The effect of dairy herd management and milking practices on milk quality

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A mi padre, por su silencio.

A mi madre, por su insistencia, persistencia y tenacidad.

A mis hermanos, por su apoyo.

A mercha, por su cariño.

A mechas, por su fé.

A Susana, por su vida.

Abstract

A mail survey of 200 dairy farmers supplying Tasman Milk Products Ltd (TML) in northern South Island, New Zealand in July 1996 received 46 % response (92 suppliers). This study was undertaken to gauge the effect of mastitis control practices of the mastitis control (SAMM) plan on milk yield and quality in seasonal supply dairy herds. This survey was written to acquire data on the relationship between important dairy husbandry practices and the status of the milk quality of the herd. These practices included dairy hygiene and teat disinfection; diagnosis and treatment of clinical mastitis; culling; dry cow therapy; and characteristics, maintenance and repair of the milking machine. The data were analysed by the Statistic Analytical Systems (SAS®) and significant results were taken to be at $p < 0.05$.

The study showed that the production of milk solids per hectare was significantly ($p=0.002$) and negatively correlated with BSCC. 60 % of TML suppliers practiced selective teat washing before milking, and 80 % of suppliers practiced teat spraying in all cows after milking for the entire lactation. Herd testing of individual cows was practiced by 87 % of the TML respondents. Most (77 %) farmers, herd tested 2-monthly. An average 8 % of cows in respondent's herds were diagnosed as having clinical mastitis; all such cases were treated with intramammary antibiotics. 80 % of the cows treated recovered satisfactorily and the remaining 20 % needed re-treatment. An average, 3 % of the cows in each herd were culled for clinical mastitis or high somatic cell counts. The mean Bulk (milk) somatic cell count during the 1995/96 lactation for suppliers surveyed was 217,000 cells/mL. 35 % of farmers achieved a season average BSCC less than 150,000 cells/mL and only 3 % of farms had a seasonal average of more than 400,000 cells/mL. 90 % of TML respondents practiced dry cow therapy selectively. 64 % of TML respondents used selective DCT in heifers with SCC at or below 80,000 cells/mL and in cows at or below 120,000 cells/mL which is below the levels for heifers and mature cows recommended by the SAMM plan. At 35 % of farmers achieved a seasonal average SCC of less than 150,000 cells/mL, clearly demonstrates the effort being made by local suppliers to produce high quality milk on their farms. The study revealed that these "low SCC" suppliers used similar practices of dairy husbandry and milking procedures to the remaining 75% of suppliers with BSCC above 150,000 cells/mL. A majority (45 %) ($p<0.05$) of suppliers who had a BSCC below 250,000 cells/mL, used the SAMM plan during the season. It was suggested that hygiene, detection and treatment of sites of infection with antibiotics (lactating or dry cow therapy), drying-off or culling will continue to be the main herd husbandry options for keeping SCC at an optimum level. It was evident that TML suppliers are willing to produce not only as much milk as possible, but also milk of a premium quality. It was concluded that the absence of significant detectable effects of the SAMM plan on milk yield among TML suppliers responding to this study begs the question as to whether or not the mastitis control programme affects the BSCC, hence milk yield. The current study, however, identified the progress achieved by the dairy company and its suppliers in this matter by using individual components of the mastitis control plan.

Key words: Milk quality, SAMM plan, somatic cells, Bulk somatic cell counts.

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Chapter One

1. Introduction

The current study is an extension of a previous project related to milk quality among local dairy suppliers in the Central North Island (Londoño, 1996). In that study, two-rounds personal interviews with three typical New Zealand suppliers:

a) a manager of a commercial farm at Massey University,
b) an owner of a farm who did not live on the farm but who was fully involved in the decision making process and
c) a 50-50 sharemilking family on farm supplying milk all year round, including the quota in winter.

The objectives were to identify attitudes, concepts and beliefs about milk quality and to design a rich picture of the major components related to milk quality management on the farm. It was found that climate conditions, herd feeding level and milking and health management practices of the herd were major key factors that affected the milk quality status on the farm. As a consequence, there was general agreement by interviewees that milk quality was a market reality which required commitment, scientific knowledge and involvement at the farm level by those responsible for the decisions made (*see Londoño, 1996*).

It is recognised world-wide that the New Zealand dairy production system is very cost-effective. This cost-effectiveness is achieved by maximising the use of high quality pasture through seasonal calving (Holmes and Wilson, 1987; Kefford *et al.*, 1992). The quality of dairy products manufactured from milk, however, varies significantly through the year. Kefford *et al.* (1992) stated that the most likely explanation is that the seasonal variation in milk production and quality is associated with the stage of lactation and the quality of the diet. To overcome this, milk companies have implemented an incentive price scheme for top quality milk in order to control milk quality through the season (Fenwick and Kirkpatrick, 1990; Holmes, 1990).

Milk production in New Zealand has been steadily increasing. The Livestock Improvement Corporation annual report (1996) reported that 788 million kilograms were processed in 1995-1996, 7.5% more than for 1994-1995 and 7.7% more than for 1993-1994. In addition, international dairy product prices are improving, reflecting the steady world demand and tighter product supplies (MAF, 1995). Consequently, several dairy companies have increased their manufacturing capacity either by expanding their existing facilities or by building new plants (MAF, 1995).

The introduction of special milk quality payment schemes and quotas world-wide have significantly increased the economic pressure on dairy farmers everywhere (Hamann, 1990). In fact, most dairying countries, including New Zealand, currently impose penalties for milk supplied to the factory with a high (more than 400,000 cells/mL) bulk somatic cell count (BSCC) to make the quality of the raw material more reliable (Lacy-Hulbert and Woolford, 1996).

1.1. Problem Statement

Without a high quality milk supply, the production of high quality dairy products becomes difficult, if not impossible. Consequently, milk quality in New Zealand is a market reality which demands commitment, experience and knowledge from dairy farmers (Londoño, 1996). Several authors (Grindal and Hillerton, 1991, Hamman, 1990, Joe, 1993) stated that the most constructive and effective approach to mastitis control is likely to remain a combination of hygiene, animal husbandry, antibiotic therapy, and milking techniques.

In New Zealand, the milk quality programme (mastitis control plan) is based on the Seasonal Approach to Managing Mastitis (SAMM) plan which has been designed to

produce the cheapest (Fenwick and Kirkpatrick, 1990) and finest milk in the world (Joe, 1993). Its target is to achieve a BSCC lower than 400,000 somatic cells/mL (SAMM plan-LIC, 1995). However, some customers, such as Japan and the EC have demanded that the New Zealand dairy industry improve the quality of milk it processes by reducing the BSCC lower than 400,000 of somatic cells/mL. As a result, some companies have set up new strategies based on the SAMM plan and have included a more severe penalty system for dairy farmers supplying poor quality milk.

" The poor adoption of mastitis control practices on seasonal calving herds result in higher somatic cell counts in bulk milk, decreasing milk yield productivity hence profitability of the dairy farm due to the lower milk quality and greater number of penalties during the season".

1.2. Project Proposal

Given the statement of the problem, some questions arise, including those about:

- *"The impact of the SAMM plan on dairy farm productivity",*
- *"The rate and level of adoption of the SAMM plan by dairy farmers",*
- *"The effect on the whole SAMM plan of individual practices for hygiene, animal husbandry, antibiotic therapy, and milking technique".*

By seeking answers to these questions, it was intended to explain the effect of the SAMM plan in New Zealand on the productivity on dairy farms.

Similar studies in this area have been conducted in the United States of America (Gill *et al.*, 1990), in Canada (Schukken *et al.*, 1990) and in New Zealand (Laycock *et al.*, 1987 and Ntum, 1995) using data from surveys, and analysing dairy farm management practices with milk production, milking practices, milking machine performance and mastitis control of the dairy herd.

1.3. Objectives

The major objective of this study is to analyse and evaluate the performance of the SAMM plan in relation to milk quality and milk productivity in New Zealand. Additional objectives of this study are:

1. To identify constraints (e.g. economic, physical, environmental and personal) to adopting the SAMM plan on dairy farms.

2. To provide information and results to farmers, local dairy companies and the dairy industry to adopt new strategies to increase milk quality.

A review of the literature on the reliability of SCC in bulk milk as an indicator of mastitis level on the farm and control of mastitis in dairying is presented in chapter two. Chapter three describes the research method used in this study. Results and discussion of results are described in chapters four and five. Conclusions are presented in chapters six.

Chapter Two

2. Literature Review

2.1. INTRODUCTION

It is widely recognised that mastitis is one of the major factors affecting profitability of dairyfarming. However, the exact economic losses due to mastitis for dairy farmers and manufacturers are unknown (DeGraves and Fetrow, 1993). Gill *et al.* (1990) reported that 70 to 80 percent (%) of estimated losses per cow per year were associated with reduced milk production especially due to subclinical mastitis because of milk discard, early culling, drug costs, veterinary costs, and increased labour. The New Zealand Livestock Improvement Corporation (LIC, 1996) estimated an annual cost of mastitis in New Zealand of $ 14,600 per farm.

The prevalence of subclinical mastitis is particularly able to be observed in an increase in the number of somatic cells which, in turn, affect individual and total milk yields, milk composition, and quality of products made from milk from mastitic cows (Auldist *et al.*, 1995). Hence, several countries have adopted bulk somatic cell counts (BSCC) as the most reliable tool to measure the level of mastitis on the farm (Bramley, 1991; Shearer *et al.*, 1992). This is due to the payment schemes and quotas adopted which have markedly increased the economic pressure on dairy farms but which have also required improvements in the quality of the raw milk on the farm (Hamann, 1990). Hence, the objective of using BSCC is to successfully reduce subclinical mastitis, particularly in high bulk milk SCC which involves improvement of the milking procedures, postmilking teat disinfection, and dry cow therapy.

Where mastitis control programmes have been adopted, it is to increase milk quality. To achieve this, research and practice have focused on udder health status (Hamann, 1990). Mastitis control programmes may be defined as all dairy herd management practices which result in good udder health and bulk raw milk with low somatic cell counts. It is based on five major points. Modifications from the original plan have been adopted by different countries, including New Zealand in order to produce the finest milk in the world (Joe, 1993)

The purposes of this literature review are, firstly, to describe the reliability of somatic cell counts as an indicator of the level of mastitis in a dairy herd, and secondly, to describe the practices that constitute a mastitis control programme, including New Zealand's Seasonal Approach to Managing Mastitis (SAMM) plan.

2.2. MASTITIS

Several authors (DeGraves and Fetrow, 1993; Gooneratne and Familton, 1989) have pointed out that among the diseases of dairy cows in United States of America and New Zealand, mastitis is the most economically important and thereby, costly for dairy farmers. Although mastitis can occur in the mammary gland at all stages of the cow's life, it is particular important during lactation, especially in early lactation and early in the dry period, soon after the last milking (Gooneratne and Familton, 1989 and Hillerton, 1996).

Mastitis is the inflammation of the mammary gland, a response by the tissue to injury, caused by bacteria which are responsible in 95% of cases (Harding, 1995). *Table 2-1* summarises the two major groups of bacteria associated with mastitis: *Contagious bacteria* and *Opportunistic bacteria* (*Environmental bacteria*) (Hillerton, 1996).

The presence of contagious bacteria *Streptococcus agalactiae, Streptococcus dysgalactiae, Staphylococcus aureus and Mycoplasma bovis* will almost certainly predicate the presence of infected cows. *Streptococcus agalactiae* and *Staphylococcus aureus* are the most important and common bacteria in this group (McDonald, 1969) and are characterised by the production of enterotoxins producing food poisoning (Robinson, 1981). These enterotoxins are heat-stable resulting in symptoms of nausea, vomiting and diarrhoea in humans.

The major source of environmental bacteria is surroundings of the cow including bedding, manure and soil and when they can be isolated in milk, they are generally related to poor milking hygiene and procedures. The primary exposure to environmental bacteria occurs between milkings (Harding, 1995). The more common of them are *Staphylococcus. bovis, Staphylococcus fecalis, Escherichia coli, Klebsiella spp, and Enterobacter spp.* (Elvinger and Natzke, 1992).

A third group of bacteria that affect the milk quality are thermoduric bacteria. These are proteolytic bacteria from the genera *Bacillus* and *Clostridium* which are capable of surviving at pasteurisation temperatures. However, the enzymes from these bacteria are destroyed by pasteurisation. Principal sources of thermoduric bacteria are poorly cleaned and sanitised equipment on dairy farms and processing plants. Consequently, measures of this bacteria in milk are considered to be indicators of the level of sanitation on the farm and the plant (Elvinger and Natzke, 1992).

As mentioned above, the major reservoir for contagious bacteria is the infected mammary glands; infections are spread from quarter to quarter or cow to cow during the milking process (Harding, 1995). Infections tend to be chronic or subclinical with periodic clinical episodes. On the other hand, environmental bacteria live on the skin of the teat and are frequently isolated from bovine intramammary infections (IMI) (Todhunter *et al.*, 1995). The contamination with environmental pathogens will take place predominantly during the milking interval (Hamann, 1990).

The classification of mastitis as being clinical or subclinical (Hillerton, 1996 and McDonald, 1969) is related to the degree and dynamics of the infection in the mammary tissue (*Figure 2-1*). Subclinical mastitis can be described as a mild response from the host defence system in the udder due to a low bacterial stimulus, poor recognition of the bacteria by the host defence system or rapid effectiveness in removing the stimulus before it can be detected by detailed investigation (Hillerton, 1996). Clinical mastitis is the result of a more severe response from the host defence mechanisms, with significant damage done by the bacteria and their toxins to the body tissues resulting in changes in the type of the secretion at lactation (Dodd, 1984).

Table 2-1: Epidemiological category for bacteria causing mastitis (Bramley, 1991).

CATEGORY	BACTERIA
Contagious	*Streptococcus agalactiae* *Corynebacterium bovis* *Streptococcus dysgalactiae* *Staphylococcus aureus*
Contagious no significant	*Staphylococcus epidermis* *Staphylococcus hyicus* *Staphylococcus xylosus* *Staphylococcus simulans*
Environmental	*Streptococcus uberis* *Other streptococci* *Escherichia coli* *Klebsiella pneumoniae* *Klebsiella oxytica* *Enterobacter aerogenes* *Proteus spp.* *Pseudomonas aeruginosa*

Subclinical mastitis requires more accurate and reliable diagnosis routines to establish the presence of infected or uninfected individual quarters (Kitchen, 1981 and McDonald, 1969). The basis on which these tests are routinely applied relies on the alteration of milk composition due to inflammatory reaction, inability to synthetise lactose or increase in blood proteins and concentration of ions in the milk because of the tissue damage (*Table 2-2*). However, it is important to note that, although lactose concentration is a reasonable diagnostic criterion, changes in lactose production by the cow is also possible by over-or underfeeding (Harding, 1995).

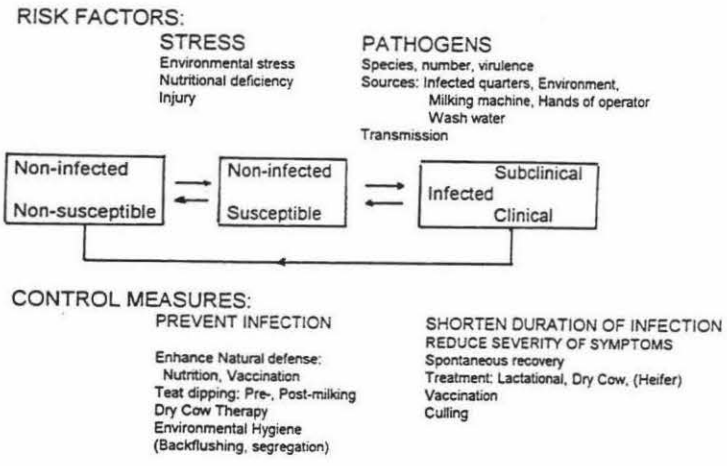


Figure 2-1: The dynamics of udder heath (Shearer et al., 1992).

Table 2-2: Main diagnostic tests for subclinical mastitis(Kitchen, 1981).

Composition change caused by	Test and Methodology
1. Disease-combating response of animal	• **Somatic cell counting** a) Direct microscope b) Automated particle size analysis c) Automated fluorescent staining of cell nuclei d) Detergent-viscosity increase tests e) Chemical DNA determination Cellular metabolite (ATP) Determination.
2. Tissue damage and blood capillary permeability	• **Lactose determination** a) Automated colorimetric b) Automated infrared • **Bovine serum albumin test** a) Immunoelectrophoresis b) Immunodifussion • **Na, K, Cl.** a) Automated flamed photometry (Na^+, K^+) b) Automated chemical (Cl^-) c) Specific ion electrodes d) Conductivity measurements • **Enzymes*** a) Catalase b) N-acetyl-β-D-glucosaminidase

* Changes in enzyme levels may be a result of both tissue damage and increases in somatic cells present in milk.

2.3. *THE RELIABILITY OF THE SCC AS IN BULK MILK AS AN INDICATOR OF SUBCLINICAL MASTITIS*

Testing milk quality have been increasingly used by dairy companies and farmers since the late 1960's. One of the tests is the number of somatic cells (SCC), either in raw milk from individual cows or bulk milk, as a tool to measure indirectly the level of mastitis on the farm (Daley and Hayes, 1992, Holdaway *et al.*, (1996, a,b,c, Holmes *et al.*, 1993, Miller *et al.*, 1993, Reneau, 1986, Shearer *et al.*, 1992).

There are many types of somatic cells, including neutrophils, macrophages, lymphocytes, eosinophils, and various ephitelial cell types of the mammary gland. Under normal conditions of the healthy mammary gland, the viable somatic cells are macrophages and lymphocytes, but a few are ephithelial cells and neutrophils (Kehrli and Shuster, 1994).

Somatic cells are, in low number (<50,000 cells/mL), normal constituents of the milk from a healthy udder (Holmes *et al.*, 1993, Shearer *et al.*, 1992). But an elevated number of somatic cells (> 1,000,000 cells/mL) is present in the milk in the mammary tissue with a mastitis infection with viable bacteria (Daley and Hayes, 1992). The primary function of these cells is to ingest and destroy bacteria when they are present in the mammary tissue (Harding, 1995).

The number of somatic cells can increase exponentially in less than 48 hours. Neutrophils are the predominant type of cells present during infection (95 % of the total) and they can increase to more than 1,000,000 cells/mL of milk (Kehrli and Shuster, 1994). This is because the pathogens which penetrate into the teat cistern activate components of the phagocytic immune system. Stimulated macrophages possibly secrete agents which cause a massive influx of polymorphonuclear leucocytes. As a result, mastitis not only results in an elevation of the cell count of milk, but also in an alteration of the proportion of each of the cell types present (Kitchen, 1981).

This influx of cells can be measured as an increase in SCC (Nickerson, 1992; Paape *et al.*, 1992). There are a number of methods to monitor SCC *e.g.* California Mastitis Test (CMT), Wisconsin Mastitis Test (WMT), Direct Microscopic Somatic Cell Count (DMSCC), and Electronic automated cell counting (Daley and Hayes, 1992, Nickerson, 1992, and Shearer *et al.*, 1992). The electronic automated cell counting in bulk milk is certainly the most reliable indirect method to evaluate milk quality.

A number of important studies to evaluate the reliability of SCC and other constituents in milk as indicators of subclinical mastitis have been reported. Holdaway *et al.*, (1996, a,b,c), investigated the effects of bacterial infection, stage of lactation and age of the cow on eight potentially useful parameters in uninfected or infected individual quarters with major or minor pathogens. The parameters were:

1) Somatic cell count
2) Sodium concentration
3) Potassium concentration
4) Electrical conductivity
5) pH,
6) Lactose concentration
7) N-acetyl-β-D-glucosaminidase (NAGase) activity and
8) 1-antrypsin concentration.

Holdaway *et al.* (1996a) found that the effect of infection status gave highly significant responses in almost all the parameters but no significant effect on potassium concentration. The authors also found that SCC did not change significantly between strict foremilk (the first 10-15 mL of milk), foremilk (the next 15 mL after the strict foremilk) and mid milking (milk yield taken by interrupting machining milking at the midpoint) while the strippings (milk obtained from the cow after the removal of the teat cups) had significantly higher SCC than those of the other milk fractions. This difference was probably due to the prolonged physical force applied to the teat end during milking which can evoke different types of teat tissue reactions such as congestion and oedema with the presence of a number of immune cells in milk (Zeconni *et al.*, 1992). Holdaway *et al.* (1996a) suggested that in the case of conductivity, this was inversely related to fat concentration in milk due to both the higher milkfat concentration and the low conductivity in the strippings in the healthy quarters (*Table 2-3*). Fat concentration in this study had a range of 3.7% to 10.7%.

In a second study by Holdaway *et al.* (1996 b), the authors found that, from all the eight indirect parameters to measure the level of infection, somatic cell count in bulk milk proved to have the greatest discriminative ability to classify infection status of the udders and quarters. The critical threshold for quarters was 245,000 cells/mL for bacteriological infection with major pathogen (coagulase positive staphylococci, *Streptococcus agalactiae, Streptococcus dysgalactiae, Streptococcus uberis and Echerichia coli*) and 80,000 cells/mL for bacteriological infection.

The authors also suggested that, in order to achieve consistent accuracy in the classification of udder quarters, lower threshold values should be used in herds with a low prevalence of infection, and higher threshold values should be used in herds with

a high prevalence of infection and the bulk somatic cell count might be used to select the appropriate threshold figure for particular herds.

Table 2-3: Mean values (log10) for all the parameters (and standard error) in three milk fractions for uninfected and infected quarters (Holdaway et al., 1996 a).

	FOREMILK		MIDMILK		STRIPPINGS		SIGNIFICANCE		
PARAMETER	UI	I	UI	I	UI	I	Status	fraction	SxF
Somatic cell count (cell/mL)	1.88 (0.131)	3.04 (0.135)	1.97 (0.120)	3.18 (0.135)	2.36 (0.111)	3.32 (0.121)	**	**	NS
Sodium concentration (mMoles/litre)	1.21 (0.009)	1.39 (0.027)	1.21 (0.009)	1.44 (0.032)	1.27 (0.021)	1.57 (0.033)	**	**	NS
Potassium concentration (mMoles/litre)	1.62 (0.012)	1.61 (0.010)	1.61 (0.012)	1.60 (0.011)	1.57 (0.015)	1.56 (0.019)	NS	**	NS
Electrical Conductivity (mSiemens/cm)	0.768 (0.012)	0.836 (0.010)	0.766 (0.011)	0.846 (0.007)	0.733 (0.022)	0.866 (0.010)	**	NS	*
pH	0.822 (0.001)	0.827 (0.001)	0.823 (0.001)	0.830 (0.001)	0.827 (0.001)	0.836 (0.002)	**	**	*
Lactose concentration (% w/ v)	0.685 ((0.004)	0.639 (0.004)	0.677 (0.005)	0.625 (0.006)	0.622 (0.004)	0.598 (0.009)	**	**	NS
NAGase activity (mMoles/mL/min)	0.697 (0.013)	1.002 (0.061)	0.720 (0.015)	1.051 (0.050)	0.781 (0.022)	1.190 (0.72)	**	*	NS
α1-Antitrypsin concentration (relative units)	-0.113 (0.015)	-0.051 (0.038)	-0.160 (0.019)	-0.068 (0.032)	-0.207 (0.032)	0.003 (0.044)	**	NS	NS

*Levels of significance: * P< 0.05, ** P< 0.01 and *** P< 0.001*

Levels of somatic cell count may be also affected by:

1. *The magnitude and duration of the infection*: Both magnitude and duration of infection increase the number of somatic cells (Holmes and Woolford, 1992). The same authors further stated that the increase in SCC can vary between types of bacteria. In addition, the authors explained that uninfected cows generally had low SCC (50,000 - 100,000 cells/mL) and infected cows had high SCC (200,000 cells/mL in herds with a very low incidence of mastitis and above 600,000 cells/mL in herds with higher incidence of mastitis). But, within each category of infected or uninfected herds, there is wide variation in the SCC of individual cows; the categorisation in a distribution curve suggests that there will be two potential types of error: false negative and false positive; some infected cows will be wrongly included in the

uninfected category and some uninfected cows will be included in the infected category (Holmes and Woolford, 1992). Thus, for instance, cows with chronic sub-clinical mastitis might be classified wrongly as false negative. Therefore, the cost of poor identification of false negative cows with treatment of false positive cows might be higher than checking individual cows under routine basis, specially in early lactation and the dry period.

