the smallholder farmers could not afford to use disinfectants, yet the water available was not potable in quality. In such instances, some form of heat treatment or acidification of milk should be promoted instead of drinking raw milk. Pasteurisation, for example, will destroy possible contaminants of which coliforms were found to be the most predominant, and in so doing possible food poisoning or spoilage of raw milk is avoided. Stimulation of dairy goat farming among smallholder farmers, particularly in developing areas, will be enhanced if the system of choice is easily adaptable.

From the study, it appears that the most favourable production system to recommend initially, in order to facilitate smallholder dairy goat farming, is the extensive production system, for the following reasons:

- It does not require drastic infrastructural modifications.
- It is not labour intensive, and the farmer is capable of full management.
- Hygiene can be enhanced with extension services regarding proper milking procedures.
- Prevalence of pathogens (*S. aureus, B. cereus* and *E. faecalis*) can be minimal.

However, the questionnaire reveals that other problem areas, such as disease control, predation, feed supplementation, would also have to be investigated in more detail.
Prior experience gained (Mann, 1962), proved that not only was it possible to produce and handle milk on a large-scale (commercially), but also under conditions prevalent in most of the less developed areas of the world. This is an effective means of improving the general standard of living among the rural population through the creation of reliable milk production.

5.3 Need for Further Work

Due to financial constraints, the study was carried out only in the early stage of lactation, analysing different variables, viz.: udder health, milking hygiene, SCC and milk production under the different production systems. There is a need to study the temporal distribution of these different variables throughout the entire lactation period. This will provide a wider database for future extension work.

Knowledge of the prevalence of other pathogens such as mycobacteria, *Brucella melitensis*, salmonella and campylobacter organisms in goat milk is required. Due to lack of the required resources this analysis could not be done. Future study in this respect would be considered informative.

Though the sample size was chosen as recommended by the statistician, it resulted in insufficient numbers required for statistically significant conclusions to be carried out in relation to certain variables. This problem was encountered when no significant conclusion could be made from the study of the udder conformation in relation to udder health, and SCC and this was attributed to the limited number of does making up the sample size of the study. It is, therefore, recommended that future study be carried out using a much bigger sample size.

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APPENDIX 1:

CONFIDENTIAL QUESTIONNAIRE: DAIRY GOAT FARMING

A. OWNER'S PARTICULARS

1. Personal Details:

Name:	Male		Female	
	Age		Age	
Village:				

2. Address:

Physical	
Postal	
Telephone	
Contact person	

3. How did you acquire the goats?

	Yes	No	Number
Bought			
Inherited			
Lobola			
Other (specify)			

4. How many goats did you start with?

Bucks (males)			
Does (females)			

5. Which breeds were they?

Breed	Yes	No
Local		
Exotic		
Cross-breed		
Not sure		

6. For how long have you reared goats?

Years		months	

7. How many goats do you have currently?

Bucks (male)				Does (female)			

B. MANAGEMENT

8. Do you keep your goats in a house?

Yes		No	

If “no”, go to Question 13.
If “yes”, state the time.

Night only	
All day	
In winter	
Other (specify)	

9. Are the goats fed when housed?

Yes		No	

If yes, list the types of feed you use.

_____

_____

_____

10. Do the goats have access to drinking water in their houses?

Yes		No	

11. Where do you get water from?

Well	
Tap water	
Dam	
Borehole	
Other (Specify)	

12. What kind of goat houses do you have?

Concrete	
Grass	
Iron sheets	
Other (Specify)	

13. Where do you graze your goats?

	Yes	No
Planted pasture		
Private grazing		
Communal grazing		

14. When do you graze your animals?

Time		Why
Morning only		
Evening only		
All day		

15. Are the goats given any supplement feed in addition to grazing?

Yes		No	

16. If yes, when do you supplement and why?

Summer		
Autumn		
Winter		
Spring		
Night		
Other (specify)		

17. What do you use to supplement and when?

Licks (salt)	Concentrate	Roughage	S = summer; A = autumn W = winter; Sp = spring

18. Where do you get your supplementary feed from?

Co-op	
Home made	
Other (specify)	

