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A Study of Dairy Herds with Constantly Low or Constantly High Bulk Milk Somatic Cell Count, – with Special Emphasis on Management

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SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

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Abstract

Swedish dairy farms with low bulk milk somatic cell counts (LC) for at least seven years and farms with high cell counts (HC) for the same period were studied. Herds had to produce >100 tons of milk and be enrolled in the official milk recording scheme to be eligible for inclusion. LC herds had to have an average arithmetic cell count over the observation period of less than 137,000 cells/ml and HC herds had to have an average arithmetic cell count of 325,000-525,000 cells/ml. There was complete separation, as regards BMSCC, between the two types of farms. The sampled farms were studied via 1) data available in Swedish databases on dairy farms (250 LC and 202 HC), and 2) through an in-depth field study (52 LC and 30 HC). The farms were located in seven different regions in the southern half of the country, Skåne and Halland excluded. Multivariable statistical methods, logistic and linear regression, were used to elucidate differences between farm types.

The LC farms were smaller, 29 vs. 37 cows, and generally had higher incidences of treatments of cattle diseases than the HC farms. The LC farms produced more milk/cow and had better fertility than the HC farms. This indicates better management on the LC farms. The results of the in-depth field study point in the same direction. Thus, the cows on LC farms were cleaner, better sheared, had better trimmed claws and were of the SRB-breed. The LC farmers used rubbermats and straw more often. The milklines had greater diameters, the milking technique was much better, and teat dipping was practiced more frequently. The calves on LC farms were more often tended by a female, they were cleaner, received whole-milk for a longer period of time and were dewormed more often than calves on HC farms. The spouses worked together more often, there were more children in the households and the owners were more patient than the owners on HC farms, where there were more employed personnel and cows of the SLB-breed. The study indicates the need for a new holistic approach for control of udder health.

Keywords: bulk milk somatic cell count (BMSCC), herd health, management, mastitis, milking machine, milking technique, udder health.

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"Think as I think," said a man,
"Or you are abominably wicked;
You are a toad."
And after I had thought of it,
I said, "I will then, be a toad."

Stephen Crane
1871-1900

To "Johansson i Kallsö"
and all his colleagues

Contents

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Chapter 1.

A review of the literature

Introduction

Inflammation of the mammary gland - mastitis - in the dairy cow remains the most common and costly disease of the dairy industry (Natzke et al., 1972; Dohoo et al., 1984[b]; Jones et al., 1984; Fetrow et al., 1991; DeGraves & Fetrow, 1993; Deluyker et al., 1993; SHS, 1997). Expression of the disease ranges from the severely affected, acutely ill cow with obvious clinical symptoms, to inflammatory processes so subtle that they can only be detected with laboratory methods. Mastitis is a multifactorial disease and its incidence, prevalence and epidemiology changes with changes in the environment and shifts in management, on national as well as farm level (Carroll, 1977). It is also a production disease because it is propagated within the farm through the management of dairy production and since its greatest impact is on the economy of the dairy farm.

In the bovine, as well as in other mammals, mastitis is mainly induced by microorganisms and is therefore largely subject to the same rules as all other contractable diseases. Each udder pathogen, however, has its own epidemiology and ecology that can be modified by managerial efforts on the part of the farmer (Bramley & Neave, 1975; Bramley & Dodd, 1984; Oz, 1985; Schukken, 1990[a]; Østerås, 1990; Goodger et al., 1993; Lam, 1996). The dairyman therefore, by his actions, can influence the resistance of his cows and the flora of bacteria that is capable of inducing mastitis on the dairy farm. Increasing quality demands, physical as well as ethical, from consumers and dairies make it important for dairy farmers to improve their levels of management.

Mastitis control programs

Great efforts in research and in design of mastitis control programs have been made since the beginning of the century. Moak, in 1916, described a mastitis control program that emphasized early diagnosis through inspection of milk before milking, use of a disinfecting teat dip after milking and "removing" infected cows from the herd. In the thirties, segregation of infected cows and milking them last was stressed as a measure of control after vaccination had proven ineffective (Minett et al., 1933; Udall & Johnson, 1933; Seelemann & Hadenfeldt, 1934; Stableforth et al., 1935). Most of the early work focused almost entirely on control of *Streptococcus agalactiæ* and in the decades after World War II treatment with antibiotics, mainly penicillin, became one of the cornerstones in the "battle against mastitis". In the late sixties and early seventies a group of researchers in England demonstrated the "dynamics of mastitis" (Dodd et al., 1964) and later, together with researchers from the USA and using large field experiments, formulated the Five Point Plan (Dodd et al., 1969; Neave et al. 1969; Dodd & Neave, 1970; Kingwill et al., 1970; Natzke, 1972). The Five Point Plan (5PP) has since been the main element in many mastitis control programs (Eberhart & Buckalew, 1972; Natzke, 1981; Dodd, 1983; Smith, 1983; Bramley & Dodd, 1984; Booth, 1988). The 5PP comprised: 1. good husbandry and good milking practice with cleaning of teats before milking and dipping the teats after milking in a disinfecting solution, 2. annual testing and regular maintenance of the milking machine, 3. treating all cows with antibiotics during the dry period, 4. prompt treatment of all clinical cases of mastitis, and 5. culling of cows with recurrent mastitis. When judging this plan today one must remember the state of udder health that prevailed at the time. The prevalence of infectious mastitis was around 60 %, the lactational incidence around 80 % and the average time of duration of infection was estimated to 75 % of the lactations, at least in problem herds (Dodd et al., 1969). The overall number of episodes of clinical mastitis in 14 monitored herds with 721 cows was 1,045 or 1.45 episodes of clinical mastitis/cow/lactation. The main bacteria cultured were staphylococci (unspecified, author's note), *Streptococcus agalactiæ (Sr a)*, *Streptococcus dysgalactiæ (Sr d)* and *Streptococcus uberis (Sr u)*. Some decades earlier, Seelemann & Hadenfeldt (1934) reported infection rates with *Sr a* at the beginning of a control effort in several herds of between 42 and 63 %. Other authors report similar figures (Booth, 1988; Booth, 1995; Hill, 1995). One must also bear in mind that one aim when designing the 5PP was to keep costs low - by not using laboratories - so that it could be available to all farmers.

One cornerstone in the 5PP was the dipping of teats after milking which had not always been the common practice in earlier programs that had put more emphasis on washing and disinfecting before milking (Gould, 1943), another was the new strategy of use of antibiotics during the dry period. The 5PP has also been called TDDCT: teat dip and dry cow treat (Natzke, 1981). (In this thesis TDDCT will mean only to "dip teats and treat all dry cows" - points 1 and 3 of the 5PP, see list of abbreviations.) The segregation and/or elimination from the herd during lactation of chronically infected cows, as was recommended in the first half of the century, was now replaced with the use of antibiotics. The recommendation to treat all cows at drying-off was never adopted in the Nordic countries, where the incorporation of diagnostic laboratories into the control programs and the use of selective dry cow therapy was recommended (Olsen, 1971 & 1975; Funke, 1988). The control programs that fight "the battle against mastitis" have evolved since the seventies, however, and most programs now also include advice on a variety of management measures such as milking technique, pre- and postmilking teat dipping and systems for "drying-off" cows as well as technical recommendations regarding the milking equipment, feed conservation systems and design of barns and milking parlors. Administration of antibiotics still remains an important part, however (Funke, 1988; Philpot & Nickerson, 1991; Anderson, 1993; Logan, 1993; Meaney, 1994; Hillerton et al., 1995; Sandholm et al., 1995).

Somatic cell count - indicator of udder health

Since most mastitis control programs use the bulk milk somatic cell count (BMSCC) as an indicator of udder health, the advice given primarily aims at lowering these counts. This does not necessarily mean that the incidence of clinical mastitis is lowered. Already in the seventies articles appeared that reported an increase in the number of clinical cases of mastitis, mainly induced by environmental bacteria, in herds that rigorously implemented the five point plan (Eberhart & Buckalew, 1977; Marr, 1978). These early reports have been followed by others (Hoblet et al., 1988; Hogan et al., 1989; Gonzalez et al., 1990). This line of research has recently been successfully pursued by researchers from Utrecht, Netherlands, who have identified a number of risk factors for clinical mastitis on farms with low cell counts (Schukken, 1990; Lam, 1996).

In Sweden, the national yearly BMSCC was around 340,000 cells/ml when measurements started in the seventies. The geometric mean for 1995 was 213,000 cells/ml (SHS, 1997). During this time the incidence of cows treated for clinical mastitis has increased from about 14 % to 23.1 %. This is not an effect solely of the reduced BMSCC, however. It is also due to the better record keeping systems, supported by computer programs, that have been introduced during this period. During 1995, BMSCC, at farm level, ranged from a yearly average as low as 10,000 to just above 800,000 cells/ml. Among the dairy farms, 1.4 % had a yearly geometric mean BMSCC above 400,000 cells/ml and almost 40 % exceeded this limit once during the control-year 1995/96 (SHS, 1997). It should also, in this context, be noted that some of the reduction in BMSCC is due to an increase in milk production/cow (Emanuelson & Funke, 1991) and not solely to better udder health.