2. *Age and stage of lactation:* Milk SCC in healthy cows is high at calving, lowest from peak to mid-lactation and highest at drying-off (Reneau, 1986). Harding (1995) further stated that the high number of somatic cells after parturition is due to the great number of antibodies present in the colostrum which are transferred to the newborn calf. By contrast, the increase in SCC in later stages of lactation is partially due to the naturally occurring decline in milk yield (Miller *et al.*, 1993). These authors added that the negative relationship between milk yield and SCC in late lactation is partly due to both true biological effects of udder inflammation and a concentration effect. Two strategies include close monitoring of SCC during lactation and drying-off those cows with SCC over a predetermined threshold value.

Holdaway *et al.* (1996 c) recognised that age had a great effect on SCC. Reneau (1986) pointed out that age was the second greatest influence on SCC variation, after infection status. Holmes and Woolford (1992) indicated that two year old cows, in their first lactation, had lower SCC than older cows. This is because older cows have a greater opportunity than younger cows for exposure to mastitis pathogens, they have infections for longer time and they suffer more extensive tissue damage (Reneau, 1986). Holdaway *et al.* (1996, c) found that the prevalence of udder infection increased with the age of the cow; infection affected normal levels of not only SCC, but also electrical conductivity, NAGase activity and concentrations of sodium, potassium, and lactose. Sodium and lactose concentrations increased with increasing age of the cow. But, the authors concluded that it is still difficult to establish whether age *per se* causes changes to the levels of each of the eight parameters, or whether the quarters from older cow have a high degree of resident infection.

In addition to the SCC as an indicator of mastitis in the dairy herd, BSCC also provides reasonably accurate information on the incidence of infection in the dairy herd

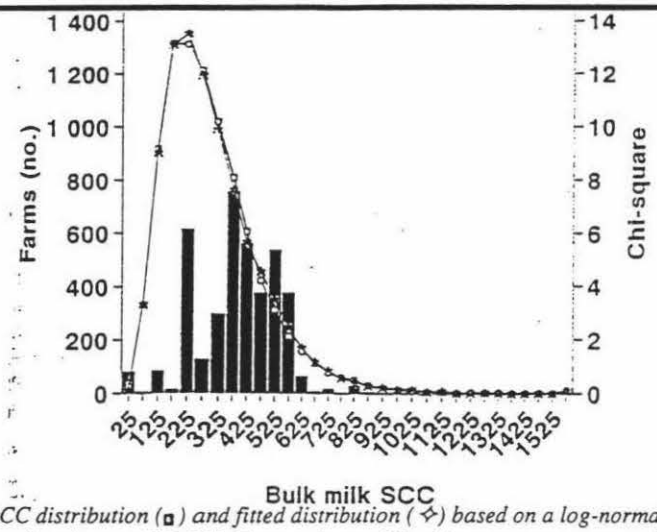
(Holmes and Woolford, 1992). Furthermore, Bramley (1991) reported a high correlation between SCC and BSCC (0.6 to 0.7). BSCC penalty programmes have been implemented throughout the world. Using 283,000 cells/mL as a threshold, BSCC is 80% efficient in correctly classifying infected and uninfected animals in United States (Reneau, 1986). The author also has recognised the benefits of SCC as an indicator of the seriousness of mastitis problem.

In Canada, Schukken *et al.* (1992 a,b) reported that a Bulk Milk Somatic Cell Count (BMSCC) programme has been introduced in Ontario since 1989 with a penalty level of 800,000 somatic cells/mL. In 1992 it was 500,000 somatic cells/mL. Through the implementation of a penalty programme in Ontario dairy industry, incentives became available to modify management and to improve udder health and milk quality. Schukken *et al.* (1992b) also evaluated the dynamics of the BSCC and found that both SCC and BMSCC followed a log-normal distribution (*Figure 2-2*). The mean and variance were strongly related (correlation 0.76) which were later used to evaluate performance of the dairy farmers. The goodness of fit of the log-normal distribution is of academic value with important implications for the dairy processing industry. In other words, the use of SCC can be recognised as an accurate tool to indicate the milk quality level on the farm for milk processing and as animal health indicator of the herd.

In New Zealand, a number of dairy companies have already implemented BSCC a a way to penalise low quality milk on a regular basis (Holdway *et al.*, 1996c) as part of the SAMM plan. Holmes and Woolford (1992) recommended that managers of dairy herds in New Zealand with a lower incidence of mastitis BSCC than 400,000 cells/mL should use a threshold of 150,000 cells/mL to practice dry cow therapy at drying-off time. Conversely, herds with a higher incidence of mastitis BSCC above 500,000 cells/mL should use a threshold of 250,000 cells/mL to practice dry cow therapy at drying-off time.

In agreement with Holdway *et al.* (1996c), the BSCC by dairy companies does not usually coincide with the day on which individual cow somatic cell counts are measured by the New Zealand Livestock Improvement Corporation. If a stated aim of the dairy industry is to improve milk quality, then progress towards achieving the aim will be greatest where data are able to be matched, such as BSCC with individual

cow SCC. Watson (1996) discussed the need for the New Zealand dairy industry by year 2000 to focus its milk quality programme in three areas toward: a) Inhibitory substances, b) milk cooling and c) Somatic cell counts. The author also added that for a herd in New Zealand to be relatively safe, the aim should be a BSCC consistently below 150,000 cells/mL.



(Observed bulk milk SCC distribution (▫) and fitted distribution (✧) based on a log-normal density function mean of 340 and variance of 32,053. The goodness of fit chi-square are presented in bars)

Figure 2-2: Log normal distribution for Bulk milk SCC (Schucken et al., 1992 b).

In Sweden, Emmanualson and Funke (1991) analysed the effect of increasing milk yield on BSCC in Swedish dairy herds and proved clearly that BSCC is affected by milk yield. The authors also found that the correlation between prevalence of mastitis and average BMSCC ranged between 0.53 and 0.77. The average herd prevalence of mastitis decreased as milk production increased, within BSCC. Furthermore, BSCC decreased 11.1% for each 1,000 kg increase in the milk yield fat corrected milk (FCM). An increase in FCM from 3,000 to 4,000 kg, 5,000 to 6,000 kg and 7,000 to 8,000 kg would reduce the BSCC by about 25%, 17% and 11%, respectively. The BMSCC were obtained by calculation from the geometric mean.

2.4. MASTITIS CONTROL IN DAIRY COWS

A general aspect of optimising dairy production in the world is that increasing yield per cow have been achieved by genetic influences, feeding techniques, or other management strategies but not by the same degree of attention by dairy farmers to udder health status after a certain number of lactations (Hamann, 1990). Poor herd mastitis control is associated with alterations in milk quality, high bacterial counts,

increased likelihood of antibiotics in milk, all of which cause significant problems to the milk processor (Bramley, 1991). This has been proved in Australia by Rogers and Mitchell (1994) who found that the use of milk containing more than 500,000 cells/mL resulted in Cheddar cheese with higher moisture content and proteolysis breakdown products, and poorer flavour and lower body and texture grades. Furthermore, during the manufacturing process rennet coagulating times were increased by 25% and there were increased losses of "fines", fat and whey protein from milk with BSCC >500,000 cells/mL. The authors reported that losses in the whey proteins resulted in decreased cheese yields of approximately 9%.

Several other authors have evaluated the effect of mastitis control on the quality of raw milk. For instance, Gill *et al.* (1990) studied the mastitis control practices among Ontario dairy farms. The authors found, once again, the negative relationship between SCC and the yield of milk, milkfat, and milk protein. It was also found that the majority of the farmers surveyed followed many of the practices recommended by the American Mastitis Council, but only 32% of the dairy producers used all five recommended practices (*i.e.* washing udders before milking, drying udders after pre-milking washing, teat dipping, dry cow treatment, and considering mastitis when culling cows). As expected, it was found that regular visits of the veterinarian were associated with lower SCC. This is consistent with unpublished findings by the author and other post-graduate students at Massey University who found that the veterinary practitioner was the major source of information for dairy farmers in order to practice a reliable and good mastitis control programme and therefore, to maintain high levels of productivity and profitability from their dairy farms. Morris (1989) also reported that veterinarians were the most common source of information and advice on mastitis control programmes in New Zealand.

Gill *et al.* (1990) found that farmers with more years of ownership and managing the farm, more education, and frequent attendance at dairy extension seminars were associated with lower SCC. But, age of the owner or operator and years in dairy farming were associated with increased SCC. The authors concluded that producers who depend on BSCC as indicator of udder health may not be receiving full information about the health and production of their herd.

Reneau (1986) pointed out that mastitis in the United States remained the single most influential factor affecting milk production. Moreover, 20 to 25% of the dairy farmers across the United States were facing serious cash flow problems that, in some cases, could be alleviated by reducing the incidence of mastitis.

In New Zealand, Laycock *et al.* (1987) carried out a survey of dairy farmers in the North Island to evaluate the use of a mastitis control plan and teat preparation and found that only 20% of the farmers considered mastitis as a major cost or source of loss. However, results from this survey were not used to establish any cause-effect relationships between practices and their effect on the level of mastitis. Schukken *et al.* (1990) described ten risk factors for clinical mastitis in housed, stall-fed milking cows which were evaluated by questionnaire *(Table 2-4)*. The authors found that the rate of clinical mastitis was significantly associated with some factors that increased the exposure of the cows to environmental microorganisms. Ironically the mastitis control plan which reduced the incidence of infectious bacteria appear to favour an increased incidence of clinical mastitis from environmental bacteria. Major contributing factors were leaking milk, poor cubicle cleanliness, rubber mats in cubicles and low quality water. The increased rate of teat disinfection and high frequency of cubicle disinfection more successfully controlled infectious bacteria, yet there was a measured increase in the rate of clinical mastitis. The breed of the cow (Holstein-Friesian cows vs. Meuse-Rhine-Yssel cows) and high milk production produced a higher incidence of clinical mastitis. Holstein-Friesian cows had a lower incidence of mastitis rate than Meuse-Rhine-Yssel cows. It is important to notice how interrelated management practices described by Schukken *et al.* (1990) were considered as significant risk factors to produce clinical mastitis.

Table 2-4: Categorisation of the Risk Factors for Clinical Mastitis (Schukken et al., 1990).

CATEGORIES	COMPONENTS
1. General Management	a) Size of the property b) Number of people working on the farm. c) Herd size and breed. d) Other farming activities e) Type of the soil f) Manure Management and bookkeeping.
2. Housing Conditions of lactating and dry cows.	a) Type of housing and ventilation. b) Grazing in summer. c) Barn size and number of stalls. d) Cubicle size and bedding material.
3. Cleaning Procedures	a) Cleaning of the barn and cubicles. b) Bedding replacements and cleaning. c) disinfection procedures and frequency.
4. Hygiene of cubicles and cows	a) Collection of information on the cleanliness of the cubicles, bedding, and cows at every 2 months on a farm visit.
5. Feeds and feeding of lactating and dry cow	a) Minerals for lactating and dry cows. b) Analysis of roughage. c) Use of production groups. d) Method of concentrate feeding and source of water.
6. Management of the dry cow and cows before calving	a) Presence of maternity or disease pens. b) Bedding in calving area. c) Cleaning and disinfection in calving area. d) Drying off procedure and Dry cow treatment. e) Teat disinfection in dry cows and mastitis tests in the dry period and length of the dry period. f) Seasonal calving pattern.
7. Milking Procedures	a) Frequency of milking. b) Number of milkers. c) Wet or dry udder preparation. d) Teat pre-dipping and post-dipping. e) Management of mastitis cows.
8. Milking machine	a) Age of the machine. b) Machine function tests and replacements of liners. c) Height of the milk pipe. d) Cleaning procedures. e) Recent changes in the machine.
9. Production records	a) Milk production and BSCC data for 12 months. b) Average breeding index.
10. Disease and disease prevention	a) Estimate of the cows leaking milk. b) Cows sleeping in the alleys. c) Use of the herd health programmes. d) Use of preventive measures such as vaccination, treatments, clipping of the udder, and summer mastitis prevention.

2.4.1. Elements of mastitis control

Hillerton (1996) pointed out that the basis of all disease control, including mastitis, is recognising the problem, understanding what it is, having the motivation to respond to it and having effective tools to use in response. The author maintained that effective management of a mastitis control programme needs not only information but systems to assist in the identification of the problem and in developing a strategy for its solution.

Mastitis is not a single disease but a collection of diseases with differing causes, usually microbial infection (Bramley, 1991; Moore and Heider, 1984). These organisms show different abilities to grow and survive on skin, in teat lesions or at the teat end, produce different pathological responses and varying in their resistance to antibiotics. Consequently, they differ in epidemiology and in the ease with which they are controlled or eradicated. *Table 2-4* summarises in detail the risk factors and their categorisation that affect mastitis status of the herd in North America (Schukken *et al.*, 1990). Even though the connection of some of the categories in *Table 2-4* with mastitis are not immediately apparent, it illustrates the importance of every individual component within a mastitis control programme.

McDonald (1969) suggested an initial approach to mastitis control which was based on three elements to prevent intrammamary infections: a) Hygiene, b) Milking equipment function and c) treatment of existing infections. Actually it is established that milking management is the most important factor of mastitis control (Elvinger and Natzke, 1992).

Hillerton (1996) described two main types of mastitis control schemes: On one hand, there is the Scandinavian mastitis control programme, characterised by the government subsidised supervision by mastitis laboratories of the monitoring of bulk milk for cell count and particular pathogens. This mastitis control programme is supplemented by technical support supervising environmental and milking machine operation. Intervention sampling of individual cow and the introduction of therapy programmes are only practiced when a particular bacteria is detected or cell counts exceeds a threshold. There is no teat disinfection and administration of antibiotics is only carried by a veterinarian.

On the other hand, there is the conventional mastitis control characterised by the identification of the essential components of the dynamics of the infection and the integration of a control programme including preventive methods with elimination of the infection. This was successfully implemented in the United Kingdom in the early 1960's (Bramley, 1991), and is now used in Australia, New Zealand and the United States with some modifications (Hillerton, 1996) (*Table 2-5*).

Table 2-5: Five-point mastitis control plan developed by the National Institute for Research in Dairying (Hillerton, 1996).

Original Plan
1. Hygienic preparation of teats for milking and disinfection of all teats. 2. Treatment of all cases of clinical mastitis and accurate recording of the occurrence. 3. Use of dry cow antibiotic preparations on all quarters of all cows intended to re-calve into the herd. 4. Culling of cows with persistent mastitis based on records. 5. Maintenance of the milking machine by frequent servicing.
Additions
6. Maintenance of the best possible teat skin condition. 7. Reduction of exposure to bacteria by management of the environment. 8. Prevention of transfer of bacteria between cows via the milking machine. 9. Prevention of the milking conditions likely to aid bacteria penetration of the teat duct.

Australia began adopting an On-Farm Quality Management System in 1995 which was scheduled for completion in May 1997 (Darmody, 1996, Dairy First News, 1996 Jan, Jun, Nov). It is based on the New Zealand experience (SAMM plan), particularly the strategy of Bay Milk Products Ltd and assisted by the New Zealand Ministry of Agriculture and Fisheries (MAF) Quality Management Programme. The programme is called *Dairy First* and has the participation of the dairy companies, the Australian Dairy Research and Development Corporation (DRDC), dairy farmers and other interested groups. All these organisations, working together have the challenge to achieve the following goals:

1) A documented on-farm quality management system available for use by the Australian dairy industry. This is the central Farm Operation Manual, divided into five sections: General Information, Quick Reference, Operational Procedures, Fact Sheets and Audit Checklists.

2) The Operational Procedures, based on Hazard Analysis and Critical Control Point (HACCP) principles are the auditable component of the programme (*Table 2-6*).
3) A greater awareness by dairy farmers of food quality issues and their relation to food quality.
4) Better and more consistent quality of dairy products.

The project is funded by The Australian Federal Government, through the Food Quality Programme and is administrated by Ausindustry, the dairy companies, DRDC and other participants. Participation in the project is voluntary, the benefits to farmers who adopt the system will be both direct and indirect and the record keeping will be a feature of the system (Dairy First News-Jan, 1996).

Table 2-6: Areas of the Farm Operations covered by Australian Dairy First Project (Dairy First News, June 1996).

1) Training	10) Sediment and other physical foreign matter
2) Animal Health (Other than Mastitis).	11) Milking Management
3) BMSCC / Mastitis	12) Colostrum
4) Antibiotics and other veterinary chemicals	13) Pathogens
5) Agricultural chemicals	14) Plant Hygiene
6) Stock water	15) Milking Plant Performance
7) Stockfeed and stockfeed additives	16) Milk Cooling and storage.
8) Shed environment	17) Effluent Management
9) Traits and odours	18) Stock movement

In the Dairy First News (Jan 1996) the current project activities were described, including the draft of the generic Farm Operational Manual. Once the Farm Operations Manual has been completed, the Farm records, Audit and Training Manuals will be compiled. At the time of the report, field testing of the programme was been undertaken on 70 farms supplying a local dairy company.

2.4.2. Aspects of the Conventional Mastitis Control Programme:

The simple approach to creating the basis of mastitis control programme is set on two principles:

1. To prevent new infections.
2. To reduce the duration of current infection (Bramley, 1992 and Elvinger and Natzke, 1992).

2.4.2.1. Prevention of mastitis:

Bramley (1992) stated that difficulty in controlling the exposure of the teat surface to pathogenic bacteria is directly related to their distribution in the environment of the herd. Moreover, if sources of contamination are strictly limited then eradication may be practically and economically feasible. Hillerton (1996) identified three levels of control of mastitis:

1. Reduction of bacterial contamination of the teat.
2. Preventing bacteria entering the gland.
3. Prevention of establishment of pathogens in the mammary gland.

2.4.2.1.1. Reduction of bacterial contamination of the teat

The reduction of bacterial contamination of the teat is the first level of prevention of pathogenic bacteria (Hillerton, 1996). Despite the best intentions and actions on the farm, teats will become dirty and it is then important to clean them appropriately. Washing can be done in a number of ways most of which benefit milk let-down, reduce bacterial number on the teat skin and reduce the rate of new infections. Washing teats firstly with clean water using disposable individual towels and then with disinfectants in the water followed by drying the teats, are essential for reducing the bacterial contamination of the teat. This is also complemented by practicing post-milking teat disinfection. Disinfectant is applied by dipping each teat separately into a cup or by spraying disinfectant on the teats from below (Hillerton, 1996). Final results will depend on the quality and regularity of the various procedures rather than the product or the method selected. A major consideration in the disinfection of teats is its cost-effectiveness. Most dairy farmers in New Zealand include time taken to milk a herd in an evaluation of cost-effectiveness.

2.4.2.1.2.Preventing bacteria entering the mammary gland.

Hygiene includes taking preventive measures (Hamann, 1990). Preventing bacteria entering the gland is practiced because, despite the efforts to limit bacteria on the teat skin, there are penetrations by pathogens into the gland (Hillerton, 1996). At this level, the milking machine influences the rate of mastitis, either by providing the mechanisms by which bacteria presented to the teat orifice can be forced through the teat duct, or by modifying the teat, or the immediate intramammary tissues, sufficiently to aid bacterial growth or inhibit the defence mechanisms.

The functioning of the milking machine during milking plays a role in mastitis either directly, by moving pathogens into the teat cistern or indirectly by increasing the external teat contamination or decreasing the teat tissue defence potential (Hamann, 1990). The author described two types of transfer during machine milking:

- Transfer of contagious pathogens between quarters resulting mainly in contamination of the teat skin.
- Transfer of environmental pathogens placed at the teat orifice into the teat cistern and hence invasion.

However, there are other related factors which affect the penetration of bacteria into the mammary gland such as miking flow rate, individual milk yield, the design and installation of the milking machine and milking time (Klein and Hakim, 1994).

Hamann (1990) described in-depth procedures for ensuring milking hygiene. The author divided milking hygiene into three elements:

a) Pre-milking udder preparation.
b) Cleanliness of the milking equipment
c) Post-milking hygienic measures.

a) Pre-milking udder preparation.

The objectives of good pre-milking udder preparation are a sufficient decontamination of the teat to ensure a good milk quality and the reduction of the risk of milking related infection. The author strongly recommended effective udder preparation because of the opportunity for:

- Examination of milk for signs of clinical mastitis.
- Decontamination of the teat skin.
- Avoiding damaging teat tissue.
- Increasing the degree of udder evacuation and shortening the milking duration.

Table 2-7 shows a proposed pre-milking teat preparation scheme to attain the goals described above.

b) Cleanliness of the milking equipment

To provide an adequate milking machine cleaning system, it is necessary to use the correct amount of detergent steriliser in the cleaning solution, at the correct temperature. It is also suggested to add to the sanitising system a back-flushing system for use between cows to reduce mastitis problems.

Table 2-7: Pre-milking Teat Preparation (Hamann, 1990).

1) Dry cleaning with paper towel after washing
2) Foremilk stripping
3) Pre-dipping/ contact time: 30 seconds
4) Dry with individual paper towel

c) Post-milking hygienic measures.

Apply disinfectants and emollients to the teats immediately after milking to help prevent mastitis. Postmilking teat dips are designed to kill bacteria that contaminate the teat end, especially the streak canal (Goldberg *et al.*, 1994).

2.4.2.1.3. Prevention of establishment of pathogens in the mammary gland

This third level of mastitis control is possible through the defence mechanisms of the cow. Nevertheless, Hillerton (1996) pointed out that the only current, successful method of mastitis control affecting the establishment of bacteria is the prophylactic use of antibiotics in the dry period. The major limitation to their use is that antibiotic residues should not persist into lactation and so efficacy towards the end of a normal dry period may be low.

2.4.2.2. Elimination of mastitis

Hillerton (1996) numbered three proven methods which can be used singly or in tandem for eliminating mastitis. These are natural cure, chemical therapy and culling.

2.4.2.2.1. Natural Cure

Natural cure leads to spontaneous recovery by successful deployment of the defensive systems (Hillerton, 1996). This may include limitation of the invading bacteria by exhausting nutrient supplies. Natural cure is basically the result of good management practices in the dairy herd rather than "spontaneous recovery" *per se*.

There are specific host factors which alter the effectiveness of mastitis treatment and which have an immediate effect on health of the animal and the udder health. For instance, Duirs and MacMillan (1979) found a high rate of spontaneous cures (71%) in animals which did not receive dry cow therapy the previous season. Hillerton (1996) reported a significantly greater cure of infection achieved by application of dry cow therapy than in non-treated animals.

2.4.2.2.2. Antibiotic Therapy

Antibiotic therapy is directed toward bacteria present in the udder which reduce the quality or quantity of milk produced (Moore and Heider, 1984). These authors stated that antibiotics must come in contact with the organisms in adequate concentration and for sufficient amount of time to either inhibit its growth or cause its destruction. The goal of antibiotic therapy in dairy cows is to alter the capacity of the causative organism to invade, colonise, or damage the udder by changing the bacterial environment.

The two main types of antibiotic therapy for dairy cows are either for dry cows or for lactating cows. Dry cow therapy (DCT) is practiced with antibiotics which have reduced rate of diffusion from the udder and create a prolonged local concentration of the drug. Such antibiotics use mineral or vegetable oils as coadjudants to reduce the rate of distribution of the associated antibiotic (Moore and Heider, 1984). However, DCT antibiotics should be applied as soon as the cow is dried-off due to its slow rate of absortion affecting its actitivity in the udder hence its efficiency.

In contrast, mastitis infusions for lactating cows use water as coadjudant in order to maintain high concentration of the antibiotic in the site of the infection and to permit a rapid removal of residual antibiotic from the udder by milking (Moore and Heider, 1984). Antibiotic treatments for lactating cows are generally not given until after the bacteria have invaded, colonised and produced sufficient damage in the mammary gland to result in detection of mastitis. It should be practiced as soon as early and accurate diagnoses of clinical cases can be obtained (Radostis and Blood, 1987).

