Microbiological quality of goat's milk obtained under different production systems

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ABSTRACT

In order to determine the safety of milk produced by smallholder dairy goat farms, a farm-based research study was conducted on commercial dairy goat farms to compare the microbiological quality of milk produced using 3 different types of dairy goat production systems (intensive, semi-intensive and extensive). A survey of dairy goat farms in and around Pretoria carried out by means of a questionnaire revealed that most of the smallholder dairy goat farms surveyed used an extensive type of production system. The method of milking varied with the type of production system, *i.e.* machine milking; bucket system machine milking and hand-milking, respectively. Udder half milk samples ($n = 270$) were analysed, of which 31.1 % were infected with bacteria. The lowest intra-mammary infection was found amongst goats in the herd under the extensive system (13.3 %), compared with 43.3 % and 36.7 % infection rates under the intensive and semi-intensive production systems, respectively. *Staphylococcus intermedius* (coagulase positive), *Staphylococcus epidermidis* and *Staphylococcus simulans* (both coagulase negative), were the most common cause of intramammary infection with a prevalence of 85.7 % of the infected udder halves. The remaining 14.3 % of the infection was due to *Staphylococcus aureus*. Bacteriology of bulk milk samples on the other hand, showed that raw milk obtained by the bucket system milking machine had the lowest total bacterial count (16 450 colony forming units (CFU)/mℓ) compared to that by pipeline milking machine (36 300 CFU/mℓ) or hand-milking (48 000 CFU/mℓ). No significant relationship was found between the somatic cell counts (SCC) and presence of bacterial infection in goat milk. In comparison with the herds under the other 2 production systems, it was shown that dairy goat farming under the extensive production system, where hand-milking was used, can be adequate for the production of safe raw goat milk.

Key words: goat milk, milk safety, production systems, smallholder farmers.

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INTRODUCTION

Goat milk and its products are popular among health conscious consumers and certain ethnic groups[11]. A recent survey showed that there are approximately 42 registered commercial dairy goat farmers in South Africa, 19 of whom are in Gauteng province[1]. Donkin[5] identified a need for increased investments in dairy goat schemes to support and expand household milk supply and promote small-scale dairy enterprises at the village level. It is also important to ascertain whether the small-scale dairy enterprises composed of smallholder farmers can compete favourably in the production of safe goat milk.

Jaubert & Kalantzopoulos[8] stated that the 'quality of goat milk may be defined as its potential to undergo technological treatment and result in a product which lives up to the consumer's expectations in terms of health (nutritional value), safety (hygienic quality) and satisfaction (sensory attributes)'.

Managing the safety of milk involves controlling the various sources of contamination, which could be endogenous (organisms entering the milk *in vivo*) or from some external source (exogenous) after milk had been removed from the udder[8]. Some of the diseases that can be transmitted to humans from milk include salmonellosis, tuberculosis, brucellosis, listeriosis, Q fever, toxoplasmosis, streptococcal and staphylococcal infections and campylobacter infections[10]. Mastitic agents in goats (endogenous contamination), include coagulase-negative staphylococcus species; *Staphylococcus aureus* and streptococcus species, *e.g. Streptococcus agalactiae; E. coli* and *Pseudomonas* species, and all have been isolated from goat milk[13].

While some may consider coagulase-negative *Staphylococcus* intramammary infections to be co-incidental and an environmental contaminant (non-pathogenic) in goats, others contend that these infections may become chronic and lead to udder sensitivity, elevated somatic cell counts (SCC) and decreased milk production[15]. *Staphylococcus aureus* has been identified as the most pathogenic staphylococcal infection both in its subclinical and clinical form in the caprine udder[9]. In this study nearly all staphylococci from subclinical cases could be isolated from goat milk removed from the udder[9]. This shows that udder disease remains widespread and consumers of raw milk still run the risk of food poisoning[2].

MATERIALS AND METHODS

Six dairy goat farms were identified in the study area, located in Winterveld, Oskraal, and Garankuwa (northwest of Pretoria); Skeerpoort (southwest of Pretoria); Lynnwood and Garsfontein (east of Pretoria). A questionnaire was completed by means of a structured interview with the farmers to obtain information regarding dairy goat farming practices and goat milk production systems. With this information, the farms were classified into 3 production system categories, namely, intensive (zero grazing) , semi-intensive (grazing coupled with supplementary feeding), and extensive (free-range grazing without supplementary feeding). The extensive system was the most commonly practised production system on the farms surveyed and the predominant dairy breed was the Saanen goat. For this reason only one farm on which milk was produced commercially for human consumption, was selected in each category for sampling.