Elevated BMSCC is an indication of subclinical mastitis (Brolund, 1985; Andersson, 1988; Reneau, 1986). Although great efforts have been made to make dairy farmers grasp the concept of subclinical mastitis it still remains a major pedagogical challenge to convince some farmers that his/her best cow is infected, and presents a risk to other cows, just because her milk contains 300,000 or more cells/ml (or > 283,000[1]), when she is eating her ration of feed and producing 30

[1] 283.000 cells/ml is the threshold between the American linear udder health scores of 4 and 5, where a score of 5 or more indicates pathology (Reneau, 1986).

kg of milk or more per day. In a preliminary study to this thesis, 55 % (n: 80) of the farmers on dairy farms that had had high cell counts (mean of 425,000 cells/ml) for ten years or more, claimed that they did not have "a mastitis problem" on their farms.

Shift in bacterial flora

As mentioned above, *Sr a* was a major problem in subclinical as well as clinical mastitis in the first half of the century, even though some authors noted problems with other bacteria such as *Staphylococcus pyogenes* (now *S aureus*) and "bacillary" - mainly coliforms, as well as streptococci other than *Sr a* (Schalm & Ormsbee, 1949; Murphy, 1956). In the late seventies and early eighties there are investigations reporting that transmissible bacteria such as *Staphylococcus aureus (S aureus or S a)* and environmental bacteria such as *Esherichia coli (E coli)* and *Sr u* have replaced *Sr a* as the major mastitis-inducing pathogen both in clinical and subclinical mastitis (Marr, 1978; Wilson & Richards, 1980; Anonymous - Unit of Epid., 1981; Robinson et al., 1985)

In Finland, the bacteria isolated from cases of clinical mastitis have shifted from a predominance of *Sr a* in the forties and fifties via a dominance of *S aureus* in the 1970s to the present situation where almost 60 percent of the bacteria isolated from cases of mastitis are coagulase negative staphylococci (CNS), coliforms and other, mainly environmental, bacteria (Myllys, 1995). In spite of this shift from a more contagious bacterial flora with "major" pathogens to a more environmental flora, with a large proportion of "minor" pathogens, Myllys reports an increase in the prevalence of infectious mastitis from around 35 % in the seventies to 47.5 % in 1989. The development in Finland is an indication that some species in the group of udder pathogens that are usually referred to as minor pathogens, such as the CNS, can cause serious disturbance of udder health on dairy farms.

Factors affecting udder health

Another, complementary, line of research to the one discussed under the heading Mastitis control programs above, where researchers have tested certain management and others measures and studied their effect on udder health on dairy farms, are the epidemiological studies of risk or protective factors on dairy farms. In these studies, the researcher looks at, or by other means tries to identify, what the dairy farmers are actually doing or what physical properties that might contribute to the result on his/her farm. Studies of udder health on dairy farms have focused on either BMSCC or incidence of clinical mastitis, or in some cases both. Table 1 shows some of the studies in this line of research. In the table, studies of high

(HC) and low cell count (LC) dairy farms are listed first. Nordic studies are listed last. The terminology follows that of the original articles as much as possible.

Table 1. Author, publishing year and country, method of selection and selection period, number of herds in study, statistical methods and identified risk or protective factors in studies of udder health on dairy farms since 1972. List of abbreviations at the end of the table

Author, year and country.	Selection method, selection period and no. of herds.	Statistical analysis and risk or protective factors in management and related factors.
Pearson et al., 1972, UK.	**High and low** incidence of pathogens. One year observation period prior to study. LC: mean = 290,000 cells/ml HC: mean = 1.287×10^6. HC: 25; LC: 25 Convenient sample. Questionnaire and on-farm visits by specialists.	Univariable analysis. LC: lower lactation age, higher culling rate, better record keeping and knowledge of cow performance, better cow comfort in housing and environment, more teat dipping (TD), better milk machine efficiency, no severe overmilking, more lab support, abrupt drying-off and more efficient use of labor. Non-significant variables (NS): dry cow therapy of all cows (BDCT), individual or shared wash cloths, inspection of foremilk etc.
Goodhope & Meek, 1980, Canada.	**High and low** "milk gel index" during 12 months prior to case/control study. Questionnaire sent to 544 of either category. Response rate: HC 49.4 and LC 80.1 %, (269 and 440). Mailed questionnaire and production data.	χ^2 and discriminant analysis: LC: more TD and BDCT, more regular visits by veterinarians, better knowledge of subclinical mastitis, more culling for mastitis, more breeding of replacements, more modern buildings with tied cows, fewer milking units / milker, less checking of foremilk, less time from start of preparation to attaching milking unit.
Le Du et al., 1985, France.	**High and low** BMSCC and rate of clinical mastitis (CM). > 600.000 or < 400.000 cells/ml during last 6 months. > or < than 1 CM / 20 cows during month preceding study. 103 "problem herds" and 32 "mastitis free" herds selected in Brittany, France. Questionnaire and visit to check milking machine.	Fisher exact, Student's *t*-test and multivariable regression. Farms with fewer problems with mastitis were larger (40 vs. 33 cows), had higher / cow milk production, more modern milking equipment such as high line milking units instead of bucket milking. They also had better milking routines with less postmilking stripping, better hygiene and a cleaner environment.

Table 1, continued

Erskine et al., 1987[a], 1987[b], 1988, Pennsylvania USA.	**High and low** BMSCC Selected Randomly selected. HC ≥ 700,000 cells/ml, LC ≤ 150,000 cells/ml, 12 months prior to study. HC: 16 and LC: 16. (6 and 12, resp, in study from 1988). Herds visited for bacteriological and blood sampling and technical study of milking machine. Questionnaire collected at farm visit.	*t*-test and Fisher exact test. LC: more TDDCT, higher mean blood GSH-Px activity and higher concentration of blood Selenium, lower prevalence of infection with all major pathogens. LC farms had more cases of clinical mastitis (CM) induced by environmental pathogens in the summer. NS: no differences in common milking hygiene practices and milking equipment maintenance or function were demonstrated.
Hueston et al., 1987, Ohio, USA.	**High and low** prevalence of udder pathogens in bulk-tank milk. Based on studies, within herds, of cows above or below 283,000 cells/ml. 12 month average. Herd BMSCC average not given. *Sr a* positive: 37 of 320. *S a* positive: 90 of 320. Questionnaire sent to dairy farmers. No visits on farms.	Least-squares analysis of variance and linear regression. Low prevalence of cows with high SCC associated with absence of *Sr agalactiae* and presence of TD and BDCT. No interaction between *Sr a* and *S a* indicating different etiologies. NS: pre-milking teat dip, method of udder preparation before milking and milking equipment maintenance and function.
Hutton et al., 1990, 1991, Washington, USA.	**High and low** prevalence of udder pathogens in bulk-tank milk. Based on studies, within herds, of cows above or below 283,000 cells/ml. 12 month average. Geometric mean, HC: 460,000 LC: 175,000 cells/ml. 2 year observation period. 31 HC and 28 LC farms visited twice - one year apart - by "field technician".	Stepwise linear - and logistic regression. LC: cases of CM milked last, automatic detachers, disinfection of tips of teats prior to intramammary treatment, drier bedding and fewer cows infected with *S a.* More attendance of dairy informational meetings and more use of computers. Lower prevalence of *S a* associated with the above + TD and frequent cleaning of the regulators. NS: no differences in milking time hygiene practices, TD (except specifically for *S a*), BDCT, milking equipment function and maintenance.

Table 1, continued

Bodoh et al., 1976, Wisconsin, USA.	**Selected herds - two different convenient samples** 16 herds sampled monthly for 2 years. 134 herds sampled once. Bulk milk sampled and analyzed at factory or university laboratory. Mean BMSCC 692,000 and 625,000 cells/ml, respectively. Mailed questionnaires filled in by dairy farmers.	Least squares analysis of variance. Lower BMSCC associated with milking parlors, TD and selective DCT. Some farms that did not practice DCT at all had low (no specification given) BMSCC. Higher BMSCC associated with high line milking systems and BDCT combined with no TD. Effect of season on BMSCC with higher counts in the summers of the two years of observation. NS: No association between herd size and BMSCC.
Moxley et al., 1978, Canada.	**All 581 DHI farms** in the Quebéc area were surveyed via a mailed questionnaire merged with BMSCC data. Observation period 4 months. Mean BMSCC: 420,300 and mean lactational production: 5,355 kg .	ANOVA and least squares analysis for unbalanced data. Lower BMSCC were associated with TD, drying of udders after washing, taking part in an udder health program and receiving monthly cell counts. NS: no effect was seen from use of separate towels or rinsing of teat cups between cows. Each increase of 100,000 cells/ml of bulk tank milk was associated with a herd loss of 59 kg milk / lactation.
Hoare et al., 1979, Australia.	**All 115 farms** delivering milk to two "dairy factories". Survey of mastitis control practices and associations with BMSCC. 377,000 and 577,000 cells/ml, respectively. BMSCC data collected during summer: Nov - May. On-farm interview of farmer and inspection of milking equipment.	χ^2 and *t*-test Lower BMSCC associated with TD, no drying of udders and a pulsation cycle with a milking phase not exceeding 30-40 %. Only 21 % of farmers practiced TDDCT on all cows but their BMSCC was significantly lower than the remainder of the farms (geometric mean 416,000 vs. 493,000). NS: no differences in farm practices were found that could explain the inter-factory difference in BMSCC.

