CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

BACKGROUND

Cow's milk has long been considered a highly nutritious and valuable human food, and is consumed by millions daily in a variety of different products. Its nutrient composition makes it an ideal medium for bacterial growth, and therefore it can be considered one of the most perishable agricultural products because it can so very easily be contaminated (Bryan 1983, Bramley & McKinnon 1990, Heeschen 1994). Many contaminating organisms only spoil the product, thereby reducing its shelf-life. Some, such as lactic acid bacteria, are useful in milk processing, causing milk to sour naturally. Other bacteria, such as those listed in Table 1, are pathogenic to man and can transmit disease if the milk is consumed untreated (Sharp *et al.* 1985, Heeschen 1994). Unlike meat and meat products, milk is less likely to be subjected to any subsequent heating by the consumer before consumption and contaminated milk is therefore potentially more dangerous (Steele *et al.* 1997). The high fat content of milk protects pathogens against gastric acid, while its fluid nature ensures a fairly short retention time in the stomach (Potter *et al.* 1984, Sharp *et al.* 1985).

Raw milk of good hygienic quality is necessary to produce milk products of good quality and adequate shelf-life and to provide a safe, sound and wholesome food for the consumer. Since milk is a liquid, it is in contact with some type of equipment or surface from the time it is removed from the cow until it is consumed. Milk freshly drawn from a disease-free udder contains small numbers of bacteria (500 to 1 000 bacteria per mℓ) which derive from organisms colonizing the teat canal (Bramley & McKinnon 1990). Milk quality starts to deteriorate immediately after milking due to bacteria entering the milk from a wide variety of sources. These bacteria may originate from soil, water and faeces that collect on the skin of the cow and unavoidably end up in the milk. Once micro-organisms get into the milk they multiply rapidly. The speed at which milk quality declines depends on the hygiene of the milker, milking equipment and bulk tank, as well as the temperature and length of time that milk is stored before sale to the consumer or treatment at a factory (Lück 1986). Microbial growth can be controlled by cooling the milk, as most micro-organisms reproduce more slowly in colder environments.

Pathogenic bacteria may also be present in raw milk as a direct consequence of clinical or subclinical mastitis (Giesecke *et al.* 1994). In 1989 Giesecke *et al.* reported that subclinical mastitis was prevalent in at least 75.5% of South African dairy herds which were affected at levels ranging from moderate to very serious. Mastitis affects a variety of compositional parameters of milk which in turn may affect the dairy technological usefulness, the nutritional and hygienic characteristics of milk (Giesecke *et al.* 1994). Among the organisms commonly producing mastitis, *Streptococcus agalactiae*, *Staphylococcus aureus (S. aureus)* and *Escherichia coli (E. coli)* are pathogenic for man (Bramley & McKinnon 1990).

PATHOGENS FOUND IN MILK

There have been numerous outbreaks of milk-borne disease in humans with pathogens such as *S. aureus, E. coli, Campylobacter* spp., *Salmonella* spp., *Listeria* spp., and *Yersinia* spp. being incriminated during the past century, especially since mass production came into effect (Bryan 1983, Vasavada 1988). Most of these outbreaks have occurred in raw milk, but there have also been outbreaks of disease after consuming pasteurised milk due to a failure in the pasteurisation system or post-pasteurisation contamination (Porter & Reid 1980, Fahey *et al.* 1995). Raw milk may contain micro-organisms pathogenic to man which originated either from within or outside the udder (see Table 1).

Human carriers may also be the source of infection in milk-borne outbreaks, as reported for *Salmonella* infections, and for cases of scarlet fever or septic sore throat due to *Streptococcus pyogenes* (Bryan 1983, Bramley & McKinnon 1990). Fortunately, all these pathogens can be destroyed by pasteurisation, but problems arise if the milk is contaminated after the heat process (Bramley & McKinnon 1990, D'Aoust *et al.* 1988).