Major emphasis is given to dry cow therapy. Radostis and Blood (1987) pointed out that this is because most of the infections occur during the dry period, specially at the beginning and end of it. At these times, teats are distended, and there is often milk in the teat canal; bacteria pass easily through the dilated canal, and there is no flushing-

out mechanism because the cow is not being milked. Additionally, Radostis and Blood (1987) reported the lowest somatic cell counts in milk when it was most diluted, the opposite the case with the recently dried-off cow and level of bacteria on the teat skin also contributed to increased risk of mastitis. But the cost of this practice is expensive and still there is no guarantee of complete recovery. The same authors recommended that treatment of all quarters (blanket dry therapy) should only be practiced when dairy herds have a quarter infection rate greater than 15%. When infection rate is less than that, selective dry therapy should be practiced. To determine this infection rate, it is necessary to practice individual SCC tests on a monthly, routine basis with cultural examination to isolate the specific bacteria when there is elevated SCC.

Another objective of the study by Radostis and Blood (1987) was to assess the efficacy of selective dry therapy in dairy cows. The authors found that 81% of the farmers adopted this practice which gave a reduction in SCC in early lactation. These results were confirmed by Gill *et al.* (1990) who reported that producers who treated only selected cows had significantly lower BSCC compared to those who followed the recommendation to treat all cows prior to drying them off. By treating only selected cows, these producers spent less money on treatments. In contrast, Schukken *et al.* (1990) reported that, when full or partial dry cow therapy was practiced, selective therapy gave minimal prevention of mastitis in herds with high prevalence of clinical cases of the disease.

Before using antibiotic treatment for mastitis, there are three main pharmacokynetic considerations (Moore and Heider, 1984):

a) Location and susceptibility of the organisms.
b) Host-animal factors.
c) Pharmacokynetics of the administered drug (administration and elimination of the drug).

a) Location and susceptibility of the organisms:

It was described in section 2.2 that bacteria are the most significant microorganisms associated with mastitis. Also described (section 2.2) were the most common types of bacteria involved with it. Due to the variation in type of bacteria, there are variations in the resistance to antibacterial agents (Moore and Heider, 1984). The same authors

further stated that the susceptibility of the bacteria to a particular agent can be determined by both *in vitro* culture methods or empirical response to treatment. In agreement with Moore and Heider (1984), clinical judgement is required to decide whether or not any of these methods should be employed for individual cases. The question which arises from this situation is whether or not the methods result in a fast response in the gland and are cost-effective to the farmer. Problem herds, in which there is an increase of clinical cases of mastitis, are often infected by one predominant organism. It is only possible to identify the micro-organism by culture methods (Moore and Heider, 1984). Unfortunately, culture methods to identify the pathogenic agent demand time and patience. A second complication described by Moore and Heider (1984) was the inadequate or inappropriate use of antibiotics which might result in the development of resistance by the bacteria. In fact, clinical cases which are not cured properly by using antibiotics may maintain a subclinical infection and even revert to a clinical condition. Experience of the author (Londoño) in the field in Colombia suggests that the most common, but not always the best practice, is the application of a broad spectrum antibiotic in the mammary gland for three to five days in the hope of achieving a rapid and complete response.

b) Host-animal factors:

Tissue perfusion and permeability changes are the major factors affecting distribution and elimination of drugs (Moore and Heider, 1984). Thus, systematic illness associated with clinical mastitis is capable of decreasing the perfusion and tissue permeability of the udder as a result of reduced vascular pressure or increased tissue resistance.

c) Pharmacokynetics of the administered drug:

An antibiotic given systematically is distributed through the tissues of the body on the basis of its concentration gradient. This gradient serves as the driving force for moving drug molecules (Moore and Heider, 1984). Antibiotics given via the teat canal distribute through the milk system. When blockages due to clots occur in the ducts the effectiveness of the distribution of intrammamary treatments will be greatly reduced and in these cases systematic treatment might be necessary. This is due to the limitation of moving a particular molecule through cell membranes and past tissue barriers.

Moore and Heider (1984) explained that concentration gradients were a function of the total dose, the frequency of administration, and the rate of absorption from this site. The higher the drug dose or the more frequently it is given, the greater the driving force for distribution to various body compartments. However, it was also stated that there were constraints to this due to toxicity and solubility of the drug which are driven by elimination route of the drug or its concentration.

From their review Moore and Heider (1984) concluded that absorption of the drug from the site of administration was essential for control the pathogen/infection. When intramammary infusion is the type applied, the mammary gland becomes the site of greater concentration. In some cases, drug preparations introduced into the mammary gland may develop a concentration gradient which may result in systemic distribution. The factors that affect absorption of drugs are: molecular size and polarity of the drug, the antibiotic's capability for protein binding and the degree of ionisation of the antibiotic.

Drug residues were also discussed by Moore and Heider (1984). They pointed out that drug residues are the gravest food-quality problem facing food-animal production and food-animal veterinary practice. It is the author's (Londoño) personal view that drug residues do represent a potential risk to humans even though some researchers and practitioners do not consider them to be of much importance. A low level of education among farmers, non-restriction of medicaments and cultural beliefs are the major factors related to this problem, particularly in developing countries. Their full impact is still unknown, but their effects are already observed.

2.4.2.2.3.Culling

Hillerton (1996) stated that the only absolutely effective method of elimination is by culling of the infected animal but it should be practiced strategically. It is the only option available, especially when the other methods have failed to eliminate the infection or prevent continual reinfections. Radostis and Blood (1987) stated that cows with chronic subclinical or repeating acute clinical mastitis should be culled. However, Hillerton (1996) claimed that culling must be considered along with the impact on the herd structure and the economic circumstances of the farmer. That is, there are many occasions when a high proportion of older cows have higher SCC or there are more chronic cases of clinical mastitis than in first calvers. When the manager culls a greater proportion of older cows than expected in a dairy herd, it will reduce the number SCC

in bulk milk but it may result in a greater herd replacement rate, increasing the cost of replacements. It also has the potential to reduce the total milk yield for the whole dairy herd hence to jeoparde the efficiency of the business.

2.4.3. Vaccination

The use of vaccines against mastitis has been described as a more classical approach of prevention (Daley and Hayes, 1992). The authors described vaccines against mastitis as having two attractive advantages over therapeutic practices. Firstly, there would be no milk withdrawal and secondly, there would be more control among sub-clinical mastitis. However, the same authors pointed out that vaccines against mastitis stimulate the immune response of the animal but they are unable to focus on the target organ (mammary gland) with the proper protective mechanisms. By contrast, Bramley (1991) stated that vaccines, specially a single vaccine, are ineffective in mastitis control and are unlikely to prevent all forms of mastitis. Obtaining high concentrations of vaccine-induced antibody in an organ producing many litres of secretion each day has proved difficult. It has been found, too, that the pathogens that cause mastitis require special conditions to grow *in vivo* which differ from those displayed *in vitro*.

Nordhaug *et al.* (1994a,b) reported two important studies related to immunisation against the bacteria (*Staphylococcus aureus*) which produce mastitis. In the first study the authors described the characteristics and principles of the vaccine. The *Staphylococcus aureus* vaccine, containing inactivated bacteria with the presence of a pseudocapsule and alpha and beta toxoids, has a mineral oil coadjutant. The principle of the vaccine is to increase the phagocytosis activity of the neutrophils by increasing the presence of IgG_2 (Nordhaug *et al.*, 1994a). Their study found that antibody response toward the pseudocapsule and alpha toxin was significant in serum from the vaccinated cows; these antibody concentrations were significally higher in serum and milk during the whole lactation compared with that of the controls. The antibody response to the pseudocapsule consisted of the IgG_1 and IgG_2 isotypes, but in milk, only the concentration of IgG_1 was significantly increased in the vaccinated cows during the lactation compared with the control cows. When antibody concentrations remain high until drying off, booster vaccinations can be performed in the dry period. This procedure is preferred because the vaccination of lactating cows may have an immediate negative influence on the milk SCC.

However, there were no specific results on SCC from vaccinated cows compared with control animals (Nordhaug *et al.*, 1994 a).

Nordhaug *et al.* (1994 b) conducted a second experiment with a total of 108 heifers. It was a placebo-controlled study of an experimental *Staphylococcus aureus* mastitis vaccine containing whole, inactivated bacteria with pseudocapsule, alpha and beta toxoids, and mineral oil coadjutant. The heifers were injected in the area of the supramammary lymph nodes twice before calving and were observed and sampled throughout the first lactation. None of the vaccinated cows suffered from clinical *Staphylococcus aureus* mastitis, and only 8.6% suffered from subclinical mastitis, but a total of 16% of the control cows suffered from clinical or subclinical Staphylococcus aureus mastitis. Mean SCC in vaccinated and control cows were the same throughout the lactation. Local swellings at the injection site were palpable in a substantial proportion of the vaccinated cows. No significant differences occurred between groups for specific immune cells against the implanted bacteria. However, when all parameters on udder health were considered together, the results indicated a potential protective effect of this vaccine during the entire lactation (Nordhaug *et al.*, 1994 a, b).

2.4.4. Genetic Selection to improve resistance against mastitis

Another significant alternative to improve mastitis control in the dairy herd is through a exhaustive breeding programme (Bramley, 1991, Kehrli and Shuster, 1994, Shook and Schutz, 1994 and Standberg and Shook, 1989). For instance, Shook and Schutz, (1994) pointed out that somatic cell testing programmes have been implemented in United States during the late 1970's and early 1980's. Actually, nearly 80% of all the cows in the American Dairy Herd Index System (DHI) are on somatic cell testing. An attractive breeding alternative is to select herds from animals with low SCC (Kehrli and Shuster, 1994). However, the same authors pointed out that there was no experimental evidence to indicate that selection for very low SCC was desirable for improved health.

Bramley (1991) also discussed how genes for mastitis resistance may have negative effects on other desired characteristic such as milk yield, milking rate or resistance to metabolic disease. This is also supported by Standberg and Shook (1989) who found with simulation studies that with breeding programmes, based on milk production and

fat content, a genetic increase of 0.02 clinical cases of mastitis per cow per year could result. This increase in mastitis would result in a decrease of 180 kg of milk (3.7% fat) per lactation. The authors predicted that if the payment schemes are more greatly emphasised bacteriological or manufacturing quality of milk, then the selection for mastitis resistance would be economically worthwhile. Kehrli and Shuster (1994) concluded in their revision that rapid genetic gains in disease resistance can be made by removal of bulls from breeding programmes when their daughters are predisposed to high SCC.

2.4.4.1. Importance of Genetic Improvement for Mastitis Resistance

The following section is a summary of the article published by Shook and Shutz (1994) in the United States of America who discussed extensively the reasons for using breeding decisions in mastitis control, why genetic improvement of resistance to mastitis had be based upon somatic cell scores, how genetic evaluations for somatic cell scores might be reported and what the consequences were of including somatic cell scores in breeding programmes.

The overall reason to include mastitis in a genetic improvement programme is to increase the total economic merit of animals, to reduce the cost of producing milk, to reduce premature culling of cows, to improve the quality of milk and dairy products, and to improve the health and well-being of dairy cows. Nevertheless, the dramatic increase of milk yield per animal from 1970 to 1995 in the United States due to genetic improvement, also resulted in increased health problems and associated costs. So therefore, and in agreement with the authors, disease is economically more important than some productive traits. Genetic improvement for milk yield is related to an increase in disease incidence which accounts for 10 to 20% of the increased value of milk yield. This is because of the changes in feeding practices that have caused the increase in disease incidence. About half of this increased disease cost is attributable to mastitis (Shook and Shutz, 1994).

2.4.4.2. Improved mastitis resistance through selection on Somatic Cell Score (SCS)

The somatic cell score (SCS) is widely used in United States as a measure of udder health and as a management tool for the control of mastitis. The SCS is a conversion of the individual SCC of dairy cows using a base 2 logarithm. The reason is because

SCS provides a more uniform variance analysis than the SCC. For mastitis, SCS is the indirect trait on which selection will be based while genetic improvement is sought for mastitis resistance. It must have a high genetic correlation between the indicator trait and the economic trait. In addition, Shook and Shutz (1994) pointed out that the indicator trait must have one or more of the following: high heritability, low recording costs, measurability in early life, and measurability in both sexes. According to the authors there is a reasonable correlation between SCS and clinical mastitis which has a higher heritability than SCC. Therefore, SCS is a useful trait for indirect selection for genetic improvement of mastitis resistance.

2.5. THE SEASONAL APPROACH TO MANAGING MASTITIS (SAMM) PLAN

The Seasonal Approach to Managing Mastitis (SAMM) plan is the 5-point plan adopted by the New Zealand dairy industry in reply to the international pressure to improve milk quality (Joe, 1993, Lacy-Hubert and Woolford, 1996). The objective of the SAMM plan is to produce the world's finest quality milk by reducing the New Zealand national average bulk somatic cell count to below 150,000 somatic cells per millilitre of bulk milk. Currently, the New Zealand dairy industry is imposing penalties for milk supply to the factory with high BSCC (>400,000 cells/mL) (Lacy-Hubert and Woolford, 1996).

The targets of the SAMM plan are on two major bacteria which cause mastitis in New Zealand, *Streptococcus uberis* and *Staphylococcus aureus* in the dry and lactation periods, respectively. The SAMM plan divides the year into five periods, depending on the stage of lactation:

1) Late lactation
2) Drying off
3) Dry period
4) Calving
5) Lactation

The benefits of the plan have already been evaluated; for instance, Morris (July 1989) in the New Zealand Dairy Exporter published an evaluation of the SAMM plan and explained that dairy farmers with low cell count herds were more ruthless in trying to control mastitis. Furthermore, farmers with low BSCC apply the 5-point control plan more thoroughly and use the somatic cell counting service to monitor their herds. Morris (July 1989) pointed out that the milking machine, teat condition, udder spraying

after each milking throughut lactation and minimal washing were the key elements in the control of mastitis. Another important aspect was the identification of the cows with clinical mastitis or high SCC. Morris (1989) also stated that several farmers with herds with low measured SCC emphasised the importance of culling high SCC cows.

2.5.1. Late lactation Period

The principal activity is to review SCC and clinical infection records to make decisions regarding dry cow therapy and culling. The strategy is to use dry cow therapy to treat existing cases or cows with a history of high SCC in late lactation and to prevent new infections over the dry period and at next calving. The herd is categorised according to its subclinical mastitis status as assessed by BSCC. The three categories are high, medium and low (*Table 2-8*).

Table 2-8: Decisions regarding the practice of dry cow therapy (LIC, 1996).

LOW	MODERATE	HIGH
Below 150,000 average bulk somatic cell count	150,000 - 400,000	Above 400,000
Below 20% of cows with cells counts above 150,000 (Jan/ Mar)	20 - 50%	Above 50%
Below 3% of cows with clinical mastitis in first month of lactation	3 - 10%	Above 10%
No cows with clinical mastitis in first 3 weeks of last dry period	No	Yes
No cows last season outbreak of clinical cases	No	Yes

Only herds in the "high" category will require the treatment of all animals. Selective dry cow therapy would be practiced when BSSC are at medium or low level. The recommended SCC threshold for treatment is 150,000 cells/mL for cows and 120,000 cells/mL for heifers (Joe, 1993, LIC, 1996). The decision to cull the cows will remain for those which still have high cell count or those which have repeated cases of clinical mastitis. LIC (1996) recommended that farmers seek expert advice in all cases to ensure that the right decision is made.

2.5.2. Drying-off Period

The recommendation is to dry the cows off by abrupt cessation of milking and to use dry cow therapy only at the last milking. Also, it is recommended to bring the cows to

the shed for periodic palpations of all quarters to identify new infections and to treat them. Other recommendations suggested by LIC (1996) are:

- Decide the date of final milking.
- Milk the cows once a day for the last seven days to prior final milking date.
- For the last three days prior to final milking date reduce feed intake to maintenance level only. Keep water available.
- After final milking, treat selected cows immediately with dry cow therapy antibiotics. If there is the need to apply more antibiotics during the dry period, milking antibiotics should be used. However, farmers may be penalised if any residues are found during next lactation.
- Do not milk cows after dry cow therapy.
- Maintain the level of feeding for seven days after drying off.
- Examine cows seven days after last milking.
- Spray teats after each treatment/ examination.

2.5.3. Dry Period

The recommendation is to fully-check the milking machine, to prepare the dairy herd for the next lactation by training the heifers to move through the dairy and to ensure a good cow numbering system is in place. LIC (1996) suggested that fully servicing of milking machines should include:

- Replacing liners.
- Ensuring milking machine is fully checked and serviced (at least once every 12 months)
- Checking by certified tester only.
- Carrying out all recommendations of the tester.

An information recording system should be prepared for the next lactation, including:

- The number of the cow.
- The quarter.
- Clinical signs.
- The date of the treatment.
- Antibiotics used.
- Number of tubes used.
- Teat damage.

2.5.4. Calving Period

The recommendation in this period is to reduce contamination of the teats with infected mud and faeces by placing the cows in clean paddocks to calve (LIC, 1996). One of the principles in this period is to look for clinical mastitis infection in the immediate post-calving period and to clean up such cases as early as possible. All the cows should be checked after calving for signs of clinical mastitis by foremilk stripping daily with the colostrum mob. Cows entering the milking shed with undetected, subclinical infections will increase the risk of having the milk downgraded (Lacy-Hubert and Woolford, 1996). The same authors pointed out that milk should be withheld for a minimum of four days post-calving for cows and five days post-calving for heifers, before the milk becomes acceptable for supply to the company. Starting from the first day after calving, the teats should be protected with an effective teatspray equivalent to 0.3% iodine containing 15 to 20% of emollient. This not only reduces the bacterial contamination of the teats but also keeps the teat skin in good condition, thereby avoiding teat sores and damage. Complete milking is important, particularly in heifers.

Lacy-Hubert and Woolford (1996) also pointed out that most dairy companies have avoided penalising farmers for high BSCC in the first weeks of the new season. The reason is that the high SCC and immunoglobulins present in milk after calving are associated with the commencement of lactation. However, levels of SCC in bulk milk should decline rapidly, at least five days after calving. The penalty schemes imposed by New Zealand Dairy Industry have resulted in a significant decrease in the number of SCC after calving. The positive effect of this was analysed by Lacy-Hubert and Woolford (1996) who reported a retrospective study for the first eight weeks of lactation over four years, conducted with Anchormilk, the company responsible for milk quality of the New Zealand Dairy Group. The study included 485 cows which were classified as infected (n=109) or uninfected (n=376) based on whether or not pathogens could be isolated from milk samples after one week post-calving. It was found that infected cows in the first week post-calving had a mean SCC of 900,000 cells/mL which declined to approximately 350,000 cells/mL over a period of eight weeks. The authors also found that up to 35% of the cows with subclinical mastitis at one week post-calving were found to be uninfected at eight weeks post-calving (*Figure 2-3*). In contrast, uninfected cows showed 210,000 cells/mL which thereafter

declined to 100,000 over a period of two weeks. This decrease in the number of SCC was accompanied by a progressive increase in milk yield (*Figure 2- 3*).

Pankey and Pankey (1994) also recommended practices which should be considered for heifers before and after calving in order to reduce the prevalence of mastitis. These were: maintain minimum stress, avoid overcondition of the animals, keep a "heifer mob" during calving and colostrum period, calve in clean paddocks, milk-out as soon as possible after calving, and apply an effective teat spray to cover the teats after every milking.

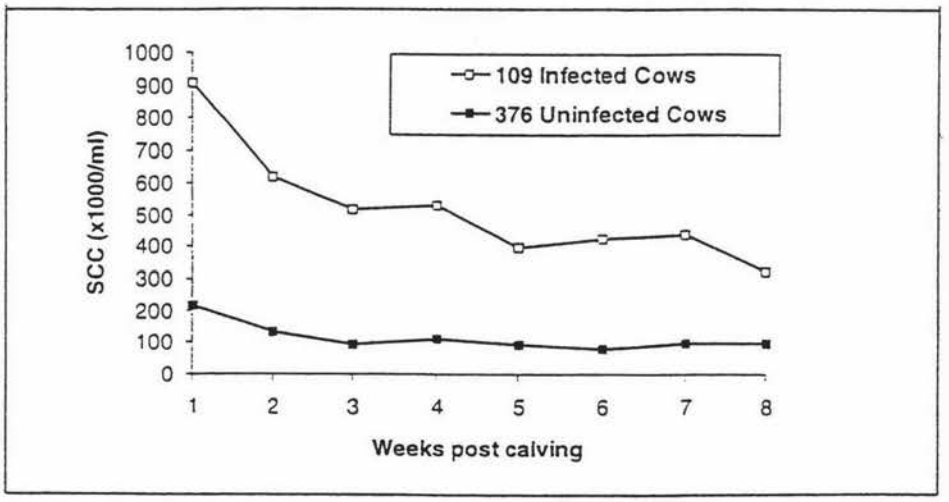


Figure 2-3: SCC decline for infected and uninfected cows pooled across four seasons (Lacy-Hulbert and Woolford (1996).

2.5.5. Lactation Period

A teatspray is recommended for use during lactation to reduce the spread of subclinical mastitis and help to maintain good teat condition. The strategy is to identify and treat clinical mastitis early for best results. It is also advisable to take milk samples to identify the bacteria and ensure the correct antibiotic is being used. However, the manipulation of the udder and/or teats prior to milking is an issue which has generated controversy. Evidence reported at the beginning of section 4 supported this. It is clear that the management practice for clean and dry udders at milking time

begins at the paddock. If cows arrive at the dairy with excess dirt or water on the udder, considerable time is required to prevent reduction in milk quality and/or high risk of mastitis (Klein and Hakin, 1994). But, in agreement with the authors, teat preparation and disinfection and washing the udder depends on the combination of factors such as number of cows at milking, labour and kind of buildings and equipment which maximise milk harvesting on the farm.

Another important aspect during lactation is to monitor the milking machine to ensure its correct performance. LIC (1996) recommended that if BSCC exceeds 400,000 cells/mL for farmer should:

1) Check suspect cows
2) Seek advice from the veterinarian and treat highest cell count cows
3) Consider strategic culling, or dry off cows or quarters.
4) Check the milking machine.
5) Graph BSCC.

2.6. CONCLUSIONS

The purposes of this literature review were to describe the reliability of the somatic cell counts as an indicator of the level of mastitis in a dairy herd and to discuss the principles that constituted a plan of mastitis control, particularly the one applied in New Zealand.

The value of SCC as the most reliable tool to measure the level of mastitis on the farm was recognised. Evidence from New Zealand showed that using information about SCC in bulk milk conferred the greatest discriminative ability to classify infection status of the udders and quarters. The critical threshold for quarters in three different studies was 245,000 cells/mL for bacteriological infection with major pathogens (coagulase positive staphylococci, *Streptococcus agalactiae, Streptococcus dysgalactiae, Streptococcus uberis and Echerichia coli*). Other countries like Canada and United States have already implemented a critical BSCC threshold for subclinical mastitis of 500,000 and 280,000 cell/mL, respectively.

It was also recognised that levels of somatic cells in milk were affected by the magnitude and duration of the infection, the cow's history of previous exposure, and the characteristics of the immune system. Other factors discussed were age and stage of lactation. It was reported that older cows tended to have a greater opportunity for

exposure to mastitis pathogens, have infections for more time and cause more extensive tissue damage.

Somatic cell counts and stage of lactation were also reviewed. It was identified that milk SCC in uninfected cows was high at calving, lowest from peak to mid-lactation and highest at drying-off. It was explained that the increase in SCC in later stages of lactation was partially due to the naturally occurring decline in milk yield. Other factors that affect the number of somatic cells were teat or gland injury, excessive milking or various forms of stress due to poor farm management, nutritional problems, climatic conditions and general illness.

The implementation of BSCC penalty programmes throughout the world is a reality and is the basis for any mastitis control programme. The high correlation between SCC and BSCC (0.6 to 0.7) makes BSCC an ideal tool to measure milk quality on the farm. High BSCC indicates a high incidence of mastitis in the herd. However, its interpretation should be made carefully to avoid misunderstanding because it could be due to either a large proportion of cows having a moderate to high SCC or it could be due to a small proportion of cows having a very high SCC. Nevertheless, it was established that Bulk Somatic Cell Counts (BMSCC) provided a reasonably accurate general indication of the incidence of infection in the herd and of milk quality.