Table 1, continued

Dohoo et al., 1983, I, 1984, III, 1984[a], VI, Canada.	**Selected DHI farms** in Ontario "with a wide range of managerial abilities and levels of milk production" within a 50 mile radius of Guelph. Study of disease, production and culling on 32 farms Questionnaire at farm visit.	Multiple linear least squares regression. None of the 3 measures of mastitis, 2 treatment regimes and BMSCC were associated with TD or BDCT. CM: Protective effect of anti-edema treatment. Higher BMSCC associated with more horsepower of tractor. Increased risk of culling due to clinical or subclinical mastitis.
Barnouin et al., 1986[a-c], France.	**Selected dairy farms** in 7 "départements" in France. Farms selected on diversity of conditions, representativity of region and willingness to co-operate. Main risk factor analyses based on 29-71 farms investigated for 2-3 years. Inspections, interviews, questionnaires, blood-, milk and other sampling. Analyses of risk and protective factors for high (> 1 x 10^6) and low (< 200,000) cell counts and CM.	ANOVA, analysis of co-variance, χ^2 and "proportions equality tests". Study I: Lower BMSCC: TD. Risk factors for CM: not checking milking equipment at least once annually. Protective factor - CM: individual wash cloth or towel, enough straw for bedding. Study II: Risk factors for CM: monthly rainfall during pasture of > 120 mm, too much energy in relation to protein, housing period, high milk yield. Protective factor - CM: protected waiting yard, Risk factors for high BMSCC: breed, genital and foot infections, high plasma copper levels. Factors associated with low BMSCC: intensive farming, *i.e.* higher efficiency in genetics, management and higher milk yields.
Dargent-Molina et al., 1988, New York, USA	**High prevalence of *S a* or *Sr a*** infected cows. Selected herds. 60 % of study population had BMSCC > 1.5 x 10^6 cells/ml on 3 of 5 tests. 40 % volunteered into the study. *S a:* 280 with 0 and 737 with high prev. *Sr a:* 630 with 0 and 734 with high prev. Herds visited once for bacteriology samples, inspection of milking equipment and questionnaire.	χ^2, Student's *t*-test and logistic regression. Risk factors in herd for IMI with both *Sr a* and *S a:* failure to TD, use of common wash cloth and larger herd. Risk factors for *S a:* the above + high vacuum level and medium to large bore teatcups. NS for *S a*: DCT and housing variables. Risk factors for *Sr a:* common risks above + dry massage, selective or no DCT (vs. BDCT) and having tie stalls or partitions. Low associations between IMI of *Sr a* and *S a* indicating different epidemiologies of these contagious, major pathogens.

Table 1, continued

Schukken et al., 1989, 1990[b], 1991, Netherlands.	**All 125 dairy farms** in the central part of the Netherlands with < 150,000 cells/ml during 1984 and producing > 200 and < 500 tons of milk. Visits for sampling, measuring and interview.	Descriptive statistics and Poisson regression. Generally the incidence of *S a* increases the incidence of CM increases. Incidence of CM has a seasonal variation and is highest in the early summer months. Risk factors for CM were: TD, poor cubicle cleanness, rubber mats, high frequency of cubicle disinfection, drinking water from other than public sources, sugar beet pulp, cows leaking milk, breed and high milk production. Risk factors - *S a*:: private source of drinking water, checking foremilk, not checking milking machine regularly, monthly disinfection of cubicles, air inlet along roof, long term (years) use of TD and lower than average milk production. Protective factor: more bedding in cubicles. Risk factors - *E c*: udder preparation with water, TD, cows leaking milk, breed and disinfecting dry cow cubicles. Protective factors: good cubicle cleaning, rubber mats in calving area.
Miller & Bartlett, 1991, Michigan and Ohio, USA.	**DHI farms responding to questionnaire.** Method of selection not specified. 406 out of 504 farmers answered a DHI, technician- administered, questionnaire attempting to put economic value on management practices.	Analysis of covariance - general linear regression. Survey of economic value of defined management practices. Positive economic practices: TD (especially quarternary ammonium -, chlorhexidine - and iodine types) and sufficient bedding (especially sawdust, long straw and sand). NS: BDCT, single-use paper towels and use of sanitizer in udder wash water.

Table 1, continued

Howard et al., 1991, Canada.	**Random sample.** Questionnaire mailed to 1,200 DHI farmers. 719 returned Q. These had larger herds (55 cows), higher production (6,673 l/lactation and lower cell counts (245,000 cells/ml) than average.	"Moment generating approach". Lower BMSCC associated with: TD, wash of udder, drying with newspaper, checking and changing rubber inflations regularly, taking samples for bacteriology when problems with udder health, longer education, regular visits by veterinarians and other advisors. Higher BMSCC associated with: more treatments with antibiotics, disinfectant in wash water, always drying udders before milking, use of straw and culling for mastitis. NS: not economically beneficial: DCT - all types, drying with new cloth/cow, inspection of foremilk.
Bartlett et al., 1992[a-d], Bartlett & Miller, 1993. Michigan and Ohio, USA.	**Random sample,** 48 herds stratified on size. Mean BMSCC during observation period: 384,000 cells/ml (SD: 156,000 and range 157,000-793,000). Mean incidence of CM: 3.06 cases / 100 cow months (SD: 2.85). One year study, monthly visits for bacteriological sampling of tank milk, inspection of sanitary conditions, milking procedure and sanitation at milking. One interview on management.	ANOVA, linear regression and regression analysis of co-variance. Lower BMSCC: hired milkers, > 30 sec prep time, use of separate drying cloth, clean teats following milking, clean and dry exercise area, stable[2] pasture situation and fewer milking cows. Low incidence of CM: fewer person-hours/cow milking cows, pre-dip not used, no inspection of foremilk, straw bedding, fewer cows, calvings in designated calving facility and fewer months on pasture. Risk factors - CPS: dirty udders, high-line milking system, less crowded barns and larger herd. Risk factors - CNS: shared wash cloth, teats not dried before milking, no TD, less bedding. Risk factors -coliforms: running water wash, increased person-hours/cow at milking, more milk left in udder, poor sanitation and free stalls. Risk factors - E sr: poor pre-milking hygiene, more days dry (mean = 59 d), poor sanitation and tie stalls.

[2] The authors have compared either stable pasture conditions meaning that you let the cows out on pasture or you don't, with letting the cows out for a couple of days or weeks and then stabling them during periods of poor weather or for other reasons and then out on pasture again.

Table 1, continued

Goodger et al., 1993, California, USA.	**Randomly selected,** 56 DHI herds. Four visits by 3 interviewers during Nov-July. Informal interview with preformed questions covering management and other aspects. BMSCC analyzed in relation to visits.	MANOVA and stepwise, all-possible-subsets multiple regression. BMSCC is affected by sanitation, milking equipment, cow condition, pre-milking procedures and mastitis control practices (factors not further specified). Significant, over time, differences between the importance of these factors were detected. Many interactions found between factors.
Sischo et al., 1993, Ohio, USA.	**Cross-sectional** (prevalence) study of major pathogens (*Sr a* and *S a)* in tank milk from 572-926-dairy farms. Records of BMSCC for 12 months during study. Questionnaire mailed to 1,032 DHI farmers. Response rate 89.7 %. 741 had 12 BMSCC records and from 572 samples for bacteriology were obtained.	Descriptive statistics, ANOVA and χ^2 *Sr a* or *S a* were isolated on at least one occasion from 3.1 and 41.1 % of herds, respectively. Both pathogens were found on 1.9 % of herds. *Sr a* and *S a* were not found in tank milk from 53.8 % of farms. 90.5 % practiced TD and 83.8 % BDCT. A lower prevalence of, but not freedom from, contagious pathogens was associated with TD and BDCT.
Berry, 1994, England.	**Low cell count farms -** convenient sample of 11 farms. 12 month rolling average BMSCC < 70.000 cells/ml Management practices studied by veterinarian, interviewing and inspecting during February. Statistically significantly smaller herds (45) than average (71).	No statistical analysis due to small number of farms. Inspection (or in-line detectors) of foremilk: 100 %; TDDCT: 100 %; cows standing after milking: 73 %; culling of chronic mastitis cases: 100 %; bedding replenished daily: 100 %; annual milking machine test: 82 %; breeding own heifers: 91 %. General impressions: clean cows, barns, stalls and exercise areas, "greater care in management standards and extra attention to detail, was observed in all herds."