Table 1: Diseases transmissible to man through milk *(Source: Heeschen, 1994)*

Disease	Principal Sources of Infection		
	Man	Milk Animal	Environment
BACTERIAL			
Anthrax*		●	●
Botulism (toxin)			●
Brucellosis		●	
Cholera	●		
Coli infections (pathogenic strains of *E. coli*)	●	●	
Clostridium perfringens (welchii) infection			●
Diphtheria	●		
Enteritis* (non-specific, from large numbers of killed or living coli, proteus, pseudomonas, etc.)			●
Leptospirosis*		●	
Listeriosis*		●	
Paratyphoid fever	●	●	
Rat-bite fever	●	●	
Salmonellosis (other than typhoid and paratyphoid fevers)	●		
Shigellosis	●	●	
Staphylococcal enterotoxic gastroenteritis	●	●	
Streptococcal infections	●	●	
Tuberculosis	●	●	
Typhoid fever	●		
VIRAL			
Infections with adenoviruses*	●		
Infections with enteroviruses (including polioviruses and the Coxsackie groups)	●		
Foot-and-mouth disease		●	
Infectious hepatitis*	●		
Tick-borne encephalitis		●	
RICKETTSIAL			
Q fever		●	
PROTOZOAL			
Amoebiasis*	●		
Balantidiasis*	●		●
Giardiasis*	●		
Toxoplasmosis*		●	

* *Not conclusively incriminated as milk-borne, but epidemiologically probable or suspect.*

The most important and serious human diseases resulting from the consumption of contaminated raw milk are tuberculosis and brucellosis (Bramley & McKinnon 1990). In both diseases the causative organism, *Mycobacterium bovis* and *Brucella abortus* respectively, may be excreted in the milk from infected animals. Often with *Brucella* infections, there is little change in the composition of the milk or udder tissue, i.e. mastitis is not present. Under normal circumstances, pasteurisation destroys both *Mycobacterium bovis* and *Brucella abortus*, so rendering the milk safe for consumption.

In South Africa, *Staphylococcus aureus* has been found to be the dominant mastitis-associated organism (Swartz *et al.* 1984, I M Petzer, Faculty of Veterinary Science, Onderstepoort, pers. comm. 1998, L Fourie, Ermelo Provincial Veterinary Laboratory, pers. comm. 1998). Staphylococcal mastitis of the cow poses a direct threat to public health, because a proportion of bovine strains produce enterotoxins (Asperger 1994). Consumption of food containing *S. aureus* enterotoxin leads to food poisoning (Bryan 1983). As the enterotoxin is heat stable, subsequent pasteurisation of the toxin contaminated milk or any heat treatment attempted by the consumer will not make it safe for consumption. Staphylococcal enterotoxin formation can be prevented by cooling the raw milk timeously, maintaining the cold chain and then effectively pasteurising the product (Asperger 1994).

S. aureus may also be present in the milk due to post-pasteurisation contamination. This can occur if people involved with the processing of the milk have colds, skin infections, diarrhoea or stomach disorders (Bryan 1983). Different surveys have shown that between 4% and 60% of humans are nasal carriers of *S. aureus*, and that between 5% to 20% of people carry the organism as part of the normal skin flora (Asperger 1994). A study done in South Africa in 1985 found that 18.9% of all *S. aureus* isolates from milk were toxigenic (Bolstridge & Roth 1985).

Numerous outbreaks of enteritis caused by *Campylobacter jejuni* (*C. jejuni*) have been associated with the consumption of unpasteurised cow's milk (Porter & Reid 1980, Jones *et al.* 1981, Taylor *et al.* 1982, Finch & Blake 1985, Hutchinson *et al.* 1985, Kornblatt *et al.* 1985, Klein *et al.* 1986). This organism can be isolated from the faeces of cattle infected or colonized with the bacteria (Svedhem & Kaijser 1981, Oosterom *et al.* 1982, Potter *et al.* 1983, Humphrey & Beckett 1987), and has been shown to cause asymptomatic bovine mastitis in which the organism is excreted directly through the milk of an infected cow (Hudson *et al.* 1984, Hutchinson *et al.* 1985, Morgan *et al.* 1985, Orr *et al.* 1995). In most outbreaks however, *Campylobacter* could not be isolated from the milk after an outbreak (Porter & Reid 1980, Jones *et al.* 1981, Taylor *et al.* 1982, Potter *et al.* 1983, Finch & Blake 1985, Kornblatt *et al.* 1985, Fahey *et al.* 1995). Nevertheless, a survey done in England in 1988 showed that 5.9% of raw milk samples were positive for *C. jejuni* (Humphrey & Hart 1988). It was also found that there was a significant association between the presence of *E. coli* in the milk and that of *C. jejuni* (Humphrey & Hart 1988).