Mastitis control programmes are defined as whole dairy herd management practices which result in good udder health and milk with low SCC. Two main types of mastitis control schemes were described: One, characterised by using a government subsidised system of supervision by mastitis laboratories, monitoring bulk milk for cell count and particular pathogens. Another one, conventional mastitis control, is characterised by the identification of the essential components in the dynamics of the infection and the integration of a control programme including preventive methods with elimination of the infection. The conventional programme has been already implemented in the United Kingdom, Australia, New Zealand and the United States with some modifications. Two major aspects are the basis of this conventional mastitis control plan:

1. To prevent new infections.
2. To reduce the duration of infection.

The components of the general 5-point plan are:

1. Early diagnosis and treatment of the clinical cases presented on the farm. Diagnosis should be based on individual SCC tests.
2. Appropriate use and maintenance of the milking machine.
3. Appropriate dry cow therapy.
4. Culling of the all chronic subclinical cases or clinical cases resistant to treatment.
5. Appropriate hygiene and preparation of the udder, including udder washing and drying, teat dipping or teat spraying.

From the five points described, major emphasis was given to dry cow therapy and milking machine performance, cleaning, and maintenance of the milking machine. There was the general recognition that most of the infections occur during the dry period, especially at the beginning and end of it. This happens because of the distension of the teats and the presence of milk in the teat canal. Therefore, bacteria can easily pass through the dilated canal, affecting the flushing-out mechanism at the next lactation. Depending on the infection rate of the quarters, two types of dry cow therapy were recommended: blanket therapy, when dairy herds have a quarter infection rate greater than 15%, and selective therapy when infection rate is less than 15%.

The literature review also discussed two additional alternatives for mastitis control, namely, vaccination and genetic selection programmes. Vaccination was suggested for circumstances where the other alternative control practices on the farm gave poor results, but where the pathogenic bacteria had been positively identified by cultural methods. Genetic improvement was described as a long-term alternative based on simulation models which could predict which animals would be resistant to mastitis. However, it was described how vaccination was not considered to be completely effective due to incomplete local immunisation in the udder. A potentially undesirable effect of improving one genetic aspect of the animal such as mastitis, might negatively affect some others such as resistance to systemic diseases. Unfortunately, there is still slow progress on those two aspects and research in this area needs to supply more evidence before it can offer new reliable alternatives for mastitis control.

The last part of the literature review focused on the SAMM (Seasonal Approach to Managing Mastitis) plan in New Zealand. It was described how the SAMM plan is a modification of the conventional mastitis plan, adapted for New Zealand conditions. The objective of the SAMM is to produce the world's finest quality milk by reducing the New Zealand national average BSCC to below 150,000 somatic cells per millilitre of bulk milk. Despite the advantages described, it was suggested that farmers still had doubts about the plan as a whole and only applied individual components. Therefore, its benefits were still unclear for them. However, it has been well recognised by milk processing companies that its implementation has increased the quality and therefore the demand for New Zealand Dairy products overseas.

Chapter Three

3. Methods

3.1. Source and collection of the Data

200 suppliers from Tasman Milk Products Ltd (TML) (Nelson, Golden Bay and Murchison, South Island New Zealand) were surveyed by mail in July 1996 in order to gauge the effect of mastitis control practices on milk yield and quality in their dairy herds. The survey used a written questionnaire and contained 53 questions divided into eight sections (*Appendix One*). The questions were written to gain information about individual practices for mastitis control; farm dairy function, hygiene and maintenance; and husbandry of the dairy herd in the environment of northern South Island, New Zealand.

Questions in Section One sought general information about the farm including supplier number; milking area; number and breed of cows; number of people working in the farm dairy (milking shed) at the peak of the season; and dates of starting calving, drying-off and milking once-a-day for selected and all cows.

Section two included questions about hygiene practices and teat disinfection before and after milking respectively during early, mid and late lactation and the reasons for such practices.

Questions in section three were about the practice of herd testing, specially the service provided by LIC in New Zealand. The section also asked questions on the method of stripping, and the number of cows diagnosed, treated, recovered and

retreated for clinical mastitis. There were also questions on culling practices both for cases of chronic clinical mastitis and for high SCC at drying-off time; dry cow therapy (DCT) practices; and diagnosis of clinical mastitis before calving.

Section four condensed questions about herd status for BSCC during the season in early, mid and late lactation. Section five asked questions about changes to the herd size. Section six quested information about the characteristics, repair and maintenance of the milking machine and vacuum system. Section seven incorporated questions about the SAMM plan and its possible effects on milk quality. Section eight contained questions about age and academic qualification of the dairy farmers and their partners.

To support the questionnaire it was considered important to use milk company data about those suppliers who gave their permission for that to happen. Suppliers were linked to records by supply number, not by name, to ensure confidentiality and to try to improve the reliability of all data collected. Milk quality and milk production records, belonging to respondents only and provided by the local milk company, were used. For each respondent there was at least one monthly record of milk volume, milk fat (kg), milk protein (kg), concentration of fat (%) and concentration of protein (%), and records of one to five milk somatic cell counts (SCC) per month. To simplify the use of BSCC records, its mathematical mean was obtained. Once the mathematical mean of BSSC was released, results were transformed into natural logarithms.

3.2. Preparation of the data for statistical analysis

Firstly, once an individual survey was collected, it was entered into the computer using a Windows Microsoft Excel® package. Secondly, a coding system for categorical data (qualitative data from suppliers) was created using one unit of gap between variables (*Appendix Two*). Questions with yes/no answers were coded with values 1 for yes and 0 for no, respectively. Other answers related to management practices on the farm were coded in descending order with as many values as were needed. Additionally, mathematical operations were performed to obtain extra data:

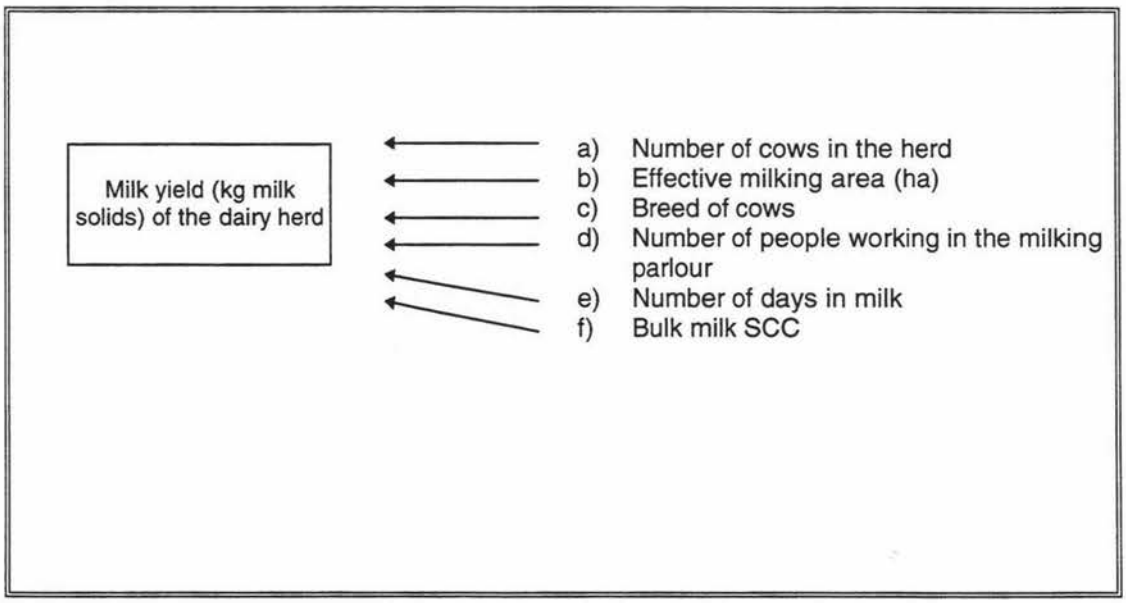
* The number of cows per hectare, by dividing the number of cows in the herd into the total milking area of the farm.
* The number of days in milking, by subtracting from 365 days the number of days before calving in 1995, which started 20 July 1995 (*i.e.* day 201, the earliest calving date recorded by respondents). The difference (164) was added to the number of days in 1996, beginning on 1 January 1996 (day 1) and ending in late May-early June (day n) when the herd was finally dried-off.
* The date of milking the cows once-a-day, by counting the number of days from 1 January 1996 (day 0) to the day when cows were milked once-a-day during the first semester of 1996 (day n). The total number of days on once-a-day milking after calving was obtained similarly to the procedure used for the number of days in milking.

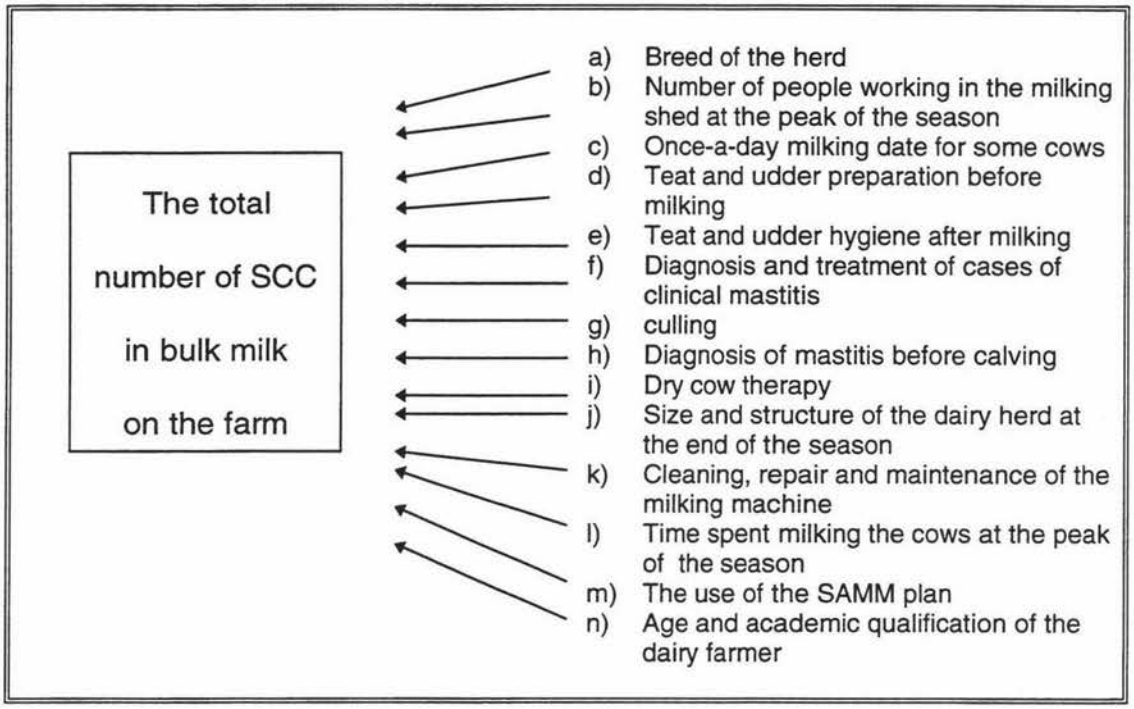
Thirdly, the input data were corrected and converted into MS-DOS text file prior to the statistical analysis. All of the analysis was performed using the statistical package SAS® (Delwiche and Slaughter, 1995).

3.3. Statistical analysis

a) A drawing of the relationships among variables (*Figure 3-1*) illustrates the models proposed for the current study.

Figure 3-1: Proposed relationships among variables for statistical analysis.





The statistical analysis of the data included:

a) Explanatory descriptive statistics for the continuous and discrete variables using the MEANS procedure in SAS®.

b) Bivariate analysis were carried out for both discrete and continuous variables using the FREQUENCY procedure in SAS®. Significant results were taken to be at a chi-square value below 0.05.

c) Cross-tabulations for selected discrete variables (*Table 3-2*) were performed. Additional cross-tabulation analysis was conducted for the use of the SAMM plan in Autumn/95 and the effect of SAMM plan on milk quality. Significant results were taken to be at a chi-square value below 0.05.

d) Correlation analysis for continuous variables by Pearson's correlation coefficient was used, incorporating the data from continuous variables from individual suppliers by using the CORRELATION procedure in SAS®. Correlated variables were significant at a P value below 0.05.

e) Regression analysis for continuous variables was conducted incorporating the data from continuous variables from individual suppliers into the following predicted model:

$$y = \mu + \beta_1 \chi_1 + \beta_2 \chi_2 + \beta_3 \chi_3 + \beta_4 \chi_4 + \beta_5 \chi_5 + \beta_6 \chi_6 + \varepsilon,$$

where y was the dependant variable and χ_n, represented the independent variables at n number of observations (*Table. 3-1*). For each variable the difference between sub-groups (e.g. breed of cow, or pre-milking hygiene practice) were significant if their P value was *(Prob>F)* less than 0.05.

e) A general linear model for discrete variables was constructed using the GLM procedure in SAS®(*Table 3-2*). The estimates were obtained by general linear model with 38 management practices and one production parameter regressed on the natural logarithm of the total BSCC.

Table 3-1: Predicted equations for the regression analysis.

$$y_i = \mu + \beta_1 \chi_1 + \beta_2 \chi_2 + \beta_3 \chi_3 + \beta_4 \chi_4 + \beta_5 \chi_5 + \beta_6 \chi_6 \varepsilon, \text{ where}$$

μ = The general mean

y_i = The total kilograms of milk solids per herd for the i^{th} supplier

χ_{i1} = (a2) Number of cows milked at the peak of lactation

χ_{i2} = (a3) Effective milking area (ha) of the farm

χ_{i3} = (a4) Breed of the herd

χ_{i4} = (a5) Number of people working in the milking shed at the peak of the season

χ_{i5} = (a8) Number of days in milking

χ_{i6} = (BSCC) Average SCC in bulk milk during lactation

β_{1-6} = Intercept and estimated parameters

ε = The random error which is expected to have a value of zero and a constant variance.

Table 3-2: Alphabetic list of selected management practices and production characteristics for suppliers surveyed.

#	Variable	Label
1	A14	Teat washing in early lactation
2	A15	Teat washing in mid-lactation
3	A16	Teat washing in late lactation
4	A17	Why teat washing in some cows
5	A18	Teat spraying in early lactation
6	A19	Teat spraying in mid-lactation
7	A20	Teat spraying in late lactation
8	A21	Why teat spraying in some cows
9	A22	Teat dipping in early lactation
10	A23	Teat dipping in mid-lactation
11	A24	Teat dipping in late lactation
12	A25	Why teat dipping in some cows
13	A26	Herd tests during the season
14	A27	Frequency of herd tests
15	A28	Strippings to check mastitis
16	A29	Method of stripping
17	PROP	Percentage of cows in the herd positive to clinical mastitis
18	PROP2	Percentage of cows in the herd recovered
19	PROP3	Percentage of cows in the herd retreated
20	PROP4	Percentage of cows in the herd culled due to clinical mastitis
21	PROP5	Percentage of cows in the herd culled due to high SCC
22	A36	Dry cow therapy practice
23	A37	Selection of dry cow therapy
24	A38	Examination of clinical mastitis pre-calving
25	A39	Selection of cows for examination
26	A43	Current size of the herd
27	A44	How the herd is increasing
28	A45	Type of milking parlour
29	A46	Number of milking cup sets
30	A47	Automatic cup removal system
31	A48	Time taken to milk the herd
32	A49	Checking of the vacuum system
33	A50	By whom
34	A51	Times the inflations were changed
35	A53	Use of the SAMM plan in Autumn/95
36	A59	Date of birth
37	A60	Academic qualification
38	A62	Years in dairy farming
39	MS	Total kg of milk solids

Chapter Four

4. Results

4.1. Production Parameters

Ninety two questionnaires from 200 TML suppliers were filled and returned giving a response rate of 46 %. According to question one, ninety suppliers (98 %) were seasonal calving suppliers whereas only two (2 %) were town (365-day) milk suppliers. The mean production parameters for seasonal calving suppliers are summarised in *Table 4-1*.

4.2. General Information

The general information of the farm is condensed in questions two to eight. Questions two and three sought the number of cows and the milking area of the farms, respectively. Frequency distributions for these questions are also observed in *Appendix Three - Tables 1A, 2A, and 3A*, including the stocking rate. The maximum effective area recorded was 260 ha and the minimum effective area recorded was 19 ha; the mean effective area was 79 ha (*Table 4-1*). Most of the suppliers (72 %) had a milking area between 50 and 150 ha, some (24 %) had a milking area smaller than 50 ha. and a few (4 %) suppliers had a milking area larger than 150 ha.

Table 4-1: Mean values for the production parameters during the 1995/96 season .

Variable	max	min	mean	cv
Total kg of milk solids	147,255	11,421	54,136	46.32
Total kg milk solids per hectare	1,907	285	735	33.03
Total kg milk solids per cow	906	167	304	28.57
Total kg milk solids/ cow /day	3.48	0.72	1.10	28.51
Percentage of fat	6.46	4.34	5.07	11.44
Percentage of protein	4.28	3.28	3.70	6.64

The Milk fat and milk protein production for seasonal calving suppliers during 1995-1996 are shown in *Figure 4-1*.

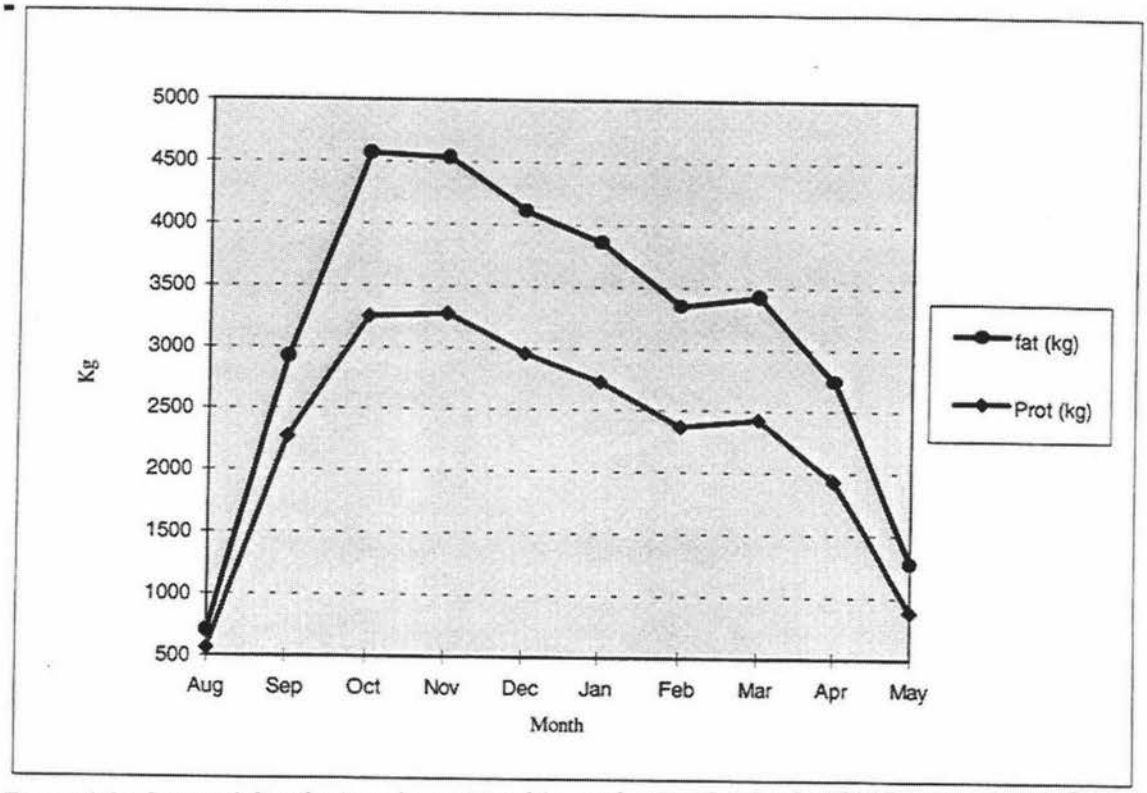


Figure 4-1: Seasonal distribution of protein and fat production (kg) for the 1995/96 season (includes only suppliers respondents.

Figure 4-1 shows both milk fat and milk protein production curves. These move in three different directions during the first half of lactation: At first, there is a steady increase in early spring (August) reaching a peak in mid--spring (September) which is maintained until late spring (November); then, there is gradual drop from November to February (summer). By contrast, in the second part of the *Figure 4-1* it can be observed that there is a small rise in February with a steady drop in late May-early June (Winter) to complete the period.

Figure 4-2 shows the variation in milk fat and milk protein concentration during the 1995 - 1996 season. It can be seen in the figure that both milk fat and milk protein concentration move from a rapid decrease in early spring, to a constant trend during most of the spring and summer, to a steady rise in autumn to complete the total trend in late May.

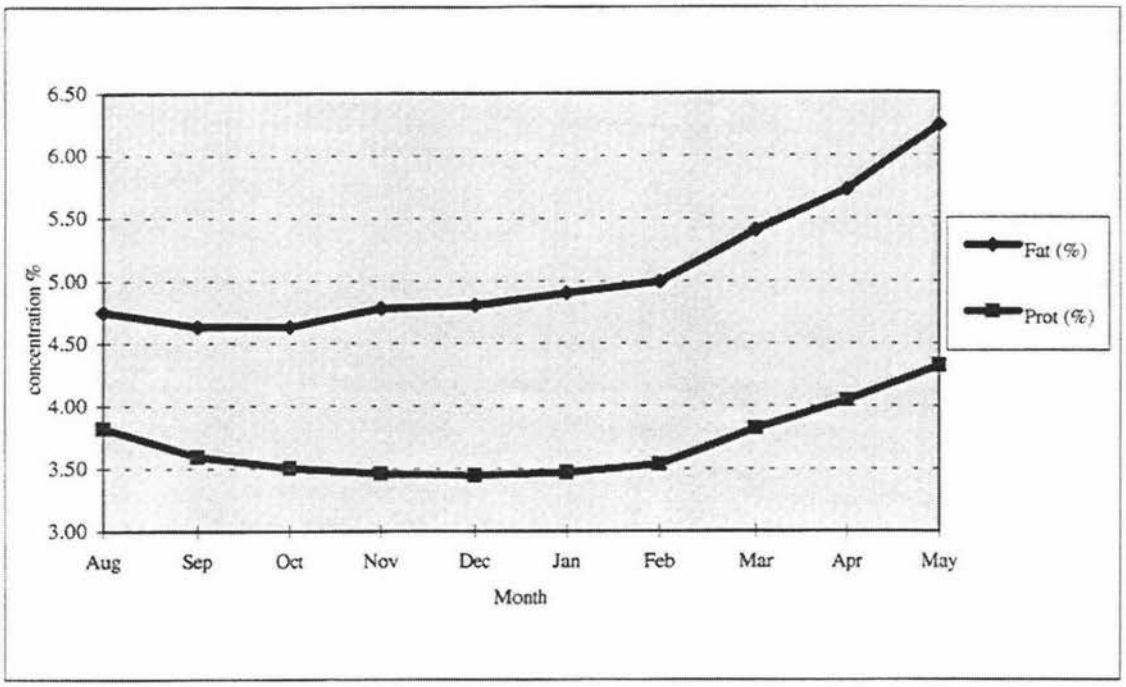


Figure 4-2: Seasonal distribution of protein and fat concentration for the 1995/96 season (includes only supplier respondents).

The mean number of cows was 182. The maximum and minimum number reported were 540 and 40 cows, respectively. Many suppliers (57 %) had between 150 and 250 cows, some 37 % had less than 150 cows and a few (6 %) had more than 250 cows.

The mean number of cows per hectare was 2.4. The maximum and minimum values recorded were 4 and 1, respectively. Most of the suppliers (78 %) reported between 2 to 3 cows per hectare (cows/ha); a few (14 %) had less than 2 cows/ ha and very few (8 %) had more than 3 cows/ha.

Question four dealt with the percentage of the major breeds used by local suppliers (*Figure 4-3*). The figure shows the dominance of the Friesian breed (54 %) over Jersey herds (24%), Friesian x Jersey crossbred herds (18 %), Ayrshire crossbred herds (2 %) and Ayrshire herds (1 %), respectively.