Table 1, continued

Fenlon et al., 1995, Scotland.	**30 selected farms** - three BMSCC-strata. 11 low: < 250,000, 8 "borderline": 250,000 - 450,000 and 11 high: > 450,000 cells/ml - 12 month arithmetic mean BMSCC. Prevalence of major gram+ pathogens in tank milk and geometric mean BMSCC analyzed fortnightly. Farmers interviewed via telephone.	Descriptive statistics and logistic regression. Good correlation between BMSCC and number of CFU in tank milk - better for streptococci than for *S a*. HC associated with less TD, not checking milking equipment regularly, not having ACR, more buying of replacements and having significantly lower yields. "Management of high BMSCC herds showed less commitment to implementing mastitis control practices than herds with a consistently low BMSCC."
Wilson et al., 1997, New York, USA.	**843 farms participating in university "DHI" service.** On-farm visits for sampling for bacteriology, assessment of cleanness - barn and cow - and filling in of questionnaire. 286 farms had BMSCC > 750,000 cells/ml. Mean BMSCC for farms < 750,000: 382,828 cells/ml. Mean BMSCC for all farms: 520,005 cells/ml. TD and DCT[3] used on 82 and 89 % of farms, respectively.	GLM: multiple linear regression analysis. Herds divided in two groups: with or without *Sr a*. *Sr a* positive herds: Lower BMSCC: lower prevalence of *Sr a* and *S a,* regular mastitis control visits and use of predipping. NS: milking CM cows last, TD, DCT[3], herd size, stall, alley and cow cleanness, over-crowding, type of housing, bedding, milking system performance, incl. ACR and backflushing. *Sr a* free herds: Lower BMSCC: lower prevalence of *S a* and *Corynebacterium bovis,* regular mastitis control visits, sawdust bedding, clean loose housing, and interaction b/w platform cleanness and type of housing. NS: use of predip, TD, DCT[3], prevalence of environmental bacteria, milking system performance, teat end cleanness and health. Lower BMSCC associated with higher milk production in both types of herds.

[3] Authors do not state clearly whether DCT or BDCT is used on farms, probably the latter.

Table 1, continued

Johannesson, 1994, Iceland.	**High and low** BMSCC. 20 HC: >500,000 and < 750,000 and 20 LC: < 300,000 cells/ml during 12 months prior to study. On-farm visits by veterinarian, inspection and questionnaire.	Statistical method not stated. LC: better milking technique with less overmilking, cows were better sheared and the floors cleaner. Manger was higher (+ 4.3 cm) and the lighting better 30 cm above the floor.
Lindström, 1983, Finland.	**Randomly selected herds** delivering to one dairy plant. Student has visited and interviewed farmers on 61 herds. Interviewer has taken measurements and evaluated practices. Technicians have sampled (bacteriology and SCC) 781 cows for 6 months.	Descriptive statistics and least squares procedure. Low SCC associated with using TD, applying grease to teats after milking and barn having normal or below normal hygiene. High SCC associated with draftiness of barn, no bedding or sawdust and having a rear-heavy or pouchy udder with less than 40 cm between teat end and floor. NS: No differences in cell counts or bacterial scores between herds using separate or shared udder cloths.
Østerås & Lund, 1988[a-b], Norway.	**Selected farms.** High BMSCC herds and herds with high incidence of CM and taking part in herd health activities in northern Norway selected for survey. Interview and inspection on 158 farms by authors 1976-1977. Mean BMSCC: 545,000 (± 355,000, Herd size 11 ± 6.	Least squares analysis - GLM. Good udder health: small, non-ventilated claw pieces, having more than one cluster, correct rate of pulsators, well functioning vacuum regulator, letting in little or moderate amounts of air when attaching cluster, longer machine-on time, a vacuum level of 36-39 cm Hg, having rubber mats, trimmed claws, a larger herd, average width stalls (105-115 cm), longer stalls (mean: 174 cm), double glazed windows and culling cows with chronic *S a* mastitis. Bad udder health: having "fairly good" liners, limping pulsators, undulation of milkline, short preparation time, overmilking for > than 1 minute and narrow or wide and/or short stalls.

Table 1, continued

Østerås et al., 1990, Norway.	**104 dairy herds participating in "DHI" program** due to high BMSCC or high incidence of CM. Data recorded 1978. Mean BMSCC: 499,000 (± 303,000) cells/ml. Aim of study: identify risk factors for teat lesions.	Descriptive statistics and analysis of covariance. Risk factors for teat lesions: Herd size, height of manger (in short stalls), pulsation ratio of ≥ 71% (compared with a ratio of 50 %), overmilking for more than 20 sec and no hoof trimming. NS: type of stall, type of stall floor and length of stall.
Østerås, 1990, Norway.	**Randomly selected,** 676 herds taking part in herd health activities in Norway. Environmental and management variables on farms collected by extension service. Mean BMSCC 293,000 (62,000-1,069,000 cells/ml) and mean incidence of CM 43.2 % (0-145 %).	Least squares analysis - GLM. No associations found between udder health and stall construction. All significant variables were management or management associated. Good udder health was associated with regular clipping of haircoat, trimmed feet, clean barn and cows, no draught, night light and no use of electric cow trainer. CM prevented by having cows on pasture in the summer.

Abbreviations: ACR: Automatic cluster remover, ANOVA: analysis of variance, BDCT: "blanket" dry cow therapy, BMSCC: bulk milk somatic cell count, b/w: between, CFU: colony forming units, CM: clinical mastitis, CMT: California Mastitis Test, CNS: coagulase negative staphylococci, CPS: coagulase positive staphylococci, DCT: dry cow therapy, DHI: dairy herd improvement (program), *E c: Escherichia coli*, E sr: environmental streptococci, GLM: general linear model, Gram+: gram-positive, GSHPx: glutathion-peroxidase, HC: high cell count farm, IMI: intra-mammary infections, lab: laboratory, LC: low cell count farm, MANOVA: multivariable analysis of variance, NS: non-significant, prev: prevalence, qrts.: udder quarters, *S a: Staphylococcus aureus, Sr a: Streptococcus agalactiœ, Sr d: Streptococcus dysgalactiœ, Sr u: Streptococcus uberis,* SCC: somatic cell count (composite cow sample), TD: post-milking teat dipping, TDDCT: post-milking teat dipping and blanket dry cow therapy.

As can be seen from Table 1, there is almost universal agreement that TD reduces BMSCC (Pearson et al., 1972; Bodoh et al., 1976, Moxley et al., 1978; Hoare et al., 1979; Goodhope & Meek, 1980; Lindström, 1983; Barnouin et al., 1986[a]; Erskine et al., 1987[a], Hueston et al., 1987; Dargent-Molina et al., 1988; Hutton et al., 1990 & 1991; Miller and Bartlett, 1991; Howard et al., 1991; Sischo et al., 1993; Berry, 1994; Fenlon et al., 1995). Schukken et al. (1990[b]) found TD to be a risk factor for clinical mastitis. As regards the practice of DCT, and especially "blanket" dry cow therapy (BDCT), the results are more ambiguous, with some studies showing lowering effects of DCT or BDCT on BMSCC (Bodoh et al., 1976; Hoare et al., 1979; Goodhope & Meek, 1980; Erskine et al., 1987[a]; Hueston et al., 1987; Sischo et al., 1993) while others show no or even a positive association (Pearson et al., 1972; Dohoo et al., 1984[a]; Hutton et al., 1990 &1991; Howard et al., 1991; Miller & Bartlett, 1991; Bartlett et al., 1992[c]; Bartlett & Miller, 1993; Wilson, 1997). This might, especially in later studies, partly be due to the fact that so many farmers in the USA treat their dry cows with various antibiotic compounds, that there is not enough variation regarding DCT practices to establish significant differences between different types of farms. This reasoning should then, on the other hand, be equally applicable to the practice of TD, which indicates that there most probably is a difference in efficacy between these two practices.

The studies of Hueston et al. (1987), Dargent-Molina et al. (1988), Hutton et al. (1990 and 1991) and Wilson et al. (1997), who examined effects of control practices on different pathogens, clearly indicate that the epidemiologies of *Sr a* and *S a* are different and that these control practices affect these two pathogens differently. It appears that TD and BDCT are more effective in controlling *Sr a* than *S a*. It is reasonable to hypothesize that this is because *Sr a* is more sensitive to treatment (penicillin) and more restricted to the parenchyma of the udder than *S a*. The bacterium of main interest at the time of the design of the 5PP was *Sr a*.

There is less agreement on the effects of some other practices that are generally accepted in daily udder disease preventive work, such as use of separate or shared wash cloths, inspection of foremilk, overmilking or the impact of the milking machine. There may be several reasons for these disagreements, such as sample size, method of selection of study group, method of inquiry, wording of questions, repeated or single visits, change of infrastructure of dairy farms, the above-mentioned shift in cell counts and bacteria involved in subclinical and clinical mastitis, regional, geographical or climatological differences, etc. One reason, of course, is that by chance alone one must expect some differing results.