Campylobacters can produce symptomless and persistent infection or colonisation in milking herds without any detectable contamination of the milk (Robinson & Jones 1981), and the excretion of *C. jejuni* can be intermittent (Humphrey & Beckett 1987). *C. jejuni* does not multiply in the milk, but can survive for at least 24 hours at room temperature, and for up to three weeks at 4°C (Doyle & Roman 1982, de Boer *et al.* 1984). *C. jejuni* is killed by proper pasteurisation (Gill *et al.* 1981, D'Aoust *et al.* 1988).

Outbreaks involving inadequately pasteurised milk have been described in England (Porter & Reid 1980, Fahey *et al.* 1995). Failure in the public electricity supply and a faulty pasteuriser were identified as the causes of the problem. In the case of the faulty pasteuriser, the indicator lights showed that the pasteurisation process was under way, even though the milk was not being heated to a high enough temperature to ensure complete pasteurisation (Fahey *et al.* 1995).

In developing countries, including South Africa, *C. jejuni* infection has been shown to be hyperendemic, with an age-related decrease in incidence of infection (de Mol & Bosmans 1978, Bokkenheuser *et al.* 1979, Glass *et al.* 1983). Acquired immunity could be important in preventing infection or preventing illness after infection (Blaser *et al.* 1987). Nevertheless, immuno-compromised people are at risk of contracting the infection (Johnson *et al.* 1984).

Faecal contamination of unpasteurised milk, a failure in the pasteurisation of milk and post-pasteurisation contamination of milk have all been associated with *E. coli* 0157:H7 outbreaks (Chapman *et al.* 1993, Upton & Coia 1994, Tast *et al.* 1997). *E. coli* 0157:H7 has been associated with haemorrhagic colitis and haemolytic uraemic syndrome (HUS) (Rea & Fleming 1994, Tast *et al.* 1997). *E. coli* 0157:H7 will not survive high-temperature short-time pasteurisation, but if inadequate pasteurisation or post-pasteurisation contamination does take place, *E. coli* 0157:H7 can grow in milk at 8 °C, which is not an uncommon temperature for the holding of refrigerated milk in consumer's homes (Wang *et al.* 1997).

Unpasteurised milk has also been implicated in outbreaks of human salmonellosis (Marth 1969, Bryan 1983, Barrett 1986, Ryan *et al.* 1987, El-Gazzar & Marth 1992). Salmonellas usually contaminate milk as a result of faecal contamination. The largest outbreak of salmonellosis ever identified in the United States involved between 168 791 and 197 581 people, mostly children, and was traced back to pasteurised milk (Ryan *et al.* 1987). A strain had persisted in the pasteurising plant and had repeatedly contaminated milk after pasteurisation.

Susceptibility of food-borne pathogens varies greatly from person to person. Milk often is an important component of the diets of the young and the elderly and, unfortunately, young children, the elderly, pregnant women and the immuno-compromised are most at risk from food-borne pathogens (Wang *et al.* 1997). The immune systems of these groups of individuals are often not sufficiently responsive to prevent infection by pathogenic bacteria (Johnson *et al.* 1984, Wang *et al.* 1997). For these reasons greater emphasis should be placed on the safety of milk. However, food-borne pathogens can also cause disease in all other segments of the population, as they do not only lead to the classic, acute syndromes, but may often result in serious chronic sequelae such as cholecystitis, colitis, endocarditis, meningitis, myocarditis, septicaemia, haemolytic-uraemic syndrome and pancreatitis (Mossel 1987).

EPIDEMIOLOGY OF MILK-BORNE DISEASES

No appropriate epidemiological statistics on milk-borne diseases in South Africa are readily available. Unless data were to become available to prove to the contrary, it seems realistic to assume that milk-borne diseases are probably at least as prevalent in South Africa as in other countries where there is mass production and distribution of raw and pasteurised dairy products. Surveys conducted on raw milk samples in other developing countries, showed that on the whole the quality was bad. Even if this milk is later pasteurised, the process will not guarantee a perfectly safe, sound and wholesome product as the bacteriological quality of the raw product has an influence on the shelf-life of the finished product (Lück *et al.* 1977, Antila 1982). Similar results to those of the other developing countries may be expected on some South African dairy farms, especially the smaller ones, who sell their milk to the milk-shops as their milk does not qualify for sale to the large distributors.