The field study had 2 phases, the 1st involving the analysis of milk obtained from the 3 dairy goat farms under the different production systems and the 2nd a comparative analysis of milk harvested from the same farm, using 2 different milking methods.

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Samples were taken as follows on the farms:

- Udder half milk samples, taken aseptically, for SCC, bacterial counts and bacterial identification to assess udder health.
- Bulk milk samples for bacterial identification, coliform and *E. coli* type 1 counts and total bacterial count (TBC) to assess environmental and milking hygiene.
- Bulk milk samples for SCC to assess the level of herd udder inflammation.
- Equipment swab samples for bacterial identification, coliform and *E. coli* type 1 counts and standard colony counts to assess milking hygiene and cleaning efficiency.
- Water samples for hardness testing (testing strips) to assess effect on cleaning efficiency.
- Water samples for standard colony counts and coliform and *E. coli* type 1 counts to assess bacteriological quality of the water.

Milk samples

Each herd was visited 3 times with a 7-day interval, as stipulated in the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972)[6]. Sampling was done in the 1st stage of lactation. Ninety udder half milk samples were obtained from each farm. The origin of the udder half milk samples is shown in Table 1. In total, 270 udder half milk samples were taken for analysis from the animals on the 3 selected farms.

In addition, 1 bulk milk sample, 1 water sample and swab samples of the milk contact surfaces of milking equipment were taken from each farm during each visit.

Milk sample analysis

Bacteriological tests on both the udder half samples and the bulk milk samples were carried out as stated in the Foodstuffs, Cosmetics and Disinfectants Act, 1972, (Act No 54 of 1972)[6]. Udder half sample analysis was achieved using the prescribed blood tryptose agar culturing method. Colony characterisation after incubation of the culture was done, using the colour, shape, texture and the presence of haemolysis of the colonies to identify the organism. Quantitative identification of the colonies was also done and finally the identity of the organisms was confirmed.

The potassium hydroxide test was carried out to differentiate between Gram positive and Gram negative bacteria respectively. The catalase test differentiated between staphylococci (catalase positive) and streptococci. *S. aureus* was differentiated from other staphylococci that are coagulase negative using the staphylase test.

Table 1: **Origin of udder half milk samples.**

Production system	Herd size	Number of goats sampled	Number of udder halves	Total number of udder half samples (× 3 visits)
Intensive	66	15	30	90
Semi-intensive	45	15	30	90
Extensive	66	15	30	90
Total number of udder half milk samples				270

Bulk sample milk analysis included the standard colony count using the dry re-hydrated film method, as prescribed by the manufacturers (3M Microbiological Products, USA). 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 mℓ of milk. The value obtained was multiplied by the factor of 3 and 2, respectively, and the average value recorded. This then gave an estimate 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.

Coliform and *E. coli* counts were evaluated with the dry rehydrated film method. 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.

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 0.061 g of the $K_2Cr_2O_7$ was mixed thoroughly in 51 mℓ of udder milk samples by inverting each test tube 5 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 $\mu\ell$ of the milk sample was then drawn from the milk sample for SCC analysis.

Swab samples from the milk contact surfaces of the milking equipment in each of the milking systems were soaked in a phosphate buffer (*c.* 30 minutes) and a 1 mℓ sample from this dilution was cultured on 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)[17]. Identification of quantitatively dominant colonies was carried out, with further testing for *Pseudomonas* species. Bacterial enrichment was done on the Methyl Red Voges Proskauer (MRVP) broth as stated by Clemons & Gadberry (1982)[3].

Data analysis

Analysis of variance was carried out within each production system to determine variation in udder health. Mean differences of the bulk milk bacterial counts gave an indication of the difference in milking hygiene under the different systems. Correlation between somatic cell count and presence of infection in udder half samples was determined using Fisher's exact test.

RESULTS AND DISCUSSION

Milk production

The amount of milk produced per goat per milking ranged from 0.10 ℓ (extensive: mean 1.07 ℓ) to 2.90 ℓ (semi-intensive: mean 1.25 ℓ) (Table 2).

Spearman's correlation value was 0.421, showing a correlation between increase in parity and the amount of milk produced ($P \geq 0.0061$).

Udder health

The percentage infection rate within the production systems is reflected in Table 3.