It has been shown by many authors that different bacteria have different epidemiologies regardless of whether they are contagious or environmental and that most of them, to some extent, are both. Lam et al. (1996[b]) showed, with "DNA-fingerprinting", that even some strains of *E c* can be of a contagious nature, with fewer strains than isolates causing recurrent clinical mastitis in some herds. These findings of differing epidemiologies of the bacteria involved in bovine mastitis fit well with the shift in bacterial flora and characteristics of the disease and support the general impression in the literature that the 5PP worked best in the beginning of its implementation. As the importance or *Sr a,* as a pathogen in subclinical bovine mastitis, diminished so did the effect of the 5PP. This calls for more research on the design of control programs that are more adaptable to a changing environment and to different situations on different dairy farms.

One reason for differences between studies, which becomes evident in the works of Goodhope and Meek (1980) and Howard et al. (1991), is the reluctance of farmers with high BMSCC to answer and complete questionnaires. Studies with randomly selected farms and mailed questionnaires could be expected to get differing results from studies where the farmers have less of a choice of whether to take part or not. Goodhope and Meek (1980) report significantly different response rates between LC and HC farms, and Howard (1991) reports that the 719 farmers (out of 1,200) that answered a questionnaire, had larger herds, higher production and lower cell counts than the average farm. Another reason for differences between studies or for various variables not to appear in regression models is the one of causality. It can never, in studies of management practices, be proven that the actions recorded led to the result achieved by the farmer. The reasons for this are related both to time and management. The farmers' actions change with time, as demonstrated by Goodger et al. (1993) and the differing udder health situations on different farms call for different managerial actions on the farmers' part. A farmer with low BMSCC and few clinical cases of mastitis may not need to teat dip or to treat dry cows due to other ways of controlling udder pathogens. On the same token, he may not have to consider mastitis as the primary reason for culling in his herd. Lack of appearance in a regression model is, therefore, not proof that a practice, generally considered effective in the control of mastitis, is ineffective but rather an indication that the causalities behind events need to be analyzed more closely.

Most studies that allocate farms to a cell count category or as a selection criterion in a randomized scheme do this based on the cell count from a limited time period before the study, generally 12 months. Schukken (1990[a]) showed that BMSCC change considerably over time and that changes are more pronounced on high cell count farms. With such short observation times as one year, or less, one must expect conditions to vary and overlap in management practices to occur between cell count strata. Thus contributing to differences in effect estimates.

Hypothesis

Based on the review of the literature the following hypothesis was generated: Keeping BMSCC constantly low is the result of the management of the dairy farms by the LC farmers and the environmental conditions on those farms.

Design, aim and problem areas discussed in this thesis

To test the hypothesis a biological study of factors that influence BMSCC was designed, utilizing epidemiological principles for sampling of farms, gathering of data and for statistical analyses. The material and methods are described in Chapter 2. The aim of this thesis is to determine which factors that contribute the most to a good and stable udder health, as measured by BMSCC, by discussing:

1. descriptive statistics of LC and HC farms (Chapter 3)

and comparing effects of:

2. environmental factors (Chapter 4)
3. feed and water (Chapter 5)
4. the cows and other stock (Chapter 6)
5. the milking machine and milking technique (Chapter 7)
6. and the human influence (Chapter 8)

on sampled dairy farms with constantly low or constantly high BMSCC, and located in seven geographical regions in the southern half of Sweden.

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Chapter 2.

Materials and methods

Design of study

Selection of dairy farms

To be eligible for inclusion in the study, herds had to A) have complete yearly BMSCC records from 1985 through 1991; B) produce >100 tons of milk during 1991, and C) be enrolled in the official milk recording scheme (an equivalent of dairy herd improvement (DHI) -programs). In order to obtain as large a differentiation as possible between the herd types, the following selection criteria were devised. Low cell count herds (LC) had to have an average arithmetic cell count over the entire observation period of less than 137,000 cells per ml and permitting the average BMSCC for an occasional year/-s to reach a maximum of 150,000 cells/ml. The high cell count herds (HC) had to have an average arithmetic cell count over the entire observation period of 325,000-525,000 cells/ml and permitting occasional years to deviate ±75,000 cells/ml, setting the range for occasional years to 250,000-600,000 cells/ml. There was thus complete separation, as regards BMSCC, between the two types of farms. Six hundred thousand cells per milliliter of milk was the highest tolerated annual average arithmetic BMSCC for dairy farms in Sweden at the time. The production criterion was a proxy for sufficient herd size and meant that herds with less than approximately 16 cows were not included in the study. The selection of farms took place in the spring of 1992.

Schukken (1990[a]) has shown that farms with a low annual cell count during one year were more likely to have low cell counts during a six-year observation period than high cell count farms were likely to remain in the high cell count category. In a study of repeatability of mastitis-related variables under Swedish conditions, Emanuelson, using a material from 13,046 herds, reported repeatability between years of 0.21, 0.40 and 0.57 for clinical mastitis, subclinical mastitis and BMSCC, respectively (Emanuelson, 1995). These considerable differences between years, although BMSCC is the more stable of these parameters, indicate the need for observation periods of several years in order to achieve stable conditions on the sampled farms.

In this study, we have made sure that the inclusion criteria regarding annual bulk milk somatic cell count for the two groups of farms were met every year during the observation period that preceded selection and that they were met at the time of the visit by the technicians. A longer observation period than seven years would have been even better and another dataset with a ten-year observation period was tried initially but proved impractical due to the higher turnover and loss of HC farms. The final decision to use a seven-year observation period was a trade-off between the demand for stability of conditions on the sampled farms and the need for HC farms.

The initial dataset comprised 272 LC farms and 391 HC farms. When the farms were divided according to which local livestock association they belonged to, it was seen that they were not evenly distributed over the country. Only 15 (5.5 %) of the 272 LC farms and as many as 183 (46.8 %) of the 391 HC farms belonged to the numerically large associations of Skåne and Halland. Because of this skewness between types of farm and a cognate skewness in the distribution of breeds, all farms in Skåne and Halland were excluded from further studies. If farms from Skåne and Halland had been made eligible to the study a random selection of farms would have meant that we, most probably, would have compared HC farms with dairy cows of the Swedish Friesian breed (SLB) from these two regions with LC farms with cows of the Swedish Red and White breed (SRB) from Skara and Malmen (Table 2). Since the aim of the study was to identify differences between LC and HC farms other than breed and region, a more balanced selection of farms was needed. It was also necessary to limit the number of associations involved since the study had limited economic resources. Following discussions with representatives of the Swedish Association for Livestock Breeding and Production (SHS) and different local livestock associations, it was decided to conduct the in-depth study together with the associations in Skara, Kalmar, Östergötland, Gotland, Malmen, Uppsala and Dala-Gävle. In these regions, there was a fairly even distribution of LC and HC farms and of the two major dairy breeds, SRB and SLB The northern associations were excluded mainly for geographical reasons, the long distances and few farms giving rise to high costs.

The numbers of LC and HC farms in different regions/local livestock associations in Sweden are shown in Table 2.

The Field Study

An in-depth study of selected dairy farms was designed that would cover environmental, animal and managerial factors and at the same time would be possible to work with for the field personnel. The study comprised:

1. - a study of the barn and some management factors registered on a record usually used by the technicians at herd health investigations regarding udder health (Environmental report A 1, see Appendix 2:1). This record will be referred to as TecGen which stands for technicians general record.

2. - measurements of the concentration of NH_3 and CO_2 in the barn air with a Gastec or Kitagawa pump and Kitagawa gas detector tubes (Kitagawa, No. 105SD and 126SC) at the two places in the barn that the technicians subjectively judged to have the best and the worst quality of air. Measurements included in TecAni (see 3. below).
3. - a record of measurements of length of ipsilateral teats, teat-to-ground distance and heart girth on 20 %, randomly selected, of the older (parity >2) lactating cows. This record will be referred to as TecAni which stands for technician's animal record (Appendix 2:2).
4. - subjective estimations, according to a defined scoring system, of the condition of the claws, the amount of body fat (body score), degree of cleanness and shearing of these cows individually (same cows as under 3 above). The dry cows (if any), the heifers and other young stock and the calves were subjectively judged on the same criteria but treated as groups. Certain aspects, such as cleanness and general suitability of stalls and holding pens and ventilation of buildings were also recorded. Measurements included in TecAni.
5. - measurements of the function of the milking machine. This part of the study was a simplified version of the ordinary milking machine study (Pipeline Milking System, Appendix 2:3). This record will be referred to as TecMiM, which stands for technician's milking machine record.
6. - a study of the farmer's milking technique during the evening milking. For design of complete record see Appendix 2:2. This part of the TecAni record will be referred to as TecMiT, which stands for technician's record of milking technique.