Surveys of raw milk samples in Trinidad showed that they were of a poor bacteriological quality. Between 20% and 75% were positive for *E. coli* and between 94% and 100% contained *S. aureus* of which 8% to 40% produced enterotoxins (Adesiyun 1994, Adesiyun *et al.* 1995).

In Kenya, *S. aureus* strains were isolated from 183 out of 300 raw milk samples collected. Ninety-seven of these 183 strains were assayed for the production of enterotoxins, and 74.2% of them were found to be enterotoxigenic (Ombui *et al.* 1992).

Surveys of raw milk purchased from street vendors and dairy shops in Egypt all showed high total colony and coliform counts, indicating contamination in the various stages of production and handling (Aboul-Kheir *et al.* 1986, Morgan *et al.* 1989, Abd El-Ghani 1993). These authors showed that between 27% and 61% of samples were contaminated with *E. coli* and 65% of samples contained staphylococci.

In Thailand, raw milk obtained from farms and collection centres, also showed poor bacteriological results with respect to total bacterial counts and coliform counts (Saitanu *et al.* 1996).

A study done on the milk from smallholder farmers in Zimbabwe showed satisfactory results on the standard plate count, with seven out of ten samples having counts of less than 100 000 colony forming units (CFU) per mℓ (Mutukumira *et al.* 1996). Coliforms were however, present in large numbers, and as *E. coli* was not specifically looked for, these coliforms may also have been faecal in origin.

Pasteurisation is the most common process used to destroy bacteria in milk. In pasteurisation, the milk is heated to a temperature sufficient to kill all pathogenic bacteria and most spoilage organisms. Correct pasteurisation reduces the prevalence of diseases generally associated with raw milk, especially raw milk produced and handled under unhygienic conditions (Holsinger *et al.* 1997). Thermally treated milk has, however, also been implicated as a source of human illness where inadequate pasteurisation or post-pasteurisation contamination has taken place (Porter & Reid 1980, Upton & Coia 1984, Fahey *et al.* 1995). Therefore the most important control measures to ensure milk safety are proper pasteurisation and avoiding post-pasteurisation contamination.

MARKETING OF MILK IN SOUTH AFRICA

Statistics on milk sales show that 60% of all dairy products are sold through hypermarkets, supermarkets and chain stores. Smaller grocery stores and cafes distribute some 35% of dairy products whilst the remaining 5% are direct milk sales from "milk-shops" (Theron 1997). Large national distributors such as Clover, Dairybelle and Parmalat base their payments to the farmer on milk received not only on the volume produced, but also on bacterial and somatic cell counts, as well as compositional quality standards such as butterfat and protein levels. Table 2 shows the criteria set by one of the distributors for the payment of milk (Jooste 1996).

Table 2: Criteria for the payment of milk set by one of the national distributors

Standard Plate Count (aerobic)	
<20 000 CFU/ mℓ	a premium is paid
20 000 to 50 000 CFU/ mℓ	no premium, no penalty
50 000 to 200 000 CFU/mℓ	3c per ℓ penalty
>200 000 CFU/mℓ	6c per ℓ penalty
Somatic Cell Count	
< 200 000 cells/mℓ	premium of 2c per ℓ
250 000 to 1 million cells/mℓ	no premium, no penalty
> 1 million cells/mℓ	penalty of 2c per ℓ

All milk is tested as it arrives at the distributor by means of the so-called "platform tests". On arrival, the temperature of the milk in the tanker is taken, which must be below 7°C. The tanker milk also undergoes a test to measure the freezing point of the milk to determine whether or not water was added to the milk. The bacterial quality is measured by means of the standard plate count and the milk is tested for the presence of inhibitory substances. Every individual supplier's milk also undergoes tests to determine the total bacterial count, the somatic cell count, butterfat, protein and lactose levels, as well as the freezing point of the milk. Large distributors usually have their own laboratories to do the quality control tests on the milk.