19. Do you wean the kids?
If not, go to question 20.

Yes		No	

20. At what age do you wean the kids?

Weeks	

21. Why do you not wean the kids?

Kids need the milk	
Lack of appropriate facilities	
Not aware of proper time	

C. MILKING

22. Who does the milking?

Farmer		Children (Age)	
Worker		Any one	

23. How do you milk the goats?

Hand milking:			Machine milking:		
i)	Plastic bucket		i)	Bucket system	
ii)	Stainless steel		ii)	Direct-to-line system	
iii)	Other (specify)		iii)	Recorder jar/Meter system	

24. Where do you do the milking?

Parlour	
Kraal	
Outside	
Other (specify)	

25. How often?

	Time	
	Morning	Evening
Once a day		
Twice a day		

26. How many goats do you milk?

27. How much milk is obtained per day?

Average production per day	M*l*
Individual goats	
Herd Production	

28. For how long do your goats produce milk every year?

Months	

D. HYGIENE

29. What do you use for cleaning your equipment?

Hot water		Cold water and detergent	
Hot water and detergent		Cold water and detergent	
Hot water & disinfectant		Other (specify)	

30. What kind of sanitisers do you use?

Disinfectant: _____

Detergent: _____

31. Do you do any of the following procedures?

Procedure	Yes	No	How
Washing hands			
Cleaning the udder			
Pre-dipping			
Drying teat			
Fore-milk stripping			

32. What do you use the milk for?

	Yes	No
Home consumption		
Sell it		
Other (specify)		

33. How is the milk processed?

Process	Yes	No	How
Freezing			
Fermentation			
Pasteurisation			

34. Which are the major diseases encountered?

_____

_____

_____

35. Which are the major problems you have encountered? (Scale: 1 - 10)

Problem	Scale	Specify
Water		
Feeds/ Supplements		
Grazing land		
Diseases		
Mastitis		
Disinfectants		
Theft / Predation		
Poor milk yield		
No market for milk		
Maintenance of equipment		

36. Any comments?

_____
_____
_____
_____

Thank you very much for your contribution. May God bless the work of your hands.

DATE: _____

APPENDIX 2:

INDIVIDUAL GOAT CHARTS

Extensive Production System

DOE IDENTI-FICATION	LACTATION NUMBER (Parity)	UDDER SYMMETRY	UDDER ATTACHMENT	TEAT SHAPE	TEAT ORIFICE
1	Not disclosed	S	1	N	1
2	Not disclosed	S	1	N	1
3	Not disclosed	S	2	CD	1
4	Not disclosed	S	1	CD	2
5	Not disclosed	S	1	CD	1
6	Not disclosed	S	1	N	1
7	Not disclosed	S	3	N	1
8	Not disclosed	S	1	N	1
9	Not disclosed	AS	2	N	1
10	Not disclosed	S	1	N	1
11	Not disclosed	AS	4	GD	1
12	Not disclosed	S	2	N	1
13	Not disclosed	S	1	N	1
14	Not disclosed	S	1	N	1
15	Not disclosed	AS	3	N	1

Legend: Interpretation of Individual Goat Chart

- Udder Symmetry: S = symmetrical AS = asymmetrical
- Udder attachment: 1 – 3 = Firm attachment (1) to loose attachment (3)
- Teat shape: N = normal; CD = conically dilated; GD = generally dilated.
- Teat orifice: 1 – 3
  - ə 1 = teat end sphincter is smooth with no evidence of irritation
  - ə 2 = teat end has a raised ring
  - ə 3 = teat end sphincter is roughened with slight cracks, but no redness is present.

Semi-Intensive Production System

DOE IDENTI-FICATION	LACTATION NUMBER	UDDER SYMMETRY	UDDER ATTACHMENT	TEAT SHAPE	TEAT ORIFICE
1	5	AS	2	CD	1
2	4	S	1	N	1
3	3	S	1	N	1
4	3	S	1	N	2
5	2	S	1	N	1
6	4	S	1	N	2
7	4	S	1	N	1
8	2	AS	1	CD	1
9	5	S	1	GD	1
10	4	S	2	CD	1
11	3	S	1	CD	2
12	2	S	1	N	1
13	3	S	1	N	3
14	2	S	1	N	1
15	3	AS	3	GD	2

Legend: Interpretation of Individual Goat Chart

- Udder Symmetry: S = symmetrical AS = asymmetrical
- Udder attachment: 1 – 3 = Firm attachment (1) to loose attachment (3)
- Teat shape: N = normal; CD = conically dilated; GD = generally dilated.
- Teat orifice: 1 – 3
  - ə 1 = teat end sphincter is smooth with no evidence of irritation
  - ə 2 = teat end has a raised ring
  - ə 3 = teat end sphincter is roughened with slight cracks, but no redness is present.