The TecGen record contained 27 variables that were environmentally related, 14 were related to animals, 9 to feed and water, 4 to the milking machine, 5 to milking technique, 3 to management and 3 to miscellaneous subjects. The specially designed record of the animals, dairy cows (lactating and dry), young stock and calves and certain aspects of their respective environments (TecAni), contained 20 variables related to the environment and 14 that were animal-oriented: 9 individual and 5 where the animals were judged as groups. Many of these variables, from TecGen and TecAni, were judged and recorded both from a descriptive and a qualitative aspect, for instance - type of roughage: hay, silage, both or other and the quality of the feed on a scale from 1-3, where 3 was the top score. For definitions of variables and scoring of variables generated by the in-depth study and analyzed in Chapters 4-9, see Appendix 3.

The field study was first tried in the Skara region during 1991 with the aid of one very experienced technician. The experiences made led to some modifications of the study, which was then carried out mainly during the winter of 1992-93, when the animals were permanently stabled. A few visits were made during the winter of 1993-1994, which meant that these farms had, at least, an 8-year observation period.

Table 2. Distribution of low somatic cell count (LC) and high somatic cell count farms (HC) among livestock associations in Sweden (SHS, 1992)

Name of Association	No. of farms in Assoc.	No. of cows in Assoc.	No. of LC farms	No. of HC farms
Skåne	1,277	40,567	7	122
Blekinge-Kronoberg	713	18,607	6	23
Halland	791	22,145	8	61
Skara	2,423	71,874	80	52
S. Älvsborg	513	12,306	8	9
Kalmar	640	21,379	16	15
Tjust	327	11,072	12	7
Gotland	513	13,818	11	15
Östergötland	786	26,923	34	14
Malmen	1,035	35,180	27	11
Uppsala	350	10,286	7	7
Örebro-Värmland	760	23,319	18	6
Dala-Gävle	942	22,194	14	14
NNP	841	17,613	12	14
Västerbotten	689	14,620	3	9
Norrmejerier	345	8,165	9	12

One experienced herd health technician in each of the above-mentioned local livestock associations was selected to conduct the farm studies in his or her region. The technicians were instructed both orally, by the author, and through an extensive written explanation (Appendix 2) of how the records were to be kept, to ensure that the measurements taken and the subjective assessments made were as similar as possible. The instructions included a randomizing table and an explanation on how to use it to select cows within herd. The author kept in touch with the technicians to check on progress of work, difficulties encountered, precision in scoring, use of randomization to select cows, etc.

Each technician was asked to visit a number of LC and HC farms that was proportional both to the total number of farms and to the LC/HC-ratio in that area. Farms were then selected for visits mainly on a convenient sample basis, meaning that the technicians went to those farms that were possible to reach within a normal working day. The technicians did not personally know most of the farms visited however, as the majority of them lay outside their ordinary working area, but they knew what category the farm belonged to. This circumstance had been discussed with the technicians, who were instructed to behave and grade as similarly as possible in spite of this knowledge in order to avoid information bias.

The Questionnaire

During the winter season of 1990-1991 a questionnaire (Q) was designed and tried, by the author (aided by some experienced udder health veterinarians), on ten farmers, 5 LC and 5 HC, and geographically distributed as follows: 3 in Uppland, 3 in Malmen and 4 in Skara. The experiences made resulted in the questionnaire that, together with an envelope, was sent to the farmers selected for the field study by the technician before his/her visit to the farm. The Q contained instructions to the farmer on how to fill it in and an appeal that it should be completed on the day of arrival of the herd health technician. There was also a reward of 300 SEK to all farmers who completed the record satisfactorily. Although not all farms returned their Q on the day of the technician's visit, finally only one, an HC farm, did not return the Q. The questions in the Q covered such subjects as ownership of the farm, marital status of the farmer, number of children and employees, degree of education and experience in farming, management of dairying and of some cattle diseases, as well as reading habits, spare time activities, membership and activities in societies or unions, and attitudes towards dairying and cows.

The questionnaire contained 7 general demographic variables, 13 related to quantity or organization of work, 21 to management of the animals (14 cow and 7 calf oriented; 7 concerned management of disease) and 25 related to conservation of feedstuffs and feeding regimes, including water quality and supply. The Q also comprised a more specific individually oriented part with 27 questions: 8 concerning education and agricultural experience, 10 concerning reading habits and spare time activities, 4 concerning membership and involvement in associations and the like, 9 concerning choice of work, and 7 concerning attitudes towards cows, milking and farming. In the questions regarding attitudes, the farmers were asked to give scores of 1-5, with 5 being the top score or most preferred alternative. The Q (translated and condensed) is added as Appendix 4.

The Interview

The majority of the farms, 31 LC and 19 HC, were also visited by the author. Selection of which farms to visit were made basically on the same premises as described above. The farmer and employees were interviewed regarding their attitudes towards dairying and animal health in general and udder health and udder disease in particular. Initially, the author visited three farms a day, one during the morning and one during the evening milking, and one in the middle of the day. After some visits it was, however, realized that the daytime visits, when the work of the farmer and/or employees during milking could not be studied, was not time well spent. Efforts were made not to disturb the milking process and to concentrate the interview part of the visit to when the milking was finished. The author only took a few notes at the farm, but summarized his impressions on leaving it. The interview, therefore, had the character of free communication. The interviewer always tried, however, to cover certain essential points such as farmer attitudes towards and knowledge about cell count, subclinical and clinical mastitis, preventive measures etc. In order to undramatize the visit the interviewer wore coveralls instead of the usual attire of a Swedish district veterinarian (a water-repellent, raincoat-like coat).

Statistical methods

Data generated in the field study and questionnaire, and presented and discussed in Chapters 4 through 9, were processed in Epi-Info 6 (1994) and Statistix for Windows (1996). LC farms were regarded as cases and HC farms as controls, and coded as 1 and 0, respectively. The data were first analyzed univariably, with type of farm as the dependent variable, to screen for differences between LC and HC farms. Main statistical methods used in the univariable analysis were, for continuous and ordinal variables, ANOVA and Kruskal-Wallis, and for dichotomized variables, Yates corrected and Fisher exact (equivalent to the χ^2 test) (Epi-Info 6, 1994). Only variables with a p-value equal to or less than 0.2 were made available to the multivariable analysis. The multivariable analysis using logistic regression was carried out in Statistix (1996) and the outcome variables, LC and HC farms, were coded 1 and 0, respectively. Variables related to the specific subjects were grouped together and are discussed in different chapters as described in Ch. 1. These variables were first screened for correlations using Pearson's correlation (Statistix, 1996). Only one of the variables with a correlation coefficient higher than 0.6 was included in the logistic regression. The variables thus not introduced into the primary full model were later tried as their correlate was eliminated. The final logistic regression models were developed with a backward stepwise elimination of variables with p-values of > 0.05 based on a χ^2-test of change in deviance. The fit of the final model was evaluated using number of outliers, proportion of overall correctly classified farms and the Wilk-Shapiro index of the Standardized residual (Statistix, 1996). If specific statistical methods have been used in a certain chapter they will be further presented in that chapter. Interactions between variables were not explored due to co-linearity between some variables and because of small sample size (52 LC and 30 HC farms). Validation of the final logistic regression models in the respective chapters, by randomly splitting the sample of farms in half, has, for the same reason, not been done.

Comments on materials and methods

Selection of dairy farms

Regional differences in udder health have been reported from Sweden and other countries (Wilson & Richards, 1980; Barnouin et al., 1986[b]; Vecht et al., 1989; SHS, 1992 & 1997). In Sweden, it has been known for many years that the udder health is better in some parts of the country than in others. Even though the reasons for this have not been scientifically investigated, it has been commonly thought that the higher cell counts seen in Skåne and Halland were due to a number of reasons such as a dominance of the SLB, which, according to several authors (Brolund, 1985; Emanuelson, 1996[b]; SHS, 1996) has a higher cell count than the SRB, differences in feeding regimes with more beet silages and other "high risk" feeds, but also because of differences in how the udder health work has been carried out. It therefore came as no surprise that there were fewer LC and more HC farms in Skåne and Halland as compared with the rest of the country. These specific conditions contributed in the decision to exclude LC and HC farms in these two regions from the study.

The majority of the HC farms were already known to the udder health veterinarians of the local livestock associations. It was their opinion, based on many herd investigations (sometimes several in the same herd), that the udder health problems on the HC farms generally were induced by infections with *Staphylococcus aureus* but also by other "major" grampositive bacteria such as *Sr d* and *Sr u*. This observation indicates that the bacteriological flora on the HC farms probably does not differ from what was normally seen at this time in Sweden when investigating dairy herds with elevated BMSCC. The normal flora of udder pathogens during the observation period 1985-1991 was: *S a*, 31-48 %; CNS, 17-26 %, *Sr d* and *Sr u*, 24-41 %; *Sr a* < 1 %, other pathogens (coliforms, *A p*, etc.) 8-10 % of the bacteriologically positive samples (SHS, 1992).