Table 2: **Variation in lactation number and amount of milk produced under the semi-intensive system** (records more complete)**.**

Lactation number	Amount of milk produced per goat per milking (litres)			
	Mean	Standard deviation	Minimum	Maximum
1	1.08	± 0.10	1.00	1.20
2	1.43	± 0.50	0.50	1.80
3	1.55	± 0.26	1.00	2.00
4	1.37	± 0.61	0.30	2.19
5	2.26	± 0.39	1.70	2.90

Staphylococcus intermedius (coagulase positive), *Staphylococcus epidermidis* and *Staphylococcus simulans* (both coagulase negative), were the most common cause of intramammary infection with a prevalence of 85.7 % of the infected udder halves sampled (see Table 4). It has been noted that under certain conditions the action of the milking machine can be responsible for propelling bacteria through the teat duct[12]. This may be one of the reasons why *S. aureus* was isolated in cases where milking machines were used, but the low number of cases involved (14.3 %) may preclude such a general conclusion.

Table 3: **Percentage infection rates of udder halves within the 3 production systems.**

Herd	System	Infection rate
A	Extensive	4 udder halves: 13.3 %
B	Semi-intensive	11 udder halves: 36.7 %
C	Intensive	13 udder halves: 43.3 %

Table 4: **Bacterial infections in udders of goats from the 3 commercial dairy herds.**

	Dairy goat herds				
	A	B	C	All herds	
Number of halves examined:	30	30	30	90	%
Infection status of halves:					
Negative	26	19	17	62	68.9
Positive				28	31.1
Other staphylococci*	4	9	11	24	85.7
Staphylococcus aureus	0	2	2	4	14.3
Streptococci	0	0	0	0	0
Coliforms	0	0	0	0	0

*Coagulase negative staphylococci (*S. epidermidis* and *S. simulans*); coagulase positive staphylococci (*S. intermedius*).

Milk hygiene

Aerobic culturing of the milk samples was carried out. The organisms isolated were recorded ranging from the most common to the least common, as shown in Table 5.

The lowest environmental contamination was found to be in the herd classified as having a semi-intensive production system in comparison with the herds in the other 2 systems. The total bacterial counts revealed that there was reduced environmental contamination when using the bucket-system milking machine for milking (16 450 CFU/mℓ) as compared with the pipeline system (36 300 CFU/mℓ) or hand-milking (48 000 CFU/mℓ). The milking method rather than the farming system is more likely to affect the quality of milk produced.

The largest variety of contaminating organisms was found in the pipeline milking machine in the herd under the intensive production system and the lowest variety from the bucket contact surface used in the extensive system. This relates to the efficiency of the cleaning procedures.

Pseudomonas aeruginosa was isolated only from the pipeline milking machine and from within the milk pipeline. *Pseudomonas* bacteria are known to be among the most common and widely distributed microbes[7]. In the presence of some moisture the *Pseudomonas* bacteria can proliferate under a wider range of conditions. In the dairy, the most common source of infection is contaminated water, soiled milking equipment and unhygienic cleaning and storage facilities for milking utensils[7].

Coliforms were the most common source of bacterial contamination of the milk obtained in the herd under the extensive system, with a coliform count of 22 CFU/mℓ of milk as compared to the intensive system (15 CFU/mℓ), and the semi-intensive system (7 CFU/mℓ) (Table 5). This appears to have been due to the water used. Water was obtained from a borehole under the extensive and semi-intensive production systems and the total bacterial counts were 523 CFU/mℓ and 85 CFU/mℓ of water, respectively. The recommended limit, according to the South African Bureau of Standards Guideline, is 100 CFU/mℓ.

Water, without a detergent, was used for udder preparation in the herd under the extensive production system, whereas in the herd under the semi-intensive system dry paper wiping was used. In the herd under the extensive production system, milking equipment was rinsed with water containing no disinfectant, but in the herd under the semi-intensive system, a disinfectant was used. This practice may have contributed to the bacterial load in the raw milk produced. With hand-milking the chances of contamination may be even higher than machine milking[18].

Chlorination using hypochlorite is frequently recommended to reduce bacterial multiplication in water of unsatisfac-

Table 5: **Bacteria isolated from bulk milk samples from 3 different production systems.**

Herd	Bulk milk vessel	Mean milk temperature (°C)	Organisms isolated	Average CC* (standard <20)	Average TBC† (standard <50 000 CFU/mℓ‡)
A	Bulk tank	4	*Enterobacter* spp. *Escherichia coli* (rough)	22	36 300 CFU/mℓ
B	Plastic bucket	27	*Enterococcus* spp. *Staph. epidermidis* *Staph. intermedius* *Enterobacter* spp.	7	16 450 CFU/mℓ
C	Bulk tank	3	*Enterococcus faecalis* *Staph. epidermidis* *Bacillus* spp. *Pseudomonas* spp. *Aureobacterium* spp.	15	48 000 CFU/mℓ

*CC = coliform counts; †TBC = total bacterial counts; ‡CFU = colony-forming units.