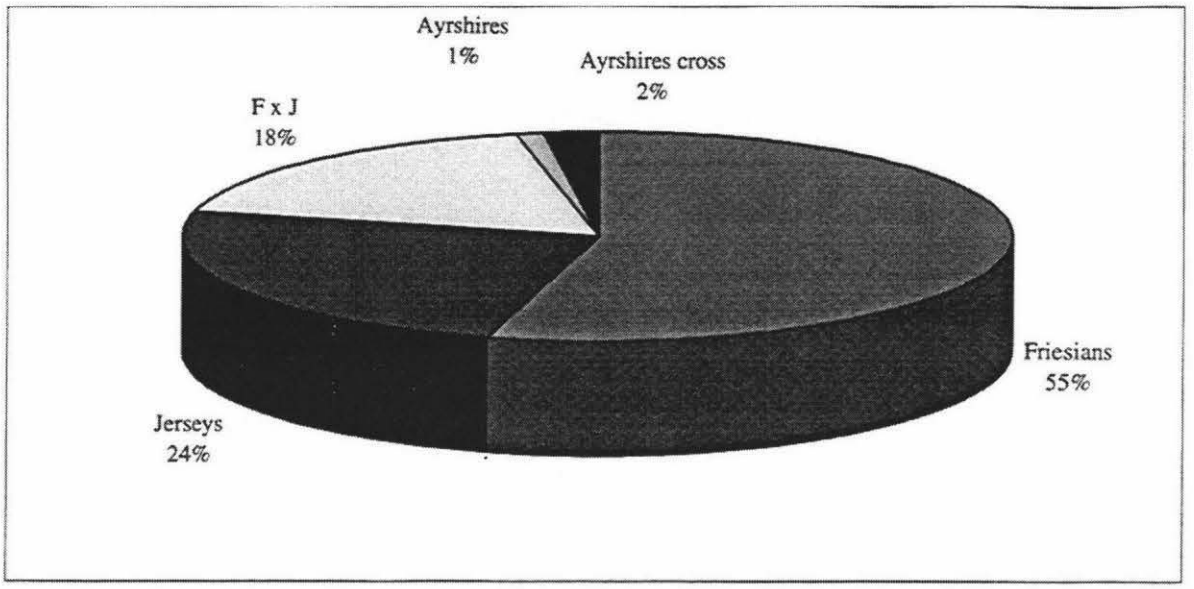


Figure 4-3: Breed percentages for suppliers in 1995/96 (includes only supplier respondents)

Question five sought the number of people working in the milking shed at the peak of the 1995-1996 season. The mean number of people working in the milking shed at the peak of the season was 1.6; the maximum and minimum values were 5 and 1, respectively. In most of the cases two people (52 %) worked in the milking shed at the peak of the season, followed by one (44 %), three (3 %) and five (1 %), respectively (*Appendix Three - Table 4A*).

The mean ratio of cows:farmer was 119 cows per farmer. The maximum and minimum values for the ratio cows:farmer were 260 and 20, respectively. In the majority (77 %) of cases, the ratio of cows:farmer was between 50 and 150 cows per farmer; the cows:farmer ratio was higher than 150 for 20 % of the respondents and only a few (3 %) recorded less than 50 cows per farmer (*Appendix Three - Table 5A*).

Questions six and seven dealt with the initial calving date and drying-off dates of the herds for seasonal milk suppliers. The results are given in *Appendix Three - Table 6A*. The mean calving date was August 8, 1995 and the mean drying-off date was May 16, 1996.

Given the initial calving and drying-off dates, the duration of lactation was obtained. The mean lactation length was 282; the maximum and minimum values for the lactation length were 315 and 234 days, respectively. In the majority (75 %) of cases the duration of lactation was between 250 to 290 days; in some cases (23 %) the duration of lactation was longer than 290 days and in a few cases (2 %) the duration of lactation was shorter than 250 days (*Appendix Three - Table 7A*).

Question eight sought the date of starting once-a-day milking for two categories: "some cows" and "the whole herd" . The mean date for once-a-day milking for some cows was April 30 1996 whereas the final once-a-day date for the whole herd was May 4 1996. In a large number of cases (70 %) farmers preferred the whole herd to be on once-a-day milking before drying-off time rather than having only some cows on once-a-day milking. When individual cows were selected for once-a-day milking before drying off it was because of the light condition of the cows (68 %), cows with high somatic cell counts (25 %) or cows milked on from the previous season (2 %).

4.3. Milking Practices On The Farm

The aim of this section was to know the routines practised by suppliers to maintain the teats of the cows clean and healthy before and after milking (Questions nine to 20). There were three options: a) teat washing before milking, b) teat spraying after milking and c) teat dipping after milking. The frequency distribution for these are shown in *Appendix Three - Tables 9A - 18A*. The percentage of the routines most used in early mid- and late lactation are observed in *Figure 4-4*.

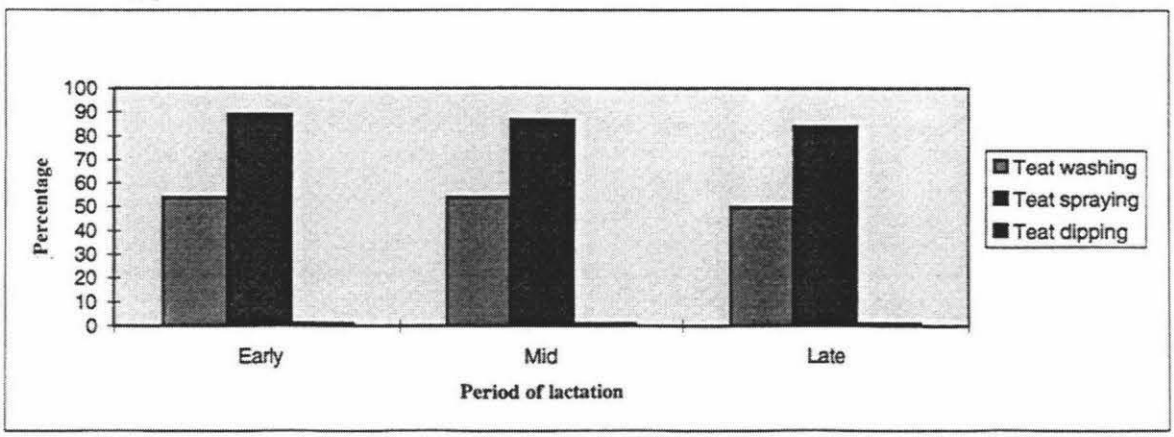


Figure 4-4: Frequency distribution for the milking practices for the 1995/96 season (includes only supplier respondents).

Teat washing before milking was practised selectively in 53 % of cases in early and mid-lactation and in 50 % of the cases in late lactation. In the great majority of the cases (93 %), the decision was made because teats were dirty, muddy or wet. In only a few cases (7 %), selected cows had teats washed after calving.

Teat spraying of all cows after milking was the most common disinfection routine performed by suppliers. In 89 %, 87 % and 84 % of the cases, teat spraying was used in early, mid- and late lactation, respectively. By contrast, most respondents replied that they did not use teat dipping using disinfectant solution after milking, during lactation. No cows were teat dipped after milking in early lactation in 95 % of cases, and in late lactation in 96 % of cases.

4.4. Herd Testing, Diagnosis and Treatment of Clinical Mastitis and Dry Cow Therapy

The objective of this section was to determine the number of dairy farmers who practised herd testing, diagnosis, treatment, and re-treatment of clinical mastitis in individual animals on the farm and their recovery rates. Additional information required included the number of cows which were culled due to both high somatic cell counts and clinical mastitis (Questions 21 to 31).

Herd testing on the farm was practised in the majority of cases (87 %). However, the number of herd tests practised by dairy farmer varied: 2-monthly (77 %) was the most used whereas very few (9 %) tested their herds twice in the season (*Appendix Three - Table 19A*).

In a majority (79 %) of cases individual cows were stripped when clinical mastitis was suspected; in some cases (19 %) cows were stripped without any specific routine and only 2 % of suppliers stripped the cows at almost every milking. Furthermore, checking clinical mastitis in individual cows was, in most (77 %) cases, by stripping the teat of the cow before milking whereas 10 % practised stripping before and after milking, 8.5 % never practised stripping and 5 % practised stripping after milking to check clinical mastitis (*Appendix Three - Tables 20A and 21A*).

Equally important were the number of cows which were diagnosed, treated, which recovered and which were retreated against clinical mastitis (Questions 24 to 27). The mean reported of diagnosis of clinical mastitis was only 8 % (8 cows per 100) per

season. Every cow which was found to have clinical mastitis was treated. 80 % of the cows treated recovered satisfactorily following treatment whereas the remaining 20 % needed re-treatment (*Appendix Three - Table 22A*).

Questions 28 and 29 dealt with culling for clinical mastitis and SCC. It was found that, on average, 1.5 and 3 % of the cows in each herd needed to be culled for clinical mastitis and high somatic cell counts, respectively (*Appendix Three - Table 23A*).

Question 30 related to the use of dry cow therapy (DCT) on the farm. It was found that 90 % of farmers practised DCT selectively at the end of lactation whereas 5 % used DCT in all the cows in their herds and the same number of farmers did not use DCT at all. Selection of the cows to receive DCT was based on four major criteria: (the percentage of respondents who used the method is given; more than one method could apply on a farm hence the total is different from 100)

a) Reaching a threshold trend SCC (64 %). Reported threshold for heifers ranged between SCC 80,000 and 120,000. For cows the threshold SCC ranged between 100,000 and 150,000
b) Cows which were older or had mastitis history (29 %),
c) Any cow or heifer with SCC higher than 300,000 mL (6 %)
d) To ensure low somatic cell counts from new purchases (5 %) (*Appendix Three - Tables 24A and 25A*).

There was varying response to the question about an examination for clinical mastitis before calving (Question 31). In most cases (62 %), checking for mastitis before calving was not practised. 30 % of the farmers attempted to diagnose mastitis in all cows and 8 % checked for mastitis in some cows before calving (*Appendix Three - Table 26A*). When clinical mastitis was checked before calving in the herd, it was done by visual examination of udders of the cows once in the dry period in 89 % of the cases whereas 6 % of respondents checked for mastitis before calving in all the cows every two weeks especially if there had been high SCC during the previous season (*Appendix Three - Table 27A*).

4.5. Somatic Cell Counts in Bulk Milk

The purpose of this section was to evaluate the SCC in bulk raw milk on the farm. The mean BSCC during the 1995/96 lactation for suppliers surveyed was 217,000 cells/mL; the maximum and the minimum values for BSCC during the lactation were 457,000 and 70,000 cells/mL, respectively (*Appendix Three - Table 28A*).

35 % of farmers achieved a mean of less than 150,000 cells/mL, 40 % of farmers achieved a mean between 150,000 and 250,000 cells /mL, 22 % of farmers had a mean between 250,000 and 400,000 cells/mL and only 3 % of farm had a mean of more than 400,000 cells/mL (*Appendix Three - Tables 29A*). These are in concordance with the responses in questions 32 to 34 which sought to evaluate the number of farms returning BSCC less than 400,000 cells/mL in early, mid-, and late lactation. 98 % of farms had BSCC less than 400,000 cells/mL in early lactation; 100 % in mid-lactation and 93 % in late lactation (*Appendix Three - Tables 30A, 31A and 32A*). *Figure 4-5* illustrates the trend of the BSCC during 1995 - 1996.

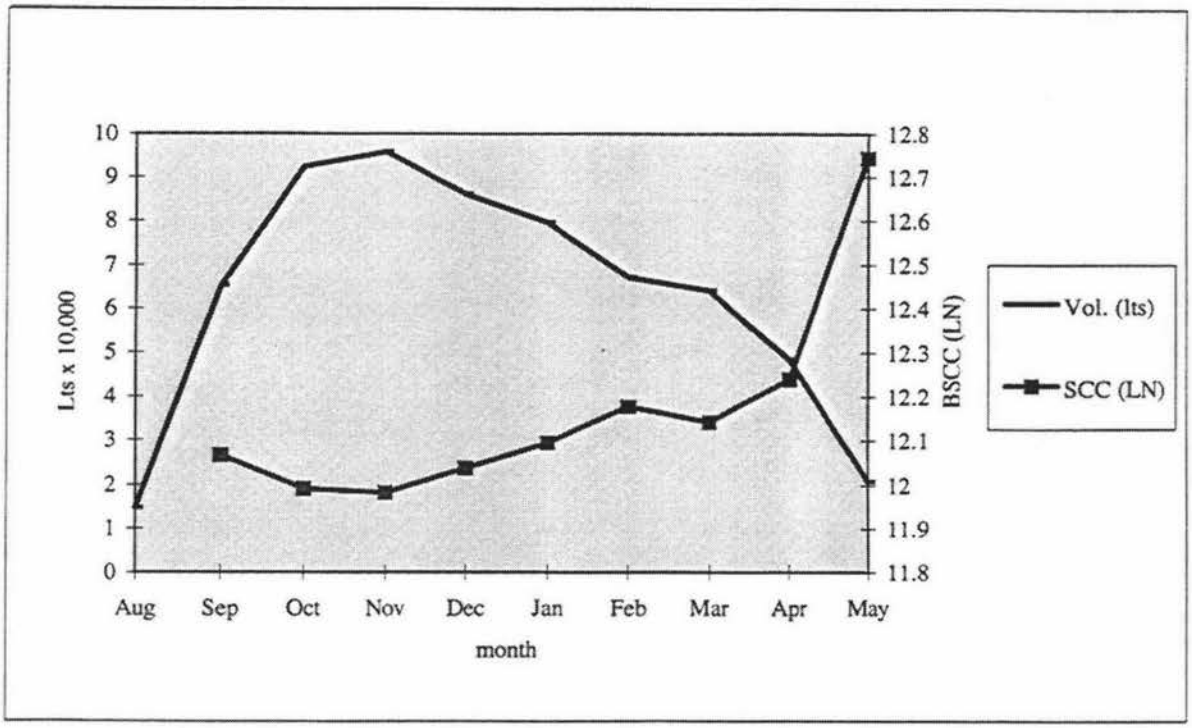


Figure 4-5: Seasonal distribution of the milk production (l) and mean BSCC in 1995/96 (includes only supplier respondents).

The curve shows that in early lactation the BSCC decreased, then gradually increased during mid-lactation. There was a small drop in late lactation but there was a dramatic increase in late lactation to the end of the season. The upper limit of 400,000 cells/mL was not exceeded at that time.

4.6. Herd Size, Cowshed and Milking

The purpose of this section was to ascertain whether or not the size of the herd was changing toward the next season (questions 35 and 36). In most of cases (94 %) it was found that the herd size was increasing or being maintained at the same number of cows. In 6 % of cases, the herd was decreasing. 79 % of farmers were increasing the size of the herd by rearing and/or buying replacements and leasing cows, 6.5 % by rearing and/or buying replacements and 15. % by fewer cullings (*Appendix Three - Tables 33A and 34A*).

Questions 37 to 42 dealt with the characteristics and maintenance of the farm dairy (milking shed) and its components. A majority (83 %) of cases reported herringbone milking parlour. Rotary milking sheds comprised 15 % and walk-trough milking parlours 2 %, respectively (*Appendix Three - Table 35A*).

The number of sets of milking cups ranged from 8 to 60 with a mean value of 10. The frequency distribution for the number of cup sets (*Appendix Three - Table 36A*) showed that the majority of milking parlours (95 %) had between 8 and 32 of set cups. There was little variation in terms of set cups per shed. On average, farmers milked 10 cows per set of cups, with a maximum 15 cows per unit and a minimum of 4. Question 39 dealt with whether or not the milking shed had automatic cup removal. It was found that most respondents (87 %) did not have an automatic cup removal system whereas the remaining 13 % of milking sheds had automatic cup removal.

Question 40 regarded information about the time spent milking the cows at the peak of the season. It was found that the mean period of time spent milking the cows was 1.5 hours with minimum and maximum values of 0.7 hours and 2.5 hours, respectively. 13 % of the farmers spent less than one hour milking the cows, 49 % spent between one and 1.5 hours, 36 % spent between 1.5 and two hours and 2 % required more than two hours (*Appendix Three - Table 37A*).

Question 41 dealt with the maintenance, testing and tester of the vacuum system of the milking machine. 86 % of the farmers had the vacuum system tested. The response to the question about who tested the vacuum system was divided; in 48 % of the cases, a local private company tested the vacuum system whereas in 47 % and 5 % of the cases the dairy company or the Ministry of Agriculture and Fisheries (MAF), respectively, tested the vacuum system (*Appendix Three - Table 38A*).

Question 42 related to the number of times inflations were changed during the season. It was found that 4.5 % of the farmers did not change the inflations during the season, 72 % of the farmers changed the inflations once, 22.5 % of the farmers changed twice and only 1% of the farmers changed the inflations thrice during the season (*Appendix Three - Table 39A*).

Suppliers were asked about the way they train new milkers who work in their farm dairy (milking shed) (Question 43). It was found that half of the respondents (51 %) did not have new milkers to train whereas the other half trained new milkers. When it happened, training new milkers was by a close supervision (39 %)and milking the cows with them during the training period (11 %) (*Appendix Three - Table 40*).

4.7. The Use of The SAMM plan

Questions 44 to 47 dealt with the use of the SAMM plan and its effects on milk quality on the farm. The majority of respondents (72 %) applied the SAMM plan in 1995-1996. However, the opinion about the effectiveness of the SAMM plan was divided as observed in *Appendix Three- Table 40.* 60% of the respondents who used the SAMM plan in 1995/96 season believed that it was useful whereas the 40 % of respondents believed that it did not have any effect on the milk quality status on the farm.

82 % of respondents believed that they received enough information from their dairy company on how to control the number of somatic cells in bulk milk. In addition, some suppliers believed that the SAMM plan booklet (44 %), the Dairy Exporter (18 %) veterinarians (13 %), discussion groups (8 %) and the private detergent companies (6 %) were also useful sources of information about lowering the levels of SCC on the farm (*Appendix Three - Table 42A*).

4.8. Personal Information

The last section of the survey (questions 48 to 52) related to personal information of the farmer, including age and academic qualification and partner's academic qualification. The frequency distribution for age and academic qualification for the farmers and partner are shown in *Appendix three- Tables 43A to 46A*.

The mean age of the farmer was 43 years old with a maximum and minimum of 66 and 26 years, respectively. Several suppliers surveyed (40 %) were between 30 and 40 years old; 38 % were between forty and fifty five years old, 11 % were younger than 30 years old and the same number were older than fifty five years old.

32 % of farmers and 36 % of their partners had obtained a high school certificate, 10 % of farmers and 14 % of their partners had obtained a diploma and 11 % of farmers and 8 % of their partners had obtained a bachelor's degree. 6% of the farmer's partners had obtained a registered nurse/teacher qualification.

Chapter Five

5. Discussion

5.1. Introduction

The current study is an extension of a previous project related to milk quality among local dairy suppliers in the Central North Island (Londoño, 1996). In that study, two-round personal interviews of three typical New Zealand suppliers of a local company were carried out. They included:

a) a manager of a commercial farm at Massey University,
b) an owner of a farm who did not live on the farm but who was fully involved in the decision making process and
c) a 50-50 sharemilking family on a farm supplying milk all year, including to a quota in winter.

The objectives were to identify attitudes, concepts and beliefs about milk quality and to design a rich picture of the major components related to milk quality management on the farm.

It was found that climate conditions, herd feeding level and milking and health management practices of the herd were major key factors that affected the milk quality status on the farm. As a consequence, there was general agreement by interviewees that milk quality was a market reality which required commitment, scientific knowledge and involvement at the farm level by those responsible for the decisions made (*see Londoño, 1996*).

Following this study, it was decided to seek information from a larger sample of dairy suppliers about their herd and milking procedures, to determine if they related to the quality of milk supplied to their processing company.

Tasman Milk Products Ltd (TML) signalled that it was required to progressively lower BSCC from its suppliers and would apply penalties to milk which did not meet their criteria. The first step was to lower the BSCC at which the penalty level had been set from 500,000 cells per millilitre (cells/mL) of milk to 400,000 cells/mL. To achieve this goal, the company used a penalty system which included milk test rates and grade limits (TML, 1996). The most recent action has been to tell suppliers that in the 1996/97 season their target is to decrease the BSCC from 400,000 cells/mL to 200,000 cells/mL *(Figure 5-1)*. The company imposed the standard in response to a New Zealand Dairy Board (NZDB) directive about the quality of the milk expected by overseas customers of products supplied under the NZDB brands.

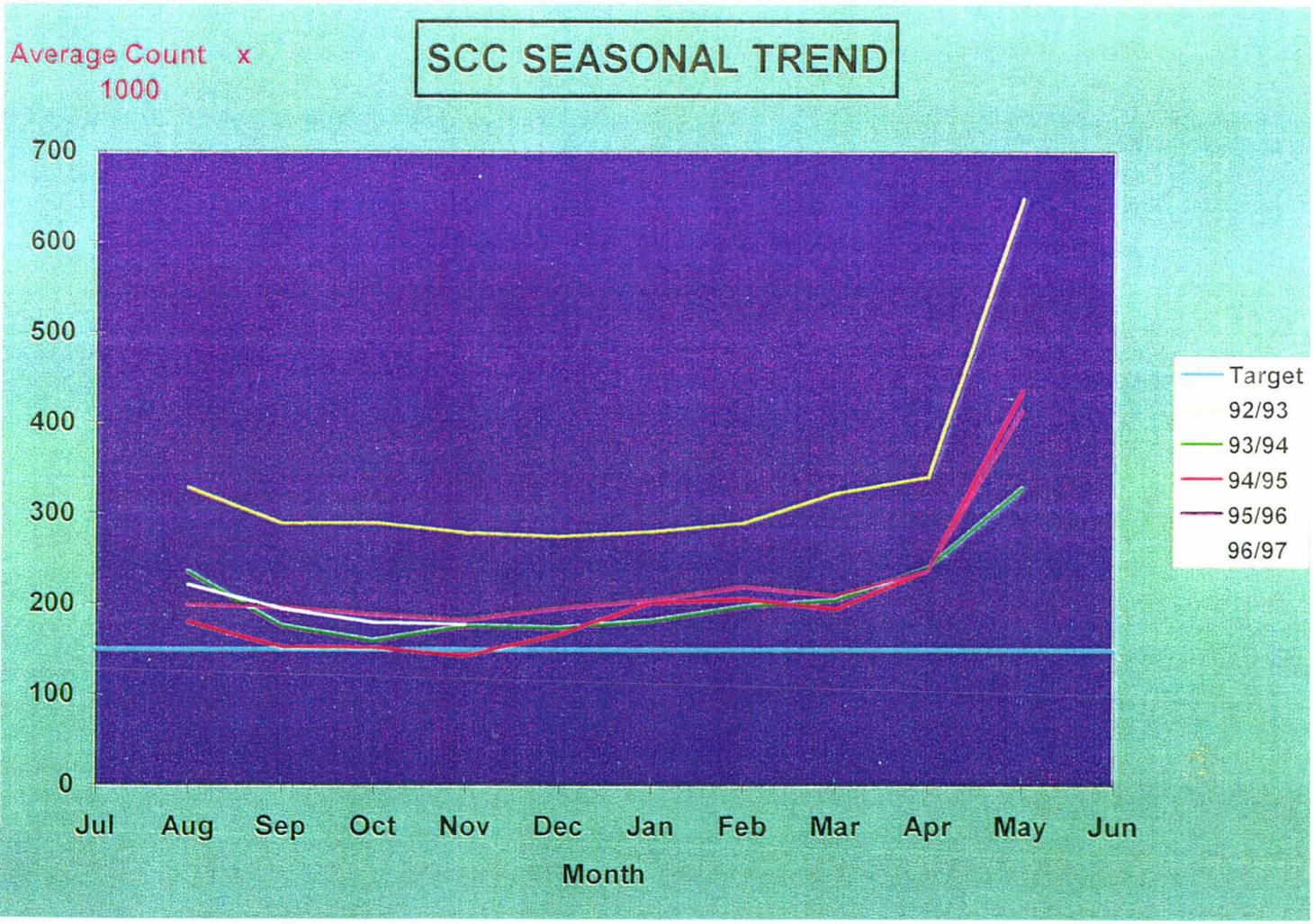


Figure 5-1: Tasman Milk Products Ltd BSCC seasonal trend from 1992/93 to 1995/96 (Perry, 1996)

To achieve this further goal, milk supplied to the company with a higher SCC than 400,000 cells /mL for seven successive days would cause milk subsequently produced to not be collected until the cause of the problem was corrected. The major goal for the year 2000, is to have an average BSCC at or below 150,000 cells /mL (Watson, 1996). At the time of the survey conducted for the study reported here the dairy company and its suppliers were still operating at a BSCC of 400,000 cells/mL threshold. The new criteria did not apply until January 1997.