The Field Study

It would have been better from a scientific point of view to not have allowed the technicians to know the type of farm they were visiting. In other studies with high and low BMSCC, this has not been done either, however (Pearson et al., 1972; Goodhope & Meek, 1980; Le Du et al., 1985; Erskine et al., 1987[a]; Hueston et al., 1987; Hutton et al., 1990; Johannesson, 1994). It was not possible to blind the type of farm since the technicians themselves made the appointments with the farmers. The author and collaborators therefore thought it better to minimize the risk of information bias by making the technicians aware of the problem of different treatments and scoring on the two types of farms. There are no indications that such bias, or more specifically Type 1 errors, disturb the results obtained in this study (see Chapter 9, General discussion).

The Questionnaire

The questionnaire directed at the farmers was rather large, a minimum of 113 questions on 10 pages if only one person was involved. This was the reason for rewarding the farmers with 300 SEK for every well completed Q. The Q was tested rather extensively, as described above, to avoid misinterpretation of questions. Since the author wanted to test the farmers' ability to formulate answers and to make them personally motivate certain actions, it was not possible to have preformed answers of multiple choice type to all questions. Some questions were not filled in by some farmers, however, and some questions were misinterpreted. These farmers were contacted by the author via telephone or at the visit and questionnaires were thus completed and corrected.

The Interview

The visit to the farms by the author served several purposes: 1, to see conditions on farms, management of animals and milking technique at first hand; 2, to try and find a common denominator among LC farmers how they were able to keep cell counts consistently low, 3, to try and trace different scoring of LC and HC farms (information bias); 4, to check scoring to trace possible systematic differences between technicians; and 5, to complete records and questionnaires. Since the visits by the technicians and the author were done on separate occasions and sometimes during different seasons of the year it was neither possible nor meaningful to check every entry by the technicians. The author has focused on conditions of a more stable nature such as general cleanliness and quality of the building and has then noted some discrepancies between score and actual condition. The authors impression is that the technicians generally have been reluctant to use the lowest score, regardless of type of farm. This might lead to an underestimation of differences between farms (Type 2 error). This will be discussed further in Chapter 9.

A questionnaire has limitations in its ability to pick up farmer attitudes, priorities or knowledge. It was therefore decided that the author should interview a representative number of farmers. There are many ways to conduct interviews to obtain information. Muggen (1969) and Seabrook (1984) have reviewed the research on human factors in management of farms and have described some of them. Many other authors also have worked with different interviewing techniques (Bigras-Poulin et al., 1985; Tarabla & Dodd, 1988; Ravel et al., 1996). Many interviewing methods place the farmer in an awkward position where he or she is not comfortable or might feel inferior to the interviewer and therefore might not volunteer valuable information. Most often the questions are formed in advance and are read from a paper or cards. This does not give room for spontaneity or free exchange of information. The interviewee therefore must be made to feel comfortable and secure. Absence of recording devices and paper and pen also helps in creating a relaxed atmosphere. On the other hand, there must be structure in the interview and the interviewer must have a clear idea of what the conversation should cover. He should also record observations as soon as possible after the interview. This way of conducting an interview in mastitis field research has been described by Goodger et al. (1993).

Scoring methods and dichotomizing of variables

The scoring system used in this study was based on the system used by the technicians in their daily work. The scores were thus usually graded from 1 to 3 but sometimes, as for body score, animal cleanness, etc., the scores were 1 to 5. The highest number usually was the best score (an exception from this is, for instance, the body score). Ordinal variables, scored 1-4 or less, cannot be regarded as continuous and therefore in a logistic regression have to be assigned "dummy" variables to be able to be studied. Due to the large number of variables generated in this study, such a procedure would have generated far too many variables. Therefore, ordinal variables scored 1-3 or 1-4 and some continuous variables were dichotomized before being introduced into the logistic regression. The top score, 3 in the 1-3 score and the two top scores in the ordinal scales 1-4 and 1-5, were then given the value 1 and the lower scores the value 0. Ordinal variables scored 1-5 were generally treated as continuous variables. If entries were missing from more than 2 HC or more than 4 LC farms, the variable was dropped from the multivariable analysis. This technique meant that variables with only a few missing values could be included in the logistic regression without introducing Type 1 errors.

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Chapter 3.

Descriptive statistics of disease, production and fertility data

Introduction

Herds with different BMSCC do not only differ with respect to somatic cell count. Factors affecting BMSCC are also likely to have impact on other measures of disease and productivity. In order to describe differences in other aspects as well, an analysis of available official records was performed.

Materials and methods

Disease, production and fertility

The disease, production and fertility data on all LC and HC farms in the selected regions were analyzed (for selection criteria of LC and HC farms see Ch. 2). Farm level data on BMSCC came from the databases of the dairy associations while milk production and disease and fertility data emanate from the Swedish milk recording system kept and run by SHS. The disease frequency data came from the national Swedish animal disease recording system (Emanuelson, 1988) that routinely records the reports of the about 350 Swedish district or large animal field veterinarians. Data emanating from the "control year" 1990-1991 were used in the analyses. A "control year" starts September 1 and ends August 30. The database was cleared of some farms that had not produced milk according to inclusion criteria (7 LC and 6 HC farms), yielding a final set of 250 LC and 202 HC farms.

Statistical methods

The statistical analyses of disease, production and fertility data in this chapter were done using SAS (SAS Institute Inc., 1985). Presence of disease was measured as annual incidence densities (AID), calculated as: (total number of cases/total number of cow-days in herd) x 365 x 100, thus representing the number of cases per 100 cow-years. Actual cow-days at risk were not considered in the calculations, since information on individual animals was not available. AIDs were calculated for veterinary-treated cases of mastitis, trodden teats, milk fever, retained fetal membranes, ketosis, feet disorders, and "other diseases", as well as for culling and udder health class (UHC). UHC is an objective measurement of udder health based on milk samples from individual cows sent to the laboratory as part of the Swedish milk recording scheme (Brolund, 1985 & 1990). UHC are graded 0-9, where each figure indicates a 10 % increase of the probability that the cow has infectious mastitis.

The proportion of stillborn calves, average calving interval, and average number of days from calving to first and last service, were calculated using the total number of calvings as the denominator. Number of artificial inseminations (AI) per service period and proportions of cystic ovaries and heat stimulating treatments were calculated using the total number of service periods as denominator. Average heart girth was measured in cm at the first or second production test after the 1st (in 95% of the cases) or 3rd calving. Milk production was measured as the average yield of kg fat-corrected milk per cow.

Ordinary least-squares analysis of variance, as applied in PROC GLM from SAS (SAS Institute Inc., 1985), was used in order to investigate the relationship between herd type (LC and HC) as independent variables and the continuous dependent variables (calving interval, days from calving to first and last AI, number of AI, heart girth, and milk production).

Associations between herd type as independent variable and the binomially distributed dependent variables, such as mastitis, ketosis, trodden teats, etc., were assessed with logistic regression analysis as applied in PROC CATMOD from SAS (SAS Institute Inc., 1985). Each observation was split into two, coded 0 and 1, and given a weight equal to the number of cow-years (or calvings or service periods) without and with the disease, respectively. The explanatory variables in the models were explicitly coded using the "partial" method (see e.g. Lemeshow & Hosmer, 1984).

The ordinary linear models and the logistic regression models were both developed by backward stepwise elimination (based on the default F- and Wald's-tests, respectively) of non-significant ($p: > 0.05$) two-factor interactions and main effects. The primary full models included the main effects of geographic region, breed composition, level of milk production, herd type, average parity number, and all two-factor interactions. The seven geographic regions represented local livestock associations, grouped according to geographical and/or managerial similarities. Breed composition was a categorical variable with three classes representing the predominant breed on the farm (>80%). The breeds were SRB, SLB and all other combinations (BLB). Level of milk production was categorized into quartiles (Qt1-Qt4), with thresholds 6582, 7154, and 7684 kg, respectively. Average parity (to take the age distribution of the cows into account) also was grouped into quartiles, with thresholds 2.25, 2.48, and 2.72 lactations, respectively.

BMSCC and bovine viral diarrhea virus

In addition to the analyses mentioned above, the sample of LC and HC herds was run against a record containing the results from a national survey of antibodies to bovine viral diarrhea virus (BVDV) in bulk tank milk performed in April in 1993 (Lindberg, 1995). Results from the survey were obtainable for all of the LC and 112 of the HC herds. Originally, candidate explanatory variables were BVD class (concentration of antibodies), average herd size in 1992 and milk production in 1992. In addition, geographical region was available. BVD class expresses the antibody concentration in bulk milk in four levels (undetectable = 0, low = 1, moderate = 2, high = 3) according to the system used in the Swedish control program on BVDV (Alenius et al., 1997). High levels of antibodies to BVDV in bulk milk are predominantly found in herds with recent or currently active infection.

Stepwise logistic regression, using the statistical package Stata, version 5.0 (Stata Corp. Texas, USA), was performed on a full model including farm type (LC/HC) as the dependent variable and BVD class, herd size and milk production as explanatory variables. Interactions tested were herd size/BVD class, and milk production/BVD class, respectively. In addition, the possible confounding effect of geographical region was investigated.