MILK-SHOPS IN SOUTH AFRICA

Since the first free elections in South Africa in 1994, the South African economy has undergone a fundamental restructuring. This was encouraged by a number of factors, the most important of which were:

1. the opening up of South African business which led to stiff competition on the world markets. This forced companies to "right size" so as to compete internationally and to become "world class". This was seen in Pretoria where ISCOR (Iron and Steel

Corporation) shut down its loss making operations, which led to a large number of retrenchments.

2. the army which the new Government inherited was enormous and sapping vital cash reserves, which it (the Government) felt could be better utilized in the area of health and education. A concerted effort was made to reduce the size of the military and one way was to offer retrenchments packages. As Pretoria had a number of military units in quite close proximity, there were a number of military personnel who accepted these packages on offer.

3. one of the key economic polices of the Government was to reduce the inflation rate in South Africa so as to bring it closer to that of South Africa's trading partners, and thus to relieve the pressure on South Africa's currency, the Rand. One way to achieve this was to be fairly aggressive in curtailing the supply of money available to the public by increasing the interest rates. This resulted in the economic growth rate slowing down to almost 0% over the last years of the 1990's. This slow down in the economic growth rate exacerbated the unemployment problem in Pretoria, as well as in the rest of the country.

Some of those people who were retrenched used that money to purchase small farms or smallholdings, and started to farm with amongst other things, dairy cattle, which can be considered a cash crop.

In the early 1990's the dairy industry was deregulated, which brought about a new, and rapidly developing practice in urban areas, especially in the lower socio-economic areas, of direct bulk milk sales to the public. These points of sale have been defined as "milk-shops" in this study. Milk-shops serve as an outlet for the relatively small amount of milk produced by the smaller farmers, and are run by farmers or businessmen who sell milk directly to the public. Consumers collect the milk in their own containers.

The premises where these milk-shops are located often range from small depots in shopping centres to fruit and vegetable shops, supermarkets and general dealers. Milk-shops have even been found in garage driveways (Jooste 1996). Many milk-shop owners do not have sufficient technical and scientific knowledge, both in dairy science and dairy microbiology, for large-scale collection and distribution of saleable milk, and often run these depots without any knowledge of milk hygiene or dairy technology.

As a result of the economic depression in South Africa, many people started looking for cheaper sources of staple products. The high prices of commercially pasteurised milk forced many consumers to buy milk from milk-shops. Virtually every household consumes milk on a daily basis as an important basic foodstuff. Few families, especially in the poorer socio-economic areas, can however afford to spend about R3.00 a day on one litre of pasteurised milk. Milk-shops became a cheap alternative to the high milk prices elsewhere. Milk-shops usually also market their products as being "fresh milk" or "fresh farm milk", giving the impression that it is full of goodness and safe!

Farmers also benefit from selling to milk-shops. At the time of this research project (June 1998), farmers received approximately R1.30 per litre if they sold their milk to one of the larger national distributors, whereas if they sold directly to a milk-shop they received approximately R1.45 per litre. Presently (January 2000), farmers receive only about R1.20 per litre from the national distributors. Another advantage to farmers of selling their milk to milk-shops, is that their milk is not analysed by the milk-shop owner, as it would have been if it had been sold to the national distributor, as milk-shops pay on volume alone and not on quality.

In Pretoria, milk-shops have, in a short period, developed rapidly. Table 3 shows the increase in the number of milk-shops situated in Pretoria from January 1996 to date.

In 1997, milk-shops in Pretoria were sampled three times per week by environmental health officers from the Pretoria Municipality. Due to severe budget restraints, milk-shops are currently only tested once a week.

A survey done by Jooste on the milk quality in South Africa in 1994 (Jooste 1996), found that pasteurised milk samples from larger distributors had significantly lower mean total bacterial counts, as well as coliform counts when compared to milk which was sold to the public from milk-shops.

Table 3: The number of milk-shops in Pretoria 1996 - 2000

Date	Number of milk-shops
January 1996	None
November 1996	14
February 1997	20
October 1997	37
March 1998	42
January 2000	Approximately 55

LEGISLATION REGARDING MILK

Milk is a product widely consumed by the public, especially by infants and children. As it has the potential to contain pathogens which can affect the health of those who consume it, standards have been established and promulgated into an Act to protect the public.