This study was designed to collect quantitative and qualitative data from farmers about the milk quality programme on their dairy farms for:

a) A description of the farms surveyed
b) Estimating relationships between practices of interest and their outcomes as assessed by milk quality records.
c) Providing useful information to the dairy company and its suppliers in order to reach its milk quality goals (Parker, 1994).

5.2. Production Parameters

The 46% response rate (92 of 200 suppliers) by mail for this study was lower than the response by mail obtained by Laycock *et al.* (1987) but higher than the response by mail achieved by Holdaway (1993). Laycock *et al* (1987) reached a 65% response whereas Holdaway (1993) achieved only a 30% response.

The analysis of the SAMM in the current study was based on the information provided by the farmers by mail. Some of the questions were not answered, resulting in missing data which in turn affected the overall statistical analysis. Thus, the results in the present study are in concordance with Gill *et al.* (1990) in United States of America who reported that there were no direct inferences from cause and effect, or from selection criteria for the dairy husbandry or milking practices on the dairy farm.

Hutton *et al.* (1990) in United States of America (n = 309 herds), collected of data during twelve months and a field technician visited each farm twice a year to collect information about the dairy production system *e.g.* milk quality and milk production records, milking practices, mastitis therapy program, culling practices, milking machines, type of records kept by the farmers and nutrition program. In addition, Schukken *et al.* (1990) used the information of 125 farms with a low mean BSCC during

12 months; with an annual mean on the 12 months preceding the study of below 150,000 cells/mL; with an average milk production of 7,138 kg FCM, 3.3% protein; and with a calving interval of 379 days. In both studies there were no conclusive findings about the dairy husbandry and milking management practices on BSCC. Furthermore, in all the cases cited it was recommended that further studies be performed to evaluate the effectiveness of milk quality practices on the farm. Thus, it suggests that the relationship of dairy husbandry and milking management practices on the farm with BSCC is still unclear and needs approaches other than those applied to date.

Milk production and its constituents followed the typical New Zealand seasonal milk production pattern (MAF, 1996). There was a significant ($p=0.002$) negative relationship between milk solids per hectare and BSCC, due to the effect on milk production of pathogens which caused the increased BSCC on the dairy farm (Holmes, 1990). The significant negative correlation between BSCC and milk production in this study is in concordance with Londoño (1996) who discussed farm profitability from milk productivity. It was affected by poor management practices by dairy farmers which influenced changes in milk production and its constituents, hence altering the quality of the milk. By contrast, there was no significant difference between classes of herds (High, > 250,000 cells/mL and Low, < 250,000 cells/mL) and total milk volume produced during the 1995/96 season among TML suppliers meaning that the total volume produced per herd among TML suppliers was not affected by BSCC. However, it was explained in chapter four (*Figure 4-5*) that the BSCC trend changes seen during lactation were due to the differences in milk volume.

Milk fat, milk protein and protein and fat percentages were not affected by BSCC which were in agreement with the findings by Ntum (1995). In addition, the same author found that there were very low correlations between BSCC and protein and fat percentages throughout lactation. No significant effects of mean BSCC on total milk solids production and its components were found. In addition, there were no significant variations from the statistical mean among suppliers (*Table 4-1*).

Table 5-1 shows a comparison between national and district records, and those obtained in this study for the production parameters during the 1995/96 season. The mean effective milking area in this study was similar to the average effective area reported by Livestock Improvement Corporation (LIC) (1996). The mean number of

cows per hectare in this study was similar to both national and district averages of 2.5 cows per hectare (LIC, 1996). According to the Ministry of Agriculture and Fisheries (MAF) (July 1996), the average lactation length was around 250 days, 32 days less than the duration of lactation recorded by respondents in this study. By contrast, LIC (1996) reported that the national and regional average days in milk were 224 and 225, respectively. However, the number of days in milk published by LIC (1996) did not necessarily reflect the average lactation length of the dairy cows because it only takes into account the number of days from the estimated start of lactation to the estimated end of lactation. Some cows enter the herd after the start of lactation and some leave the herd (through death, culling, drying-off) before the end of lactation.

Table 5-1: Comparison of the production parameters for the 1995/95 season [1]

Variable	National	District	Survey
Effective milking area (ha)	82	82	79
Number of cows	199	204	182
Number of cows per hectare	2.5	2.6	2.42
Lactation length (days)	250 [2]	250 [2]	282
Total volume of milk (litres)	663,300	677,800	635,000
Total kg of milk solids	73,500 [3]	56,200 [3]	54,136
Total kg milk solids per hectare	674 [3]	706 [3]	735
Total kg milk solids per cow	280 [3]	290 [3]	304
Total kg milk solids/ cow /day	1.12 [3]	1.16 [3]	1.10
Percentage of fat	4.72	4.72	5.07
Percentage of protein	3.60	3.60	3.70

[1] Source: LIC (1996) and survey results
[2] Source: MAF (1996 July).
[3] Fat + protein.

As observed in *Table 5-1*, the regional average milk solids production per hectare recorded in this study was very similar to the average milk solids production per hectare (kg per ha) recorded by MAF (July 1996). The average total milk solids per cow (kg MS/cow) published in MAF (1996 July) was similar to, but 6 kg MS/cow higher than the one found in this study. The average percentages of protein and fat per cow reported by LIC (1996) were very similar to those recorded in this study. There were no

significant correlations between both lactation length and milk yield at the end of lactation on BSCC.

5.3. General Information

The breed representation percentages recorded in this study were similar to those reported by LIC (1996). LIC (1996) also reported that Friesian cows produced 26 % more milk than Jersey cows but only 7% more than Friesian-Jersey crossbred (F x J). In addition, Friesian cows produced 1.4 % and 0.66 % less concentration of fat and protein, respectively, than Jersey cows. F x J cows achieved 1 % and 0.42 % less concentration of fat and protein than Jersey cows. In the present study there were no significant differences between breeds for milk constituents.

The cross tabulation in *Table 5-2* shows an association between BSCC at a 250,000 cells/mL threshold and breed (*P<0.05*). However, *chi-square* test might not be a valid test because half of the cells had expected counts less than 5.

Table 5-2: Table of BSCC by Breed (P< 0.05).

Frequency Percent Row Pct Col Pct	Friesians	Jerseys	Ayrshire	Ayrshire crossbred	FxJ crossbred	Total
Above 250000	11 12.09 50.00 22.00	3 3.30 13.64 13.64	0 0.00 0.00 0.00	2 2.20 9.09 100.00	6 6.59 27.27 62.50	22 24.18
Below 250000	39 42.86 56.52 78.00	19 20.88 27.54 86.36	1 1.10 1.45 100.00	0 0.00 0.00 0.00	10 10.99 14.49 62.50	69 75.82
Total	50 54.95	22 24.18	1 1.10	2 2.20	16 17.58	91 100.00

Frequency Missing = 1

The greater percentage of suppliers who achieved BSCC below 250,000 cells/mL recorded (*Table 5-2*) suggests that a BSCC lower than 250,000 cells/mL is associated with better animal husbandry, hygiene and other milking practices rather than with a specific breed *per se*. There was no significant association between breed for BSCC at a 400,000 cells/mL threshold in the present study.

A large proportion (70 %) of farmers preferred the whole herd to be on once-a-day milking before drying-off time rather than having only some cows on once-a-day milking. The mean date for the once-a-day milking for some cows and all the cows found in this study (April 30 1996 and May 4 1996, respectively) are in concordance with Holdaway (1993) and Knight *et al.*, (1994b) who reported that once-a-day milking is used to improve body condition of some cows towards the next season or before drying-off the whole herd.

The 70% of respondents who practised once-a-day milking prior to drying-off the whole herd was higher than the findings by Holdaway (1993) who found only 54% of respondents practised once-a-day milking prior to drying-off the whole herd. The results of the present TML study suggests that milking once-a-day is practised by dairy farmers prior drying-off the whole herd rather than being used as a management strategy for individual cows during the summer. In addition, the absence of significant effects of milking once-a-day on milk production and quality might be explained by the short interval of time between once-a-day date and final drying-off date among suppliers. Furthermore, the higher BSCC in the last stage of lactation was associated with the concentration effect of low milk production due to once-a-day milking (Carruthers *et al.* 1990 and 1992 a, b and Knight *et al.*, 1994b).

5.4. Milking Practices On TML Farm

The rate (53% in early lactation and 50% in both mid- and late lactation) of hygiene practised in the milking parlour before milking is lower than studies reported in North America (Bramley, 1992, Elvinger and Natzke, 1992, Grill *et al.*, 1990). Laycock *et al.* (1987) found that udder preparation before milking and teat disinfection (teat spraying and teat dipping) were some of the most important practices for controlling mastitis in dairy cows. However, teat washing could be changed during the lactation period, increasing the number of herds which might not have any teat washing after the end of spring (Laycock *et al.*, 1987). Results from the TML survey in 1996 showed that washing the teats before milking was not widely used including after calving in spring. The most likely explanation is the time required to dry the teats before milking, which in turn, would increase the time to milk the herd. However, hygiene procedures before milking, especially drying the teats with individual paper towels, are potentially beneficial in reducing the transfer of mastitis bacteria from cow to cow, quarter to quarter, and from the teat skin through the streak canal (Bramley, 1992, Elvinger and

Natzke, 1992, Grill *et al.*, 1990 and Laycock *et al.*, 1987). The effect of drying the teats after washing on milk quality was not considered in this study because teat drying was effectively not used by TML suppliers who responded to the survey.

There were no significant effects of teat washing before milking and teat disinfection post-milking on BSCC at the 400,000 cells/mL threshold. But, the cross tabulation in table *Tables 5-3, 5-4 and 5-5* shows a significant association between BSCC at a 250,000 cell/mL threshold and teat disinfection (teat spraying) during lactation in the current TML study. (The *chi-square* tests *($p<0.05$)* were not valid because 50 % of cells might be have values below than 5).

Table 5-3: Table of BSCC by Teat spraying in early lactation ($p=0.009$)

Early Lactation	Frequency Percent Row Pct Col Pct	All cows	Some cows	No cows	Total
Above 250000		17 18.48 73.91 20.73	0 0.00 0.00 0.00	6 6.52 26.09 66.67	23 25.00
Below 250000		65 70.65 94.20 79.27	1 1.09 1.45 100.00	3 3.26 4.35 33.33	69 75.00
Total		50 89.13	1 1.09	9 9.78	92 100.00

Table 5-4: Table of BSCC by Teat spraying in mid-lactation ($p=0.01$)

Mid-lactation	Frequency Percent Row Pct Col Pct	All cows	Some cows	No cows	Total
Above 250000		16 17.58 69.57 20.25	1 1.10 4.35 100.00	6 6.59 26.09 54.55	23 25.27
Below 250000		63 69.23 92.65 79.75	0 0.00 0.00 0.00	5 5.49 7.35 45.45	68 74.73
Total		79 86.81	1 1.10	11 12.09	91 100.00

Table 5-5: Table of BSCC by Teat spraying in late lactation (p=0.001)

late lactation	Frequency Percent Row Pct Col Pct	All cows	Some cows	No cows	Total
Above 250000		14 15.38 60.87 18.18	0 0.00 0.00 0.00	9 9.89 39.13 69.23	23 25.27
Below 250000		63 69.23 92.65 81.82	1 1.10 1.47 100.00	4 4.40 5.88 30.77	68 74.73
Total		77 84.62	1 1.10	13 14.29	91 100.00

There are two important aspects about these findings. Firstly, more than 85 % of the respondents practised teat spraying during lactation. Secondly, results in *Table 5-3, 5-4 and 5-5* show that a high number of the supplier respondents practised teat spraying in all the cows during the season with BSCC above and below 250,000 cells/mL. It might be suggested that suppliers are more conscientious in disinfecting the teats after milking to avoid the introduction of bacteria into the teat.

Holdaway (1993) found that when many of the suppliers ceased teat spraying during the season they did so because of improvements in weather conditions or in the condition of the teats. Additionally, Laycock *et al.* (1987) reported that the lower rate of suppliers who used teat spraying in summer and autumn than in spring is associated with the reduction in cost of disinfection from the start of the summer once dairy farmers perceive the main danger period is over. However, this was not the case in this TML study; there were not great differences for teat spraying between early mid- and late lactation in this study, suggesting that spraying the teats of the cows after milking is equally important throughout the lactation period.

Results from this study show that teat spraying is preferred to teat dipping. The most likely explanation is that in large dairy herds, teat spraying is more convenient, requires less time and it is easier to do than teat dipping. However, the benefits of dipping the teats after milking with disinfectant solution and emollient are well recognised in North America (Bramley, 1992, Elvinger and Natzke, 1992, Gill *et al.*, 1990). Gill *et al.* (1990) reported that 92 % of suppliers practised post-milking teat dipping. It is the most

effective, cheapest and least contaminating method that can be used (Bramley, 1992). The role of emollients in improving the teat condition is also observed in teat spraying with iodine-based products (Holdaway, 1993).

5.5. Herd Testing

The practice of herd testing in this TML study is in concordance with the New Zealand figures published by LIC (1996). The high (86%) rate for herd testing during 1995/96 season did not appear to have significant effect on BSCC among supplier respondents either at a 400,000 cell/mL level, or at the 250,000 cells/mL level. Thus, it is not possible to assess if the low number of supplier respondents who did not use herd testing in 1995/96 season were associated with higher BSCC. But the herd testing service provided by The New Zealand Livestock Improvement Corporation suggests that the information provided by using it gives an important tool for evaluating the level of mastitis on the farm.

Herd testing is a service where a farmer or a sampling officer measures milk volumes and takes milk sub-samples to evaluate milk quality of individual cows in the herd (LIC, 1996). Depending on the frequency of tests practised by a farmer (between six and eight weekly), it is possible to receive accurate information on each individual cow's milk volume; milkfat and protein yields and percentages; and individual SCC. It also includes production and breeding indexes. The more frequent the herd tests the more reliable is the information. In other words, the greater the number of herd tests used by dairy farmers the less the number of cows in the herd which might be wrongly classified as having mastitis, reducing the extra costs associated with antibiotic therapy, extra labour and culling (see section 2.3).

5.6. Diagnosis and Treatment of Clinical Mastitis During Lactation

The herds of survey respondents were classified as High SCC (> 250,000 cells/mL) or Low (< 250,000 cells/mL). Then an analysis of the effects of treating (i.e. detection; treatment; recovery; possible retreatment) cows from each of these classes for clinical mastitis on BSCC in each class was undertaken. No significant effects were found, which meant that clinical mastitis did not appear to be a major contributing factor *i.e.* was likely that similar number of cows in each class were presenting with clinical mastitis. Furthermore, the low number of cows from each class (High SCC of Low SCC) reported culled for mastitis (SCC and clinical cases) prevents any significant results of the effects of culling on BSCC. But the results suggest that the use of herd testing 2-

monthly, diagnosis of clinical mastitis by stripping the cows before milking, treatment of all clinical mastitis cases, selective dry cow therapy and examination of mastitis before calving are associated with low count herds.

The diagnosis of clinical mastitis for mastitis control is increasingly practised in New Zealand when compared to the percentage of herds tested in the last 40 years (LIC, 1996). Clinical mastitis cases are characterised by the recognition of five different signs: swelling, warmth, reddening, pain (cows kick when udder is touched) and reduced function (less milk and altered composition) (Elvinger and Natzke, 1992). But the opportunity to detect all of the clinical cases in large herds by visual examination is sometimes limited. Laycock *et al.* (1987) found that mastitis diagnosis by visual examination during the season changed from spring to autumn from 47 % to 56 % of the farmers. The most likely explanation of this is the lack of time to check all potential cases of mastitis (shape and size of the udder) during spring whereas farmers in summer and autumn are more flexible to check the udder of each cow.

Results in the present TML study show that 79 % of supplier respondents practised stripping the teats before milking whereas Laycock *et al.* (1987) found that only 32 % of the farmers stripped the cows before milking to diagnose clinical mastitis. Stripping the teat of the cows before milking in order to check mastitis is increasingly used (Duirs and Macmillan, 1979, Laycock *et al.*, 1987, Pankey and Pankey, 1994, Todhunter *et al.*, 1995). This increase might be associated with the greater assistance provided by New Zealand LIC and private veterinarian in order to decrease the number of clinical cases of mastitis in the herd and therefore, the total number of BSCC in raw milk. However, there were no significant statistical effect of the number of strippings on BSCC. It might be suggested that the use of strippings before milking and herd testing are two important tools associated with better control of clinical mastitis infection in the dairy herd.

The data of Holdaway (1993) showed that the percentage of cows treated in the herd for clinical mastitis during lactation was higher than the results of this study in nearly two cases per 100 cows in the herd. The high percentage of animals which recovered satisfactorily after being treated for clinical mastitis does not guarantee that treatment was completely successful in eliminating the pathogen but it probably reduced the number of bacteria present in the gland (Holdaway, 1993). In some cases, recovery

might have been due to natural cure during treatment or effective activation of the immune mechanisms of the udder during the treatment period (Hillerton , 1996). Once cows have been diagnosed and treated, those cows should be milked last at each milking to avoid spreading the infection to other cows (Hutton *et al.*, 1990, Joe, 1993).

5.7. Culling

The figure of three cows culled per every 100 animals in the herds of the respondents in this study for both high SCC or clinical mastitis at the end of the lactation are consistent with findings by Holmes and Moore (1980) in New Zealand and Schukken *et al.* (1990) in United States of America. In addition, the rate of culling with the increase of the size of the dairy herd reported in this study might suggest that culling is a management decision which is used strategically. It this way, culling might be used as a way to reduce the average duration and prevalence of mastitis infection in the herd (Eden, 1994, Elvinger and Natzke, 1992, Morris, 1989).

Culling is an important management decision used in low-SCC herds which have shown high SCC in individual animals, including high yielding cows (Morris, 1989). It might be explained by the negative effect of the continuously high SCC from high yielding cows on the total BSCC and lower milk yield than potentially expected. However, Eden (1994) stated that the decision to cull the cows at the end of the season should be based, not only on the infection status of the animals, but also on the level of milk produced and mastitis history.

Culling did not solve the mastitis problem on long-term problem herds (Eden, 1994). It means that culling is a effective management strategy to improve the health status of herd and milk quality on the farm in the short-term time when the number of clinical mastitis infection cases have been identified as the major cause of the milk quality problem. Nevertheless, when other related causes *e.g.* inappropriate milking practices or poor performance, maintenance or repair of the milking machine have resulted in poor milk quality, culling will not solve the problem in the short-term time and maybe neither in the long-term until the original cause has been identified.

5.8. Dry Cow Therapy

The use of selective dry cow therapy (DCT) in 90 % of the respondents in this TML study is higher than the findings by Laycock *et al.* (1987) (81%) and Holdaway (1993) (66 %) in New Zealand; and Schukken *et al.* (1990) (29%) and Gill *et al.* (1990) (24%) in United

States of America. The major criterion for selective DCT in this TML study was the number of SCC rather the age or previous mastitis history of selected cows in the herd (95 % of the cases). This is in concordance with the recommendations by the SAMM plan-LIC (1995). However, the 64 % response rate for the threshold of 80,000 cells/mL for heifers and 120,000 cells/mL for cows, shows that many respondents are using DCT in their herds at SCC below those recommended by the SAMM plan booklet (1995). The SAMM plan recommends DCT in every heifer/cow which reaches a 120,000/150,000 cells/mL threshold at drying-off time. The implications of practising DCT at a lower level than recommended by the SAMM plan (1995) might be a failure of the defence mechanisms of the mammary gland due to the low number of somatic cells present in the host tissue. It can result in a low defence response by the mammary gland during the preparturient period and produce a greater bacteria multiplication with the release of a large amount of toxins (Kehrli and Shuster, 1994).

5.9. Somatic Cell Counts in Bulk Milk

The mean of 217,000 somatic cells/mL in bulk milk in the 1995/96 season found in this study for suppliers respondents was very similar to the National (206,000 cells/mL) and regional (223,000 cells/mL) BSCC averages (LIC, 1996). The mean BSCC obtained in this study is above the target expected by the dairy company in the 1995/96 season by 17,000 cells/mL. However and once again, there are important geographical constraints which should be considered in conjunction with the mean obtained in this study. The widespread distribution of the suppliers, who are located in three different areas of northern South Island, results in more difficult production and collection of milk from TML suppliers. It is possible, although difficult to quantify, that such constraints as the need to walk cows long distances for milking (farm shape); hot summer conditions and geographical isolation of some suppliers are contributing to their difficulties in reducing BSCC. While progress is evident in each of the main TML suppliers collection areas, it is likely to remain gradual for some suppliers as problems are identified, and the monitoring process becomes refined and more conscientiously adopted. It is also a practical reality that as suppliers herds move closer to optimum SCC levels (*i.e.* below 200,000 cells/mL) the rate of progress will inevitably slow.

The frequency distribution in *Appendix 3 - Table 29 A* shows that only 3% of the supplier respondents had an average BSCC above 400,000 cells/mL. These few suppliers might have some animals with chronic mastitis infection giving a high SCC which could

affect the overall BSCC in the herd. It is well established that a high BSCC in some herds is the result of a small number of animals (3 %) with a very high number of SCC which could raise the total number of SCC in bulk milk by as much as 100%. Removing such animals, therefore, could reduce BSCC as much as 50% (Dohoo and Meek, 1982, Eden, 1994, Schutz, 1977). The concentration of somatic cells in a cow's milk sample is a function of the individual counts of the four quarters, their respective milk production and the stage of lactation of the cow (Holmes and Woolford, 1992 and Dohoo and Meek, 1982, Reneau, 1985). This is specially important, particularly with high-yielding cows, when mastitis control plans are established to detect and classify as infected, cows which have sub-clinical infections in one or more quarters, (Reneau, 1985).

The high adoption rate among TML suppliers of practices to lower BSCC, *e.g.* milking hygiene; herd testing; diagnosis and treatment of clinical mastitis, suggests that the concentration effect of lower milk yield on BSCC in late lactation is most pronounced for a small number (3%) of suppliers, rather than for the majority. This in turn is likely to be the result of a few chronic subclinical cases of mastitis, which are most common just before the herd is dried off.

There were no significant effects of hygiene practices and management procedures on individual number or High or Low BSCC classes during lactation in this study of seasonal supply dairy producers. The narrower the threshold BSCC values the more difficult it is to assess the effects of hygiene procedures and management practices on average BSCC (Emanuelson and Funke, 1991). Furthermore, results in this study show that 75 % of herds achieved SCC lower than 250,000 cells/mL which is below the critical threshold of 265,000 cells/mL advocated by Holdaway *et al.* (1996b) in New Zealand and 283,000 cells/mL advocated by Reneau (1985) in United States. Thus, the dilution of high SCC milk from infected by milk from uninfected quarters will have important effects on the final interpretation of cow milk sample cell counts (Dohoo and Meek, 1992, Holmes *et al.*, 1992). Ultimately, it will be technically and financially suitable to have individual quarter conductivity tests to attempt to identify quarters with unacceptably high SCC to enable treatment or drying-off of the quarter. It is not likely to ever be practical to separate high and low SCC milk or milking time in New Zealand. Hence hygiene, plus detection and treatment of sites of infection with

antibiotics (lactating or dry cow therapy), drying-off or culling will continue to be the main herd husbandry options for keeping SCC at a desirable level.

Table 5-6 illustrates the BSCC during spring, summer and autumn of this study. These figures are associated with a reduction of volume and increase of involuting lobules toward the end of the season (Holdaway, 1993, Reneau, 1985). In addition, a decrease in the threshold BSCC value could be also attributable to the increase in milk yield (Emanuelson and Funke, 1991, Holdaway et al., 1996b).

Table 5-6: Bulk Somatic Cell Counts for each season 1995/96.