Table 6: **Bacteria isolated from the inner surfaces of milking utensils under the different production systems.**

Production system	Bacteria isolated	Source
Intensive (pipeline milking machine)	*Aureobacterium* spp. *Staphylococcus epidermidis* *Pseudomonas aeruginosa*	In-line filter
	Aureobacterium spp. *Staphylococcus* spp.	Teat cup liner (rubber)
	Staphylococcus spp. *Pseudomonas* spp.	Teat cup rim
	Klebsiella oxytoca	Metallic bucket (inner surface)
Semi-intensive (bucket-system milking machine)	*Chryseobacterium meningosepticum* *Acinetobacter wolffii* *Enterobacter* spp.	Teat cup liner (silicon)
Extensive (hand-milking)	*Enterococcus* spp. Non-haemolytic *Staphylococcus* spp.	Plastic milking bucket (inner surface)

Table 7: **Comparison of bacterial infection in udders of goats from the same smallholder dairy farm, using different milking methods.**

	Milking methods	
	Hand-milking	Bucket system
Number of halves examined:	**12**	**33**
Infection status of halves:		
Negative	8	28
Coagulase-negative staphylococci	8	4
Staphylococcus aureus	0	1
Streptococci	0	0
Coliforms	0	0

tory bacteriological quality used for final rinsing of the milking equipment. Bacteria isolated from the inner surfaces of milking utensils under the different production systems are listed in Table 6.

Somatic cell counts

According to the Foodstuffs, Cosmetics and Disinfectants Act, 1972, (Act No. 54 of 1972)[6] SCC higher than 750 000 cells/mℓ in goat milk indicates that it is not fit for human consumption.

It is not clear on what basis this assumption has been made, because this and other research do not support it[16,18]. The correlation between SCC equal to or greater than 750 000 cells/mℓ of the udder half milk samples and presence of infection in the milk was assessed using the Fisher's exact test for association under the different production systems. Infection status of the udder was considered positive, where bacterial growth was identified from cultured milk samples. There was no significant relationship found between the SCC and udder infection in the herds studied ($P = 0.2$).

Follow-up study

A comparative study to assess the effect that a change in milking systems had on the microbial quality of milk produced at the smallholder dairy farm under the extensive production system was studied, with the following results (Table 7). The farmer decided in the middle of the project to change from milking by hand to the bucket system machine milking.

These results could not be evaluated statistically, but the trend suggests a reduction in infection with coagulase-negative staphylococci.

In addition, a higher environmental contamination was observed during the hand-milking regime (total bacterial count 58 000 CFU/mℓ) than when the bucket milking system was introduced (total bacterial count 750 CFU/mℓ). Though the water used in both cases was from the same borehole source (same quality at a TBC = 240 CFU/mℓ), udder preparation differed. In the latter regime teats were sprayed with a disinfectant in addition to washing the udder with water containing a detergent.

CONCLUSION

Many countries are trying to initiate or stimulate dairy husbandry, through dairy development programmes. Success in such an enterprise requires an understanding of the smallholder farmers, characteristics of their enterprises and the resources available[4,14]. These studies revealed that the system of choice for the smallholder farmers studied was the extensive production system. The 1 herd using an extensive production system that was studied in this project revealed that it is possible to produce goat milk that is safe for human consumption.

Although of low prevalence (31.1 %), bacteria potentially capable of producing either food poisoning or enhanced spoilage of dairy products were cultured from the goat milk samples. Pathogens such as *Staphylococcus aureus, Bacillus* spp. and *Enterococcus faecalis* were isolated from raw milk in the study. These were associated with use of milking machines. With hand-milking, contamination was mainly due to coliforms, *i.e. Enterobacter* spp. and *Escherichia coli* (rough).

This study showed that the fundamental principles of producing safe and clean milk in production systems where milking is done by hand are identical to those where machines are used. The implementation of basic principles of public health practice in dairy routines, may, however, be difficult to achieve. Training should, nevertheless, be carried out to ensure the use of hygienic practices to enhance good milk hygiene principles.

Dairy goat farming can, therefore, be promoted in developing communities through smallholder farmers using the extensive type of production system, where it is appropriate. Milk quality obtained from this system has been shown to be comparable to that obtained under the 2 other systems. This can be enhanced with the aid of extension services aimed at improving management on the farms. This, consequently, could assist in alleviating the problem of food insecurity in these communities.

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