Intensive Production System

DOE IDENTI-FICATION	LACTATION NUMBER	UDDER SYMMETRY	UDDER ATTACHMENT	TEAT SHAPE	TEAT ORIFICE
1	3	AS	2	N	1
2	3	AS	2	GD	2
3	3	AS	3	CD	1
4	3	S	2	GD	2
5	5	AS	3	CD	3
6	5	AS	3	CD	1
7	6	AS	2	GD	2
8	1	S	1	GD	1
9	6	AS	4	N	2
10	1	S	1	N	1
11	1	AS	1	CD	1
12	2	S	1	N	1
13	2	AS	1	N	1
14	1	S	1	CD	1
15	1	S	1	N	1

Legend: Interpretation of Individual Goat Chart

- Udder Symmetry: S = symmetrical; AS = asymmetrical
- Udder attachment: 1 – 3 = Firm attachment (1) to loose attachment (3)
- Teat shape: N = normal; CD = conically dilated; GD = generally dilated.
- Teat orifice: 1 – 3
  - ə 1 = teat end sphincter is smooth with no evidence of irritation
  - ə 2 = teat end has a raised ring
  - ə 3 = teat end sphincter is roughened with slight cracks, but no redness is present.

APPENDIX 3

UDDER HALF SOMATIC CELL COUNT (SCC) AND INFECTION STATUS

Extensive Production System

GOAT IDENTITY	UDDER HALF	MEAN SCC (x 1 000/m*l*)	INFECTION STATUS
1	R	104	-
	L	121	-
2	R	200	-
	L	153	-
3	R	120	-
	L	185	-
4	R	295	-
	L	376	-
5	R	52	-
	L	810	+
6	R	104	-
	L	69	-
7	R	1904	-
	L	1628	-
8	R	51	-
	L	47	-
9	R	577	-
	L	446	-
10	R	55	-
	L	50	-
11	R	749	-
	L	1 011	-
12	R	687	+
	L	64	-
13	R	71	-
	L	141	+
14	R	532	+
	L	691	-
15	R	1 830	-
	L	477	-
Mean Bulk Milk SCC = 518 000 cells/ml			

Semi-intensive Production System

GOAT IDENTITY	UDDER HALF	MEAN SCC (x 1000)	INFECTION STATUS
1	R	380	+
	L	627	-
2	R	266	+
	L	306	+
3	R	121	+
	L	112	-
4	R	79	-
	L	65	-
5	R	689	+
	L	493	-
6	R	258	+
	L	56	-
7	R	801	-
	L	561	+
8	R	130	-
	L	80	-
9	R	54	+
	L	91	+
10	R	139	+ (*S. aureus*)
	L	133	+ (*S. aureus*)
11	R	303	+
	L	129	-
12	R	21	-
	L	27	-
13	R	191	-
	L	158	-
14	R	85	-
	L	114	-
15	R	216	+
	L	100	+
Mean Bulk Milk SCC = 210 000 cells/ml			

Intensive Production System

GOAT IDENTITY	UDDER HALF	MEAN SCC (x 1 000)	INFECTION STATUS
1	R	69	-
	L	12	-
2	R	873	+
	L	140	-
3	R	105	-
	L	321	-
4	R	532	+
	L	193	+
5	R	1011	+(S. aureus)
	L	470	-
6	R	213	-
	L	2028	+(*S. aureus*)
7	R	56	+
	L	38	+
8	R	747	-
	L	226	+
9	R	201	-
	L	1166	+
10	R	68	-
	L	126	-
11	R	331	-
	L	195	-
12	R	1561	+
	L	563	-
13	R	534	-
	L	76	+
14	R	1055	+
	L	218	-
15	R	494	-
	L	907	-
Mean Bulk Milk SCC = 872 000 cells/ml			