Season	Max.	Min.	Mean	Std. Dev
Spring	407,000	61,000	184,000	78,000
Summer	462,000	42,000	198,000	78,000
Autumn	636,000	50,000	265,000	105,000

The results in this current study suggest that an average BSCC lower than 250,000 cells/mL for 75 % of suppliers is a consequence of their increased application of the principles and practices of the New Zealand mastitis control plan.

5.10. Herd Size

The increased size of the herd found in this TML study is in concordance with the figures reported for the New Zealand Dairy Industry (LIC, 1996). Two major factors were related to this increase in 1995/96:

a) more herds in 1995/96 compared to 1994/95 and

b) more cows per herd for the same period.

But the average stocking rate has remained constant since 1992 because the effective area has also increased for the same period of time.

5.11. Performance, Maintenance and Repair of the Milking Machine and Testing of the Vacuum System

The current TML study revealed no statistically significant effects on BSCC of the type of milking parlour, its maintenance and testing, time spent milking or times that the liners were changed. However, the estimated means (*Appendix 3 - Table 35A*) do

suggest that testing the vacuum system once a year after drying the herd off, and changing the liners twice a year are associated with lower count herds. The most likely explanation is that adjusted vacuum system and high quality components of the milking machine might provide a better performance of the milking machine, maintain the integrity of the teat and reduce the new rate of mastitis infection in the herd.

One of the practices of the 5-point mastitis control plan in New Zealand is testing the performance of the milking machine (LIC - SAMM plan, 1995). A result from this TML study was that a higher proportion of farmers than those surveyed by Holdaway (1993) and Laycock *et al.* (1987), had their milking machine checked, suggesting that testing the vacuum system during the season is becoming more widely adopted. Winter, during the herd's dry period, was found to be the most popular period for inspection (Holdaway, 1993) and most of the farmers tested their milking machine twice a year Laycock *et al.* (1987). In agreement with Holdaway (1993), the preferred milking machine testing agencies were private companies and the dairy company (95%), whereas MAF tested a smaller number of milking machines (5%).

The design and function of the milking machine provides many opportunities to improve milking and to give increased benefits from dairying (Nickerson, 1992, Mein, 1978, Mein, 1992, Woolford and Phillips, 1982). Both the design and function of the milking machine influences the rate of mastitis by providing mechanisms for the bacteria to enter and modify the teat duct or the immediate intramammary tissues and inhibit the defence mechanisms of the teat and the udder (Hillerton, 1996, Nickerson, 1992, O'Shea, 1985, Spencer, 1989, Zecconi *et al.*, 1992) (*Table 3).*

Table 5-7: Machine related mechanisms that potentially affect new infection rate (Nickerson, 1992).

MODE OF INFECTION	MAIN MILKING RELATED MECHANISMS	EVIDENCE FOR IMPORTANCE
1. Changing number of bacteria on the teat or teat orifice.	Transfer of bacteria from: a) Environment to teat b) Cow to cow c) Teat to teat (within the cow). Increasing skin and/or orifice lesions.	Teat disinfection reduces bacterial number on the teat skin and orifice and decreases new infection rate. Experimental inoculation of bacteria in the teat skin and into the teat.
2. Changing the resistance of the teat canal to bacterial infection.	By affecting: a) Teat canal integrity b) Teat congestion and/or oedema.	New Infection rates are increased by remaining keratin from the teat canal and by visible teat canal injuries. New Infections are increased when pulsation is ineffective.
3. Providing forces to overcome resistance of the teat canal to bacterial infection	By causing impacts of: a) Microscopic droplets (Inertia effects) b) Macroscopic droplets (Inertia effects) c) Slugs of milk. By inducing penetration associated with: a) Low energy pressure events and/or flow rates b) High energy pressure fronts	Experimental inoculation of Escherichia coli through the canal teat. High velocity air/liquid flows toward the teat end increases new infections rates. No evidence.
4. Dispersing bacteria within the udder	By dispersing pathogens from: a) Teat canal to the sinus b) Teat sinus to the gland sinus and/or ducts.	Few infections occur if bacteria placed within the teat sinus are carefully removed by stripping but bacteria placed within the gland sinus frequently cause new infections.
5. Frequency and/or degree of udder evacuation	By changing: a) Susceptibility of gland to invading pathogens. b) Concentration of pathogens on the teat end c) Duration of exposure to pathogens.	New infection rates are higher in dried-off cows at the start of the dry period. Incomplete or omitted milking tend to increase new infections or clinical.

5.12. The number of people working in the milking shed, the steps followed by farmers to train new milkers and the cows:person ratio

The number of people working in the milking shed, the steps followed by farmers to train new milkers and the cows:person ratio at the peak of the season found in the current study reflects the tendency of the New Zealand dairy farming system to use familiar and/or occasional personnel to milk the cows (MAF, 1996 July). Furthermore, the same source stated that there was a large problem employing and keeping farm staff especially at the peak of the season which is likely to happen again in the 1996/97 season.

The ratio of cows per milker (119 cows) found in this TML study is higher than the ratio of 61 cows:milker reported by Holdaway (1993). The number of milkers in the milking shed at the peak of the season and the number of cows per cluster found in this study are similar to the findings by Holdaway (1993).

The mean average time spent milking the cows was 90 minutes and the number of cows per set of milking cups in the milking shed was 10. It means that every cow is milked in 9 minutes average which is in concordance with data reported in the literature (O'Shea, 1985). Nickerson (1992) pointed out that when the time spent milking the cows is increased, it will increase the congestion of the teat or will affect the integrity the teat canal by changing the resistance of the teat canal resulting in a potentially new infection rate, with increased SCC. There were no significant effects of the time spent milking the herd or the cows:person ratio on BSCC in the present TML study. Results from the current study suggest that in larger herds, the extra costs from employing one extra person to milk the cows could be compensated by the extra incomes from premium quality milk. The addition of one person during the milking time will alleviate the pressure on the dairy herd, minimising the risk of injury to cows, reducing the overall time spent milking and improving the environment in the milking shed.

5.13. The Use of The SAMM plan

Table 5-8 shows the cross-tabulation for the use of the SAMM plan during the season and the number of suppliers that believed that it was useful to improve the milk quality on the farm. It is observed in the cross-tabulation that in the majority of cases (72 %) the SAMM plan was effective for those who used it in 1995-1996. (The *Chi-square* test might not be valid due to more than 50 % of cells having expected counts less than 5).

Table 5-8: Use of the SAMM plan in Autumn/95 by the belief of the benefits of the SAMM plan for milk quality

No. of respondents Frequency Percent Row Percentage Column Percentage	Yes	No	Total
Yes	24 60.00 72.73 100.00	9 22.50 27.27 56.25	33 82.50
No	0 0.00 0.00 0.00	7 17.50 100.00 43.75	7 17.50
Total	24 60.00	16 40.00	40 100.0

Frequency Missing = 52 chi-square 0.001

The use and benefits of mastitis control plans in many countries are well recognised (Dohoo and Meek, 1982, Elvinger and Natzke, 1992, Gill *et al.*, 1990, Hillerton, 1996, Schukken et al, 1990,). Gill *et al.* (1990) reported that only one third of Ontario producers used all five recommended mastitis control practices. In New Zealand, the SAMM was just implemented in the early 1990's. It means that the benefits from the mastitis control plan have only begun, as supported by the findings of this TML study and others (Holdaway, 1993, Laycock *et al*, 1987, Morris, 1989).

It was found from this TML study that only half of the farmers formally followed the SAMM plan. However, the study also showed that many respondents practised the individual components of the SAMM plan, suggesting that they know and practice every component of the SAMM plan individually without formally recognising it as such. A significant ($p < 0.05$) finding from this study was that a greater proportion of the farmers (45 %) whose herds were in the Low BSCC class (< 250,000 cells/mL) used the SAMM plan than did farmers whose herds were in the High BSCC class (> 250,000 cells/mL) (*Table 5-9*). Thus, suppliers who wish to produce more milk of top quality are practising the SAMM plan on the farm, but they need more encouragement to use the concept of SAMM plan.

Table 5-9: Table of BSCC (Higher than 250,000 cells/mL and Lower than 250,000 cells/mL) by the use of the SAMM plan ($p < 0.05$).

No. of respondents Frequency Percent Row Percentage Column Percentage	No	Yes	Total
Above 250,000 cells/mL	18 19.57 78.26 32.14	5 5.43 21.74 13.89	23 25.00
Below 2500,000 cells/mL	38 41.30 55.07 67.86	31 33.70 44.93 86.11	69 75.00
Total	56 60.87	36 39.13	92 100.0

Evidence from a number of sources in New Zealand (*e.g.* This TML study (83 % of responses); Production Managers, and Milk Quality Officer of TML; researchers from LIC; and Londoño, 1996) suggests that the use of the information provided by the dairy company in order to maintain low herds is increasingly used by local suppliers to produce milk below 200,000 cells/mL. The information provided by the local company includes an explanation of the components of the SAMM plan. It explains, in part, why the BSCC trend for the last 5 years has been a significant decrease.

The percentage (13 %) of respondents using veterinarians as another source of information for the SAMM plan was lower than the findings of Morris (1989). That author reported that 87 % of suppliers used the veterinarians as the main source of information to maintain low cell count in their herds. By contrast, Gill *et al.* (1990) reported that 25% of Ontario dairy farmers involved their veterinarians in the regular mastitis control programme on their farms.

5.14. Personal Information

The age of the farmer found in this study is in concordance with the findings by Gill *et al.* (1990) who reported a mean age of Ontario dairy farmers of 43 years old. Additionally, high school certificate was the mean academic qualification obtained

by suppliers according to the results in this TML study and the findings by Gill *et al.* (1990).

This study could not ***prove*** that the various hygiene routines, management practices, clinical status, on-farm situation and academic qualifications ***caused*** certain ***effects*** on the overall mean BSCC but it identified the progress achieved by the dairy company and its suppliers in milk quality because of the use of the individual components of the mastitis control plan. This is in agreement with Holmes and Moore (1980) and Laycock *et al* (1987). In addition, the lower threshold value for BSCC could might result in smaller differences between herds which could make harder it to identify differences between herds and the reasons for differences. The cost effectiveness of the control measures will always remain an important issue for dairy producers, and future studies could well address that. Great care would need to be paid to the number of farms in the sample, especially those in subgroupings, the reliability of the data and the way that some on-farm factors are handled before any statistical analysis is undertaken.

Chapter Six

6. CONCLUSIONS

The study was an extension of a previous project in milk quality among local suppliers and it sought to explain the effect of the mastitis control (SAMM) plan on the productivity on dairy farms in New Zealand. To achieve this goal, an attempt was made to find the relationship between major dairy husbandry, hygiene and teat disinfection practices of the herd; diagnosis and treatment of clinical mastitis; culling; strategies for dry cow therapy; and characteristics, maintenance and repair of the milking machine and the status of the milk quality of the herd. The study was expected to provide useful information to farmers, local dairy companies and the dairy industry about strategies to reduce the BSCC below 150,000 cells/mL before year 2000.

The significant ($p=0.002$) negative correlation between milk solids per hectare and BSCC will be of importance to those who, for practical reasons discussed in chapter five, may be working hard to boost milk production but are not paying adequate attention to the BSCC limit set by the dairy company, or who may not yet have been able to implement all of the components of the SAMM plan. Thus, the use of BSCC as an indicator for improving the milk quality status of a dairy farm should be maintained to achieve high milk yield productivity and increased profitability of the business.

The findings about the decision to place the whole herd on once-a-day milking confirms that dairy farmers practice it prior to drying-off rather than as a management strategy for individual cows during feed shortages on the farm, or for the health status for some cows. It is suggested, however, that once-a-day milking for some cows might have practical applications for suppliers when more human and infrastructure resources are available on the farm to focus on specific animals. Once-a-day milking

might also be regarded as an useful strategy by farmers who want high milk production per cow.

The frequency distribution of the hygiene and disinfection practices during milking confirmed that they are important management practices for TML suppliers. 85% of the respondents practised teat spraying during lactation, suggesting that suppliers were more conscientious in disinfecting the teats after milking to avoid the introduction of bacteria into the teat.

The percentage (less than 60 %) of respondents who were teat washing before milking was lower than the percentage (more than 85 %) teat spraying after milking. It was suggested that the most likely explanation for the lower use of teat washing was the time required to dry the teats before milking, which in turn, would increase time to milk the herd overall. It is recommended, however, that hygiene procedures before milking would be highly beneficial in reducing the transfer of mastitis bacteria from cow to cow, quarter to quarter, and from the teat skin through the streak canal, They should be complemented with teat drying with individual towels after washing, even though washing the teats before milking and drying them after washing was not proven in this study to improve milk quality status on the farm.

The finding that 86 % of suppliers use herd testing was in concordance with the results published by LIC (1996). However, the high rate of herd testing during 1995/96 season did not significantly affect BSCC among supplier respondents, whether at the 400,000 cell/mL threshold, or the 250,000 cells/mL threshold. Thus, it was not possible to establish whether or not the remaining 14% of supplier respondents who did not use herd testing in 1995/96 season had higher BSCC. But the herd testing results obtained by The New Zealand Livestock Improvement Corporation suggests that its information provides an important tool to evaluate the level of mastitis on the farm. It is also important to match the herd BSCC results from the dairy company with the information provided by LIC on individual cows as soon as possible to identify those animals which are adversely affecting the overall BSCC in the dairy herd.

The figure of eight per 100 cows in the herd diagnosed as having clinical mastitis suggests that the strategies used to reduce the number of clinical mastitis cases on the farm during lactation are similar to others reported in the literature. The high

percentage of animals which recovered satisfactorily after being treated for clinical mastitis did not guarantee that the treatment of clinical mastitis with antibiotics was completely successful in eliminating the pathogen, but it probably reduced the number of bacteria present in the gland. It is recommended that the SCC of those individual cows be closely monitored after recovery to assess the effectiveness of the antibiotic treatment in the reduction of infection.

Increases in the size of dairy herds and the percentage (3%) rate of culling reported in this study might suggest that those are important management decisions related to the reduction of the average duration and prevalence of mastitis infection in the herd. Culling does not solve the mastitis problem in long-term problem herds. It is, however, regarded as an effective management strategy to improve the health status of herd and milk quality on the farm in the short-term if the number of cases of clinical mastitis is identified as the major cause of the milk quality problem. Culling is not recommended in the long term if other causes *e.g.* inappropriate milking practices, or poor performance, maintenance and repair of the milking machine are the cause of poor milk quality status of the farm. The decision to cull cows at the end of the season should be based, not only on the infection status of the animals, but also on the level of milk produced and mastitis history.

The high (90 %) rate of selective use of dry cow therapy (DCT) suggests that its use remains as an essential part of the SAMM plan in New Zealand. However, the relatively large number of farmers (64 %) who used DCT in heifers with SCC at or below 80,000 cells/mL and in cows at or below 120,000 cells/mL shows that respondents are using DCT in their herds at a SCC below that recommended by the SAMM plan Booklet (1995). The implications of practising DCT at a lower level than recommended might be the failure of the defence mechanisms of the mammary gland due to the low number of somatic cells present in the host tissue. The activation of the defence responses by the mammary gland might be low, especially around parturition. It is recommended that the SCC threshold used for DCT should be the one recommended by the dairy industry.

The figure of 35 % of farmers who achieved a mean of less than 150,000 cells/mL, clearly demonstrates the effort of local suppliers to produce high quality milk on their farms. It suggests that suppliers from TML are willing to produce not only as much milk

as possible, but also milk of premium quality. The 35% of suppliers who reached BSCC below 150,000 cells/mL put in practice similar dairy husbandry and other milking practices to the remaining 75% of suppliers above 150,000 cells/mL in bulk milk. The figure of 3 % of herds which reached a BSCC above 400,000 cells/mL might indicate that there would be other as yet unidentified considerations, (*e.g.* a higher proportion of older cows in the herd, chronic subclinical mastitis infections or systemic health problems for individual cows) in addition to those analysed in this study which are affecting the overall BSCC. The small proportion of herds above 400,000 cells/mL could be of practical significance to the dairy company which may be interested in evaluating the factors affecting the overall BSCC on the farm.

It was discussed how the dilution of high SCC milk from infected quarters by milk from uninfected quarters will have important effects on the final interpretation of a cow's SCC. Ultimately, it will be technically and financially feasible to have individual quarter conductivity tests to attempt to identify quarters with unacceptably high SCC to enable treatment or drying the quarter off. It is not likely to ever be practical to separate high and low SCC milk at milking time in New Zealand. Hence hygiene, plus detection and treatment of sites of infection with antibiotics (lactating or dry cow therapy), drying-off or culling will continue to be the main herd husbandry options for keeping SCC at a desirable level.

The study revealed no significant effects on BSCC of the type of milking parlour, its maintenance and testing, time spent milking or times that the liners were changed. However, the estimated means do suggest that testing the vacuum system once a year after drying the herd off, and changing the liners twice a year were associated with low count herds. The most likely explanation is that adjusted vacuum system and high quality components of the milking machine might provide a better performance of the milking machine, maintain the integrity of the teat and reduce the rate of new mastitis infection in the herd.

It was discussed how only half of the farmers formally followed the SAMM plan entirely but all the supplier respondents practised its individual components without considering the SAMM plan as part of those practices. At the other hand, a majority (45 %) of suppliers who used the SAMM plan, reached a BSCC below 250,000 cells/mL during the season. That suggests that TML suppliers know and practice every

component of the mastitis control plan individually but they are still unsure about the SAMM plan as a whole. The use of the SAMM plan in New Zealand is relatively new compared to other countries; it was implemented in the early's 1990's and its benefits are just beginning to be recognised.

The information provided by the dairy company to help suppliers to maintain low SCC herds is increasingly used by them to produce milk below 200,000 cells/mL. The information provided by the local company includes an explanation of the components of the SAMM plan. It might explain why the BSCC trend for the last 5 years has decreased significantly.

The absence of significant detectable effects of the 5-point mastitis control plan on milk yield among TML suppliers observed in this and others studies begs the question as to whether or not the SAMM plan practices affect the overall BSCC in the dairy herd, hence milk yield productivity. But, the current study identified the progress achieved by the dairy company and its suppliers in this matter by the use of the individual components of the mastitis control plan. The cost effectiveness of the control measures will always remain important for dairy producers, and future studies could well address these. Thus, it is recommended that further research be directed at the effectiveness of these dairy husbandry and milking practices, by using different approaches to those applied in this and previous studies.

Chapter Seven

7. REFERENCES

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Appendix 1

Survey of dairy herd owners
Pablo Londoño Gutiérrez and Warren Anderson
Agricultural-Horticultural Systems Management Department.
Massey University.

Please answer the questions by ticking the selected space or filling in the blank line given.

- **General information 1995/ 96 Season**

1. Supply number: _____
2. Milking area (ha): _____
3. How many cows were in your herd at the peak of the 1995/1996 season ? _____ (cows).
4. What is the main breed of cow in your herd ? _____ (Breed).
5. How many people worked in the milking shed during the peak of the season in 1995 ? _____ (people).
6. When did your cows begin calving in Spring 1995 ? _____ (date).
7. When was your herd dried off in autumn 1996 ? _____ (date).
8. a) When did you first begin once-a-day milking before drying-off _____ (date).

   b) Please explain which cows were chosen to go onto once-a-day milking.

   _____

   _____

   _____

   c) When did you go onto once-a-day milking for the whole herd ? _____ (date).

- **Milking practices on the farm: Teat washing, spraying or dipping**

Teat washing

Please tick boxes to indicate which cows had teats washed at different stages of the season.

	All cows	Some cows	No cows
9. Calving to the end of October.			
10. November 1 to December 31.			
11. January 1 to drying-off			

12. If only some cows had teats washed, please explain why these were selected ?

_____

Teat spraying

Please tick boxes to indicate which cows had teats sprayed at different stages of the season.

	All cows	Some cows	No cows
13. Calving to the end of October.			
14. November 1 to December 31.			
15. January 1 to drying-off			

16. If only some cows had teats sprayed please explain why these were selected ?

_____

_____

_____

Teat dipping

Please tick the following boxes to indicate which cows had teats dipped in disinfectant after milking at different stages of the season.

	All cows	Some cows	No cows
17. Calving to the end of October.			
18. November 1 to December 31.			
19. January 1 to drying-off			

20. If only some cows had teats dipped please explain why these were selected ?

_____

_____

_____

- **Mastitis Diagnosis and Treatment**

21. Did you herd test last season to get individual cow SCC information?

Yes ☐

No ☐ (Go to question 22)

Please indicate the frequency of the herd test

☐ monthly

☐ 2-monthly

☐ 3-monthly

☐ other (please explain) _____

_____

_____

22. Do you strip each quarter of each cow to check for mastitis:

☐ at every milking.

☐ most milkings.

☐ only if mastitis is suspected.

☐ no regular stripping.

23. If cows are stripped, is this:

☐ Before milking.

☐ After milking.

24. How many cows suffered clinical mastitis during the 1995/96 season? _____ (cows).

25. How many of these cows were treated with antibiotics ? _____ (cows).

26. How many of these cows recovered and needed no further treatment for mastitis ? _____ (cows) .

27. How many cows needed repeat treatment for mastitis? _____ (cows).

28. How many cows were culled last season for clinical mastitis ? _____ (cows).

29. How many of your cows were culled last season for high SCC ? _____ (cows).

30. At the end of last season, was dry cow therapy practiced on:

☐ the whole herd

☐ no cows

☐ some cows

If "some cows" were treated, please explain how these cows were selected :

_____

_____

_____

31. Before calving last spring did you check for mastitis in:

☐ the whole herd.

☐ no cows.

☐ some cows.

If "some cows" please explain how these cows were selected :

_____

_____

_____

Please tick the following boxes to indicate the SCC range for your herd at different stages of lactation in the 1995/96 season.

- **Somatic Cell Counts**

	< 150,000	150,000-400,000	> 400,000
32. Six weeks after calving.			
33. mid-lactation (January).			
34. Six weeks before drying-off			

- **Herd size**

35. Is your herd size currently:

☐ Increasing.

☐ Decreasing.

☐ Staying about the same.

36. If your herd is increasing, will that be achieved by (Please, tick all options which apply):

☐ Buying replacements.

☐ Rearing extra replacements.

☐ Leasing cows.

- **Cowshed and Milking**

37. What type of milking shed do you have ?

☐ Herringbone.

☐ Walk through.

☐ Rotary.

38. How many sets of milking cups does your cowshed have ? _____ (sets).

39. Does your cowshed have an automatic cup removal system ?

☐ Yes. ☐ No.

40. At the peak of the season, how long does it take to milk

(first cups on to last cups off) ? _____ (hours).

41. During the 1995/96 season was the vacuum for the milking plant checked ?

☐ No. ☐ Yes; by whom ? _____ .

42. How many times during the 1995/96 season was the rubberware

(inflations) in milking machine replaced ? _____ (number of times).

43. Please explain the steps you take to train new milkers who work in your cowshed:

_____

_____

_____

_____

- **SAMM Plan and its effects**

44. Did you use the SAMM plan in Autumn 1995 ? ☐ Yes. ☐ No.

If "No", go to question 46.

45. Did using the SAMM plan improve your milk quality last season ?.

☐ Yes ☐ No.

Please explain why you think this occurred: _____

_____

_____

46. Do you receive enough information from your milk company on how to control somatic cells in your milk ? ☐ Yes. ☐ No.

If "No", what additional information would you like ? _____

_____

_____

47. Which source of information other than the milk company has been most useful for improving the milk quality in your herd ?

_____

Personal data (we would appreciate answers to these questions, but they are not as essential to our study as the preceeding questions are):

48. In what year were you born_____ (year)

49. What is your highest academic qualification ? _____ .

50. What is your partner's highest academic qualification ? _____

51. How many years of dairy farming experience do you have? _____ (years).

52. How many years of dairy farming experience does your partner have?_____(years)

53. Would you like to have a copy of the results ? ☐ Yes. ☐ No.

- **Use of Milk Quality Records**

I give / decline (delete one) my permission for you to contact the dairy company to obtain my milk quality records. I understand information from my herd will remain confidential.