The only Act in South Africa which governs the safety of milk *per se*, and which sets the standards to which milk and dairy products must conform to, is the Foodstuffs, Cosmetics and Disinfectants Act, No. 54 of 1972: Regulations relating to milk and dairy products. This Act is administered by the Directorate of Food Control of the Department of Health.

According to this Act, pasteurised milk may not be sold if it contains any antibiotics or antimicrobials in amounts that exceed the maximum residue levels stipulated in the Maximum Limits for Veterinary Medicine and Stock Remedy Residues Regulations. It may also not contain pathogenic organisms, extraneous matter or any inflammatory product or other substance which may render the milk unfit for human consumption.

Pasteurised milk must pass the Aschaffenburg and Mullen phosphatase test. Bacteriologically it may not contain more than 20 coliforms (using the dry rehydrated film method also known as the Petrifilm plate for coliforms), or any *E. coli* per mℓ. On subjection to the standard plate count it may not contain more than 50 000 bacterial CFU per mℓ.

The Regulations further stipulate that all pasteurised milk shall, immediately after pasteurisation, be cooled and maintained at a temperature not exceeding 5 °C.

Compositional standards of milk are controlled by the Agricultural Product Standards Act, No.119 of 1990: Regulations relating to dairy products and imitation dairy products, as amended. They were not dealt with in this study as these components had no direct effect on the safety of milk, or the health of the consumer.

JUSTIFICATION

The aim of this research project was to evaluate the quality of milk available to the consumer, comparing two different marketing systems. The sampled milk was evaluated to determine the bacteriological quality, as well as to look at the prevalence of selected pathogens and toxins and for the presence of inhibitory substances. Current South African regulations (The Foodstuffs, Cosmetics and Disinfectants Act, No. 54 of 1972: Regulations relating to milk and dairy products, 21 November 1997) were used as reference to the standards which had to be adhered to. The hypothesis was that:

H_O There is no difference in quality at point of sale between milk sold from "milk-shops" and milk which originates from a commercial national distributor

H_A There is a statistically significant difference in quality at point of sale between milk sold from "milk-shops" and milk which originates from a commercial national distributor

In South Africa, there was no data published in the last ten years on the bacteriological quality of milk to which the consumer was exposed. There was also no published data on the prevalence of inhibitory substances in milk at point of sale. The milk was therefore sampled so as to evaluate:

1. **The safety of the milk for human consumption**:

Milk shops are generally situated in the poorer socio-economic areas, where consumers buy the milk because it is cheaper. If consumers are unwittingly exposed to unnecessary health risks and become ill as a result of drinking unsafe milk, it will not only affect their health, but also their productivity. This could put burdens on primary health care services and on employers.

2. **The potential shelf-life of the milk:**

The shorter the shelf-life of the milk, the quicker it will deteriorate, especially in the absence of adequate refrigeration facilities which some consumers do not have in their homes. However, milk with a short shelf-life will also deteriorate in a refrigerator. Many consumers end up throwing milk away which has become sour or has an off-flavour, in effect increasing the price they pay for a litre of milk.

The objectives of the research project were to:

1. Compare aspects of safety and the potential shelf-life of the milk available to the consumer in a selected area of Pretoria between two different distribution chains who either do or do not pay the farmer for the quality of milk produced namely:
   * a commercial national distributor who buys milk from farmers on which a premium is paid for quality. Processing and packaging takes place at the plant under strict hygienic conditions before distribution.
   * "milk-shop" distributors who buy milk from farmers on volume alone with no incentives paid for quality. The milk is processed in the shop before sale to the

public, but not necessarily packaged. Hygienic conditions may vary depending on the level of training which the staff who work with the milk, have received. It is sold to the consumer in the consumer's own container or it may be bottled in the shop.

2. Determine whether the milk fell within the parameters laid down by law according to the Foodstuffs, Cosmetics and Disinfectants Act, 1972: Regulations relating to milk and dairy products of 21 November 1997.

3. Determine whether the milk was safe for human consumption.

4. Determine whether the potential shelf-life of the milk was adequate.

5. Determine whether there was a difference in milk quality on different days of the week.