Signature _____

Date: _____

Thank you for your co-ooperation

Pablo Londoño Gutiérrez

Warren Anderson

Appendix Two
Coding system of the survey for TML's suppliers 1995-1996

Q		SAS	Item	Code
1		A1	Supply number	
2		A2	Milking area	
3		A3	Number of cows	
4		A4	Friesians (F)	1
			Jerseys (J)	2
			Ayrshires (A)	3
			Ayrshire crossbreeding	4
			F x J/ Jx F	5
			Mixed JF x FJ	6
			Friesian crossbreeding	7
			Friesian and F x J	7
			Jerseys crossbreeding	8
			50% J and 50% F	9
5		A5	Number of people in the shed	
6		A6	Starting calving date	
7		A7	Date of dry-off	
8	a	A9	Once-a day-milking (partial)	
	b	A11	The whole herd at once before drying-off to put some condition on	1
			Young and older cows with light body condition and low milk production	2
			First calvers/ 2-year old cows to gain body condition	2
			Cows under light condition score	3
			Carry-off cows from previous season	4
			High SCC cows	5
			2 & 5	6
			Once-a-day milking cows are on the basis of protection and then, dry them off	7
			When cows are producing less than 4 litres per day	8
			Climate conditions	9
	c	A12	Date of once-a-day milking (total)	
9	a	A14	Teat washing all the cows (Early lactation)	1
	b		Teat washing some cows (Early lactation)	2
	c		Teat washing no cows (Early lactation)	3
10	a	A15	Teat washing all the cows (Middle lactation)	1
	b		Teat washing some cows (Middle lactation)	2
	c		Teat washing no cows (Middle lactation)	3
11	a	A16	Teat washing all the cows (Late lactation)	1
	b		Teat washing some cows (Late lactation)	2
	c		Teat washing no cows (Late lactation)	3

12		A17	Dirty and muddy teats	1
			All cows washed at calving (one week); after there, only dirty udders	2
			Dirty and wet udders	3
			Cows are only washed during the colostrum period	4
			Muddy udders	5
			Lazy	6
			Because they needed	7
13	a	A18	Teat spraying all cows (Early lactation)	1
	b		Teat spraying some of the cows (Early lactation)	2
	c		Teat spraying no cows (Early lactation)	3
14	a	A19	Teat spraying all the cows (Middle lactation)	1
	b		Teat spraying some cows (Middle lactation)	2
	c		Teat spraying no cows (Middle lactation)	3
15	a	A20	Teat spraying all the cows (Late lactation)	1
	b		Teat spraying some cows (Late lactation)	2
	c		Teat spraying no cows (Late lactation)	3
16		A21	Labour shortage	1
			Rotary shed	2
17	a	A22	Teat dipping all the cows (Early lactation)	1
	b		Teat dipping some cows (Early lactation)	2
	c		Teat dipping no cows (Early lactation)	3
18	a	A23	Teat dipping all the cows (Middle lactation)	1
	b		Teat dipping some cows (Middle lactation)	2
	c		Teat dipping no cows (Middle lactation)	3
19	a	A24	Teat dipping all the cows (Late lactation)	1
	b		Teat washing some cows (Late lactation)	2
	c		Teat washing no cows (Late lactation)	3
20	a	A25	Sore caused by blackpox	1
	b		Crack on the teats	2
	c		Chapped or damaged teats	3
21	a	A26	Yes	1
			No	2
	b	A27	Monthly	1
			2-monthly	2
			3-monthly	3
			One herd test or one extra test (April)/ one off test for SCC	4
			Five times during the season	5
			Four times during the season	6
			Two tests a year to get SCC information	7
			Twice a year	7
			Three tests per year	8
			One test every six weeks (five times)	9

22	A28	Stripping at every milking	1
		Strippings most of the milkings	2
		Strippings only when mastitis is suspected	3
		No regular stripping	4
		3 & 4	5
		Every milking until September and then only if mastitis was suspected	6
23	A29	Before milking	1
		After milking	2
		Both	3
24	A30	Number of cows with clinical mastitis	
25	A31	Number of cows which received antibiotic treatment	
26	A32	Number of cows recovered satisfactorily	
27	A33	Number of cows which required another treat.	
28	A34	Number of cows culled	
29	A35	Number of cows culled due to SCC	
30 a	A36	Dry cow therapy in all cows	1
		Dry cow therapy in no cows	2
		Dry cow therapy in some cows	3
b	A37	Cows which still had high SCC at any or last herd test	1
		Cows with high SCC	1
		Cows with any mastitis history or mastitis risk	2
		Older cows, any cow with clinical mastitis and high SCC or > 5 calvings	2
		Any cow or heifer above 150,000 somatic cells at any herd test	3
		Heifers 150,000 and cow over 200,000 to 250,000	4
		Cows over 250,000	4
		All clinical case + any cow over 100/150,000 at any stage of the season/h.test	5
		Cows above 100-120,000 somatic cells heifers 80,000	6
		Heifers above 100-120,000 and cows over 120,000 SCC-150,000	6
		Cows above 120,000-150,000	7
		Heifers over 120,000 SCC and cows over 150,000 SC	7
		2 & 4	8
		2 & 6	9
		Mastitis hand held detector	10
		2 & 3	11
		All cows above 300,000	12
		All cows above 500,000	13
		Udder size and shape	14
		1,2 & 14	15
		1,2 & 4	16
		New purchases to ensure low SCC	17

31	a	A38	Mastitis before calving in all cows	1
			Mastitis before calving in no cows	2
			Mastitis before calving in some cows	3
	b	A39	Cows suspected not healthy or quarters higher than normal	1
			Visual observation of the cows before calving	1
			High somatic cell cows and enlarged quarters	2
			Every cow checked every two weeks	3
32	a	A40	Early lactation <150,000	1
	b		Middle lactation <150,000	2
	c		Late lactation <150,000	3
33	a	A41	Early lactation 150,000-400,000	1
	b		Middle lactation 150,000-400,000	2
	c		Late lactation 150,000-400,000	3
34	a	A42	Early lactation >400,000	1
	b		Middle lactation >400,000	2
	c		Late lactation >400,000	3
35		A43	Herd is increasing	1
			Herd is decreasing	2
			Herd is staying about all the same	3
36		A44	Increasing because of buying replacements	1
			Increasing because of rearing extra replacements	2
			Increasing because of leasing cows	3
			Increasing by fewer culls	7
			1,2 & 3	4
			2 & 3	5
			1 & 2	6
37		A45	Herribone milking parlour	1
			Walk through milking parlour	2
			Rotary milking parlour	3
38		A46	Number of sets of milking cups	
39		A47	Automatic cluster removal yes	1
			no	2
40		A48	Time	
41	a	A49	No	1
			Yes	2
	b	A50	Registed milking machine company/ tester	1
			Tasman Milk Products (Rural Service Centre)	2
			Rural Service Centre	2
			Nu pulse	1
			Knudsen's Westport	1
			MAF	3
			By themselves	4
			1 & 3	5

42	A51	Times that inflations were changed	
43	A52	Training new milkers - Don't have any/ don't apply (family farm)	1
		Teach a few cows, let the milker to milk and observe how they do it	2
		Supervise another milker's job by a closed supervision	3
		Paying special attention to overmilking	3
44	A53	Yes	1
		No	2
45 a	A54	Yes	1
		No	2
b	A55	Because it is a need to all the dairy farmers	1
		Because less cows treated each year	2
		Because of a better vigilance on mastitis	3
		Because of the better recording of the cows and mastitis status of the herd	3
		Because of the lower SCC	4
		Because high count cows were eliminated	5
		Because cows were more resistant to antibiotics at spring time	6
		Because right cows were treated at drying-off time	7
		Because most of the mastitis cases came from 1st calving animals	8
		Because of a better dairy herd management	9
		Because SAMM plan shows problem areas and how to help them	10
		Because the SAMM plan improve milk quality by culling repeatly attainders	12
		Because some SCC cows increased greatly	11
		Because the increasing number of cows	13
		Because common sense	14
46 a	A56	Yes	1
		No	2
b	A57	Not sure	1
		Better attitude from the company	2
		More information about drying-off to avoid grading, mainly on 1st pick-up	3
		Free SCC information for problem cows & information on lowering SCC	4
		The SAMM plan	5
		More information about milking machines, types and options	6
		More information on late season SCC increases	7
		Basic information	8
47	A58	Breeding	1
		SAMM/ LIC monthly page	2
		LIC	2
		Dairy Exporter/ dairy magazines	3
		Dairy farmers discussion groups	4
		3 & 4/ 2 & 3	5
		Veterinarian club	6
		Dairy Detergent Co. at Nelson, South island	7
		Dairyman programme for SCC & mastitis information	8
		Free SCC information for problem cows	9

		2 & 7	10
		None	11
		Rural press	12
		Auckland Chemicals Rep.	13
		Other farmers	14
		Experience	15
		Jan Fox (Books)	16
		Any information about lowering of the penalties on cell counts	17
		LIC & MAF	18
48	A59	Year of birth	
49	A60	Secondary school (not finished)	1
		Fifth and sixth secondary correspondence	2
		Fourth secondary correspondence	3
		Diploma in dairy technology	4
		High School certificate	5
		Bachelor in Agricultural Science	6
		Trade certificate	7
		None	8
		Bachelor in Science/ University Degree/ University Certificate	9
		Diploma in Agriculture	10
		Seventh form degree	11
		High School certificate in U.K	12
		University Entrance	13
		Bachelor of Commerce	14
50	A61	High school (not finished)	1
		Fifth and six secondary correspondence	2
		Third and Fourth secondary correspondence	3
		Diploma in dairy technology	4
		High School certificate	5
		Bachelor in Agriculture	6
		Trade certificate	7
		None	8
		Bachelor in Science/ University Certificate	9
		Registered Nurse/ teacher/ Dentistry	10
		Seek hygiene Agriculture	11
		Six and seventh form degree	11
		University Entrance	12
		Diploma University	13
		Higher learning certificate UK	14
51	A62	Years of farming	
52	A63	Years of farming (partner)	
53	A64	Copy of the results yes	1
		no	2

Appendix 3

Table 1A: Area of the farm

AREA (Has)	Number of Respondents	Percentage of respondents	Cumulative percentage
0-50	22	24.4	24.4
51-100	55	61.1	85.5
100-150	10	11.1	96.6
151-200	2	2.2	98.8
201-250	1	1.2	100.0

Frequency Missing = 2

Table 2A: Number of cows on the farm

COWS	Number of Respondents	Percentage of respondents	Cumulative percentage
0-50	2	2.2	2.2
51-100	9	23.9	26.1
101-150	22	9.8	35.9
151-200	30	32.7	68.6
201-250	19	20.7	89.3
251-300	5	5.4	94.7
301-350	2	2.1	96.9
351-400	1	1.0	97.9
501-550	2	2.1	100.0

Table 3A: Number of cows per hectare on the farm

cows per hectare	Number of Respondents	Percentage of respondents	Cumulative percentage
1 cow/ ha	2	2.2	2.2
1 - 1.5 cows/ ha	2	2.2	4.4
1.5 - 2 cows/ ha	9	9.9	14.3
2 - 2.5 cows/ ha	36	39.6	53.9
2.5 - 3 cows/ ha	35	38.5	92.7
3 - 3.5 cows/ ha	7	7.6	100.0

Frequency Missing = 1

Table 4A: Number of people working in the milking shed at the peak of the season.

People	Number of respondents	Percentage of respondents	Cumulative percentage
1	40	43.5	43.5
2	48	52.2	95.7
3	3	3.3	98.9
5	1	1.1	100.0

Table 5A: Cow:farmer ratio per herd.

RATIO	Number of respondents	Percentage of respondents	Cumulative percentage
< 50 cows/farmer	4	4.5	4.5
50 -100 cows/farmer	32	36.4	40.9
100-150 cows/farmer	35	39.8	80.7
150-200 cows/farmer	16	18.2	98.9
> 250 cows/farmer	1	1.1	100.0

Frequency Missing = 4

Table 6A: ***Initial calving, dry-off, once-a-day milking for some cows and the whole herd dates.***

Event	Minimum	Maximum	Mean	CV
Initial calving date	Jun 20-1995	Sep 20-1995	Aug 8-1995	9.6
Initial once-a-day milking date	Jan 1-1996	May 25-1996	Apr 30-1996	21.5
Final once-a-day milking date	Jan 5-1996	May 29-1996	May 4-1996	19.0
Dry-off date	Apr 14-1996	May 31-1996	May 16-1996	9.5

Table 7A: ***Frequency distribution for the lactation length during the season.***

Lactation Length	Number of respondents	Percentage of respondents	Cumulative percentage
230-250	2	2.3	2.3
250-270	16	18.2	20.5
270-290	50	56.8	77.3
290-310	19	21.6	98.9
> 310	1	1.1	100.0

Frequency Missing = 4

Table 8A: ***Reasons why cows were on once--a-day milking at the end of the season.***

Why	Number of respondents	Percentage of respondents	Cumulative percentage
The whole herd	55	68.8	68.8
Light condition & low production	20	25.0	93.8
Carry-off cows from previous season	1	1.3	95.0
High SCC cows	3	3.8	98.8
Weather conditions	1	1.2	100.0

Frequency Missing = 12

Table 9A: ***Milking practices during lactation: Teat washing in early lactation***

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	22	24.4	24.4
Some cows	48	53.3	77.8
No cows	20	22.2	100.0

Frequency Missing = 2

***Table 10A:** Milking practices during lactation: Teat washing in mid lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	17	19.3	19.3
Some cows	47	53.4	72.7
No cows	24	27.3	100.0

Frequency Missing = 4

***Table 11A:** Milking practices during lactation: Teat washing in late lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	16	18.2	18.2
Some cows	44	50.0	68.2
No cows	28	31.8	100.0

Frequency Missing = 4

***Table 12A:** Why Teat washing in some cows*

Practice	No. of respondents	% respondents	Cumulative percentage
Dirty wet and muddy teats and udders	51	92.7	92.7
All the cows after calving	4	7.3	100.0

Frequency Missing = 37

***Table 13A:** Milking practices during lactation: Teat spraying in early lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	82	89.1	89.1
Some cows	1	1.1	1.1
No cows	9	9.8	100.0

***Table 14A:** Milking practices during lactation: Teat spraying in mid lactation*

Practice	Number of respondents	Percentage	Cumulative percentage
All the cows	79	86.8	86.8
Some cows	1	1.1	87.9
No cows	11	12.1	100.0

Frequency Missing = 1

***Table 15A:** Milking practices during lactation: Teat spraying in late lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	77	84.6	84.6
Some cows	1	1.1	85.7
No cows	13	14.3	100.0

Frequency Missing = 1

***Table 16A:** Milking practices during lactation: Teat dipping in early lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	1	1.0	1.0
Some cows	3	3.9	4.9
No cows	77	95.1	100.0

Frequency Missing = 11

***Table 17A:** Milking practices during lactation: Teat dipping in mid lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	1	1.2	1.2
Some cows	3	3.7	4.9
No cows	78	95.1	100.0

Frequency Missing = 10

***Table 18A:** Milking practices during lactation: Teat dipping in late lactation*

Practice	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	1	1.2	1.2
Some cows	2	2.5	3.7
No cows	78	96.3	100.0

Frequency Missing = 11

***Table 19A:** Times the herd tests were performed during the 1995-1996 season*

Frequency	Number of respondents	Percentage of respondents	Cumulative percentage
1-monthly test	4	5.3	5.3
2-monthly test	59	77.6	82.9
3-monthly test	4	5.3	88.2
Four of five tests	2	2.6	90.8
Two test per season	7	9.2	100.0

Frequency Missing = 16

***Table 20A:** Number of strippings to check individual cows against clinical mastitis*

Number of times for strippings	No. of res.	% respond	Cumulative Percent
Every or most of milkings	2	2.2	2.2
No regular basis	17	18.9	21.1
Only when mastitis was suspected	71	78.9	100.0

Frequency Missing = 2

***Table 21A:** Method of stripping to check individual cows against clinical mastitis*

Method of strippings	No. of res.	% respond	Cumulative Percent
Before milking	63	76.8	76.8
After milking	4	4.9	81.7
Before and after milking	8	9.8	91.5
Never	7	8.5	100.0

Frequency Missing = 10

Table 22A: ***Percentage of cows diagnosed positively, treated, cured, retreated against clinical mastitis during the 1995-1996 season***

Diagnosis and treatment of clinical mastitis	Min	Max	Mean	CV
Percentage of cows in the herd diagnosed positively against clinical mastitis	0	28.6	8.40	68.92
Percentage of cows in the herd treated against clinical mastitis	60.0	100.0	99.6	4.28
Percentage of cows in the herd recovered against clinical mastitis	0	100.0	80.0	22.96
Percentage of cows in the herd retreated against clinical mastitis	0	100.0	20.0	89.00

Table 23A: ***Percentage of cows culled due to both clinical mastitis and high SCC at the end of the 1995-1996 season***

Culling	Min	Max	Mean	CV
Percentage of cows in the herd culled due to clinical mastitis	0	10.0	1.4	131.4
Percentage of cows in the herd culled due to high SCC	0	18.2	2.7	112.8

Table 24A: ***Dry cow therapy***

Dry cow therapy	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	5	5.4	5.4
No cows	5	5.4	10.9
Some cows	82	89.1	100.0

Table 25A: ***Selection for dry cow therapy***

Dry cow therapy	No. res.	% res.	Cum. %
Older cows with high SCC or mastitis history	23	28.8	28.8
SCC higher than 80,000 - 120,0000 for heifers and 100,000 - 150,000 for cows	51	63.8	92.5
Any cow or heifer with SCC higher than 300000 cells/ml	5	6.3	98.8
New Purchases to ensure low SCC	1	5.3	100.0

Frequency Missing = 12

Table 26A: Examination of mastitis pre-calving

Mastitis pre-calving	Number of respondents	Percentage of respondents	Cumulative percentage
All the cows	27	31.1	31.1
No cows	53	60.9	92.0
Some cows	7	8.0	100.0

Frequency Missing = 5

Table 27A: Selection of cows for examination

Selection of cows for Examination before calving	No. res.	% res.	Cum. %
Visual examination	13	86.7	86.7
Previous high SCC	1	6.7	93.3
All the cows every two weeks	1	6.7	100.0

Frequency Missing = 77

Table 28A: Average BSCC during lactation

BSCC	Max	Min	Mean	Std dev
Mean BSCC	457,000	70,000	217,000	81,000

Table 29A: Frequency distribution for BSCC.

Frequency for BSCC	Freq	Percent	Cumulative Percent
< 150,000 cells/ml	32	34.8	34.8
150,000 - 250,000 cells/ml	37	40.2	75.0
250,000 - 400,000 cells/ml	20	21.7	96.7
> 400,000 cells/ml	3	3.3	100.0

Table 30A: BSCC in early lactation

BSCC in early lactation	No. respond.	% respond.	Cumulative percentage
< 150,000 cells/ml	43	47.8	47.8
150,000-400,000 cells/ml	45	50.0	97.8
> 400,000 cells/ml	2	2.2	100.0

Frequency Missing = 2

Table 31A: BSCC in mid- lactation

BSCC in mid lactation	No. respond.	% respond.	Cumulative percentage
< 150,000 cells/ml	40	44.9	44.9
150,000-400,000 cells/ml	49	55.1	100.0

Frequency Missing = 3

Table 32A: BSCC in late lactation

BSCC in late lactation	No. respond.	% respond.	Cumulative percentage
< 150,000 cells/ml	24	26.7	26.7
150,000-400,000 cells/ml	60	66.7	93.3
> 400,000 cells/ml	6	6.7	100.0

Frequency Missing = 2

Table 33A: Size of the herd

Size of the herd	Number of respondents	Percentage of respondents	Cumulative percentage
Increasing	47	51.1	51.1
The same	39	42.4	93.5
Decreasing	6	6.5	100.0

Table 34A: How the herd is increasing

How the herd is increasing	Number of respondents	Percentage of respond.	Cumulative percentage
Rearing of buying replacements	3	6.5	6.5
Rearing replacements and leasing cows	36	78.3	84.4
Fewer culls	7	15.2	100.0

Frequency Missing = 46

Table 35A: Type of milking parlour

Type of milking parlour	Number of respondents	Percentage of respondents	Cumulative percentage
Herribone	76	82.6	82.6
Walk through	2	2.2	84.8
Rotary	14	15.2	100.0

Table 36A: Number of cup sets

Number of cup sets	Number of respondents	Percentage of respondents	Cumulative percentage
0-8 set cups	4	4.4	4.4
9-16 set cups	43	47.3	51.7
17-24 set cups	29	31.9	83.6
25-32 set cups	11	12.1	95.7
33-40 set cups	2	2.2	97.9
41-48 set cups	1	1.1	99.0
57-64 set cups	1	1.1	100.0

Frequency Missing = 1

***Table 37A:** Time spent milking the herd*

Time spent milking the herd	Number of respondents	Percentage of respondents	Cumulative percentage
0-1 hour	12	13.3	13.1
1-1.5 hours	44	48.9	62.2
1.5-2 hours	32	35.6	97.8
2-2.5 hours	2	2.2	100.0

Frequency Missing = 2

***Table 38A:** Personnel of company who checked the vacuum system of the milking machine*

By whom	Number of respondents	Percentage of respondents	Cumulative percentage
Private Company	34	47.2	47.2
Milk Company	34	47.2	94.4
MAF	4	5.6	100.0

Frequency Missing = 20

***Table 39A:** Times the inflations were changed*

Times the inflations were changed	Number of respondents	Percentage of respondents	Cumulative percentage
0	4	4.5	4.5
1	64	71.9	76.4
2	20	22.5	98.9
3	1	1.1	100.0

Frequency Missing = 3

***Table 40A:** Steps used to train new milkers*

Steps to train the new milkers	Number of respondents	Percentage of respondents	Cumulative percentage
Do not have any	32	50.0	50.0
Teach with a few cows	25	39.1	89.1
Close supervision	7	10.9	100.0

Table 41A: Why the farmers believed that the SAMM plan improved the milk quality

Because ...	No. res.	% res.	Cum. %
All the farmers need it	5	20	20.0
Less cows treated each year	1	4	24.0
Better vigilance of mastitis	5	20	44.0
Better mastitis status in the herd	3	12	56.0
Lower BSCC on the farm	1	4	60.0
Better identification of high SCC cows	1	4	64.0
Better selective dry therapy	2	8	72.0
Most mastitis treatments came from first calvers	1	4	76.0
Better Dairy Farm Management	1	4	80.0
Shows problem areas and how to solve them	1	4	84.0
Increase SCC on the farm	1	4	88.0
Improve milk quality	1	4	92.0
Increasing number of cows	1	4	96.0
Common sense	1	4	100.0

Frequency Missing = 67

Table 42A: From which additional source of information would you like to know about low BSCC in your herd

Source of information	Number of respondents	Percentage of res.	Cumulative percentage
Breeding magazines	2	2.5	2.5
LIC publications	35	44.3	46.8
Dairy Exporter	14	17.7	64.6
Discussion groups	6	7.6	72.2
Veterinarian	10	12.7	84.8
Detergent Private Company	5	6.3	91.1
None	1	1.3	92.4
Rural Press	1	1.3	93.7
Experience	2	2.5	96.2
Books	3	3.8	100.0

Frequency Missing = 13

Table 43A: Age of the farmer

Age of the farmer	Number of respondents	Percentage of respondents	Cumulative percentage
< 30 years old	10	10.9	10.9
30 - 40 years old	37	40.2	51.1
40 - 45 years old	13	14.1	65.2
45 - 50 years old	11	12.0	77.2
50 - 55 years old	11	12.0	89.2
55 - 60 years old	6	6.5	95.7
> 60 years old	4	4.3	100.0

Table 44A: Academic qualification

Academic qualification	Number of respondents	Percentage respondents	Cum. percent
None	2	2.6	2.6
High school not finished	22	28.2	30.8
High school certificate	25	32.1	62.8
Trade certificate	9	11.5	74.4
Diploma	8	10.3	84.6
Bachelor degree	9	11.5	96.2
University entrance	3	3.8	100.0

Frequency Missing = 14

Table 45A: Partner's academic qualification

Academic qualification	Number of respondents	Percentage respondents	Cum. percent
High school not finished	18	28.1	28.1
High school certificate	23	35.9	64.1
Diploma	9	14.1	78.1
Bachelor degree	5	7.8	85.9
Registered nurse/teacher	4	6.3	92.2
University entrance	5	7.8	100.0

Frequency Missing = 28