Results

Univariable analysis of LC and HC data

The average and median incidence of treatments of different diseases, milk production, some fertility parameters, herd size, etc., from the LC and HC farms and corresponding values for all farms of similar size in the selected local livestock associations are in Table 3. As can be seen in Table 3, LC farms had, compared with HC farms, higher incidences of all diseases (stillborn calves and trodden teats not regarded as disease), higher milk production, shorter fertility intervals, and more inseminations per service period. The cows on LC farms were smaller (but larger than the association average) of about the same age as cows on HC farms. LC herds were smaller than HC herds. Some of these incidences can be expected to be influenced by confounding factors such as breed, region, production level and parity. As can be seen in Table 4, the distribution of breeds on LC and HC farms was statistically significantly different. Two-thirds of the LC farms were pure-bred (> 80 % of the breed in question on a farm) SRB farms, whereas mixed herds constituted the largest group (48 %) of the HC farms. The SLB was the dominating breed on 38 % of the HC farms. The SRB breed, during the control year 1990-1991, constituted 54.3 % and the SLB 38.6 % of the cows in Sweden.

Table 3. Mean/median incidence of treatments of disease and mean of fertility parameters, milk production and herd size of low cell count (LC) and high cell count dairy farms (HC) and corresponding figures from the selected local livestock associations

Variable*	Type of farm: LC (250)	Type of farm: HC (202)	Associations
Stillborn calves, AID**	3.4/3.1	4.3/3.6	3.9/3.6
Cystic ovaries, AID	3.8/2.7	1.3/ 0	2.7/1.1
Heat stimulation, AID	5.8/3.6	3.9/ 0	5.0/2.7
Milk fever (Paresis puerp), AID	7.1/5.5	5.2/4.2	6.5/5.3
Retained fetal membranes, AID	4.9/4.0	4.5/3.4	4.6/3.8
Ketosis, AID	5.0/3.0	2.6/ 0	4.1/0
Mastitis, AID	19.4/17.6	16.5/12.3	19.5/16.7
Trodden teats, AID	4.2/0	4.2/2.5	4.4/3.1
Feet disorders, AID	3.5/0	2.0/0	2.8/0
Other diseases, AID	10.5/7.7	6.5/5.1	8.7/6.3
Culling, %	38.0/38.0	39.6/38.7	40.1/36.1
Milk production, kg	7432	6634	7034
Calf-to-calf interval, d	381	393	387
Calving to 1. AI, d	81	90	83
Calving to last AI, d	107	118	111
Inseminations / service	1.64	1.59	1.65
Heart girth, cm	189	191	186
Average lactation number	2.51	2.54	2.53
Mean no. of cows/herd,	28.8	36.8	33.0

* Production, fertility, etc. parameters on the lower half of the table are shown with means only since the mean and median for these parameters were very similar.

** AID: annual incidence density - number of cases/100 cowyears at risk.

Table 4. Distribution of breeds on 250 LC and 202 HC farms. Numbers in parenthesis are %. χ^2: 68.5 and p-value: << 0.001

	Type of farm: LC	Type of farm: HC
Farms with SRB	170 (68)	28 (14)
Farms with SLB	10 (4)	77 (38)
Farms with mixed herds	70 (28)	97 (48)

Multivariable analysis of LC and HC data

Significant interactions between farm type and other explanatory variables were found for several of the dependent variables. The interactions between farm type and region were deemed not biologically interesting or plausible and will not be discussed further. Since differences between LC and HC farms were the principal interest in this study only those results will be presented. Tables 5 a and b show results where herd type proved to be significant.

There was a statistically significant difference in treatment of mastitis and "other diseases" (various diseases with low incidences; SHS, 1992) with higher incidences for all breeds on the LC farms.

The level of milk production showed an interaction with farm type for some of the disease incidences, whereby the differences disappeared in the highest production quartile (Qt 4). This concerned mastitis and "other diseases", where the incidence is lower on the HC farms than on the LC farms in all Qts except the highest. Ketosis shows a similar trend, but with a higher treatment incidence on HC farms in the three lower Qts, although the lowest quartile marginally includes 1. Only the incidence for "trodden teats" shows a reverse pattern with no significant differences in the lower Qts and a higher incidence in the top production quartile on the HC farms.

The treatment incidence of clinical mastitis was statistically significantly higher on LC farms than on HC farms (Figure 1 and Table 5 a). The risk of having a cow with subclinical mastitis (UHC 6-9) was greater on HC farms for all breeds and production levels, with odds ratios ranging from 5.54 to 8.07 (Figure 2 and Table 5 a).

The culling of cows on HC-SRB farms was lower than on LC-SRB farms, whereas the culling of cows on HC-SLB and mixed breed (BLB) farms was marginally and significantly higher, respectively.

The results of the analysis of the association between milk production, herd size, the fertility variables CFI, CLI, CCI, & INS/SER and farm type are in Table 6. Only for INS/SER was there any interaction with any of the confounders and farm type, and only in the two higher production quartiles were there any statistically significant or near significant differences between LC and HC farms.

Table 5 a. Odds ratios and confidence intervals of mastitis-related disease incidences on low cell count (LC) and high cell count (HC) farms, estimated with logistic regression, according to breed and production quartiles. If breed or production quartile is not stated for a disease the logistic regression did not demonstrate a significant interaction with herd type

Disease or diagnosis	Breed[1] Prod. Quartiles[2]	More (>) or less (<) on HC compared with LC	Odds ratio	Confidence interval
Mastitis, treatment incidence	SRB	<	0.55	0.44-0.69
	SLB	<	0.75	0.64-0.87
	BLB	<	0.76	0.65-0.88
	Qt1	<	0.57	0.48-0.66
	Qt2	<	0.62	0.52-0.74
	Qt3	<	0.69	0.56-0.85
	Qt4	NS	0.87	0.71-1.07
Trodden teats	Qt1	NS	0.79	0.63-1.01
	Qt2	NS	0.81	0.61-1.09
	Qt3	NS	1.24	0.91-1.70
	Qt4	>	1.37	1.00-1.88
Percentage of cows in udder health class 6-9	SRB	>	6.01	4.97-7.26
	SLB	>	6.85	5.82-8.06
	BLB	>	6.68	5.68-7.85
	Qt1	>	5.54	4.62-6.37
	Qt2	>	5.87	4.94-6.97
	Qt3	>	8.07	6.66-9.77
	Qt4	>	6.94	5.71-8.44

[1] SRB: Herd with Swedish Red, SLB: Herd with Swedish Friesian, BLB: Mixed breed herd

[2] Production levels between quartiles: 6582, 7154, and 7684 kg

Table 5 b. Odds ratios and confidence intervals of disease incidences on low cell count (LC) and high cell count (HC) farms, estimated with logistic regression, for breed and milk production in quartiles. If breed or production quartile is not stated for a disease or measure the logistic regression did not demonstrate a significant interaction with herd type

Disease, treatment or measure	Breed[1] Prod Quartiles[2]	More (>) or less (<) on HC compared with LC	Odds ratio	Confidence interval
Cystic ovaries	SRB	NS	1.34	0.83- 2.18
	SLB	<	0.55	0.35-0.85
	BLB	<	0.62	0.40-0.95
Heat stimulation	SRB	>	1.92	1.39-2.64
	SLB	<	0.69	0.51-0.93
	BLB	<	0.61	0.46-0.82
	Qt1	NS	0.86	0.64-1.15
	Qt2	<	0.59	0.42-0.82
	Qt3	NS	1.02	0.73-1.43
	Qt4	>	1.47	1.06-2.04
Feet disorders	SRB	<	0.46	0.26-0.79
	SLB	<	0.53	0.36-0.77
	BLB	NS	0.87	0.63-1.21
	Qt1	<	0.35	0.24-0.51
	Qt2	<	0.50	0.33-0.76
	Qt3	NS	0.84	0.54-1.30
	Qt4	NS	0.86	0.54-1.37
Ketosis	SRB	>	1.62	1.40-1.87
	SLB	NS	0.95	0.57-1.60
	BLB	>	1.27	1.10-1.50
	Qt1	NS (>)	1.25	0.96-1.64
	Qt2	>	1.38	1.10-1.76
	Qt3	>	1.31	1.04-1.65
	Qt4	NS	1.10	0.85-1.35
Other diseases	SRB	<	0.66	0.49-0.90
	SLB	<	0.65	0.52-0.82
	BLB	<	0.62	0.50-0.78
	Qt1	<	0.51	0.41-0.64
	Qt2	<	0.58	0.45-0.75
	Qt3	<	0.63	0.47-0.85
	Qt4	NS	0.93	0.70-1.23
Culling	SRB	<	0.78	0.66-0.92
	SLB	NS (>)	1.11	0.98-1.26
	BLB	>	1.15	1.02-1.30

Table 5 b, continued

[1] SRB: Herd with Swedish Red, SLB: Herd with Swedish Friesian, BLB: Mixed breed herd

[2] Production levels between quartiles: 6582, 7154, and 7684 kg

Table 6. Differences in fertility parameters, milk yield, average lactation number and herd size between low cell count (LC) and high cell count (HC) farms, estimated with analysis of variance and presented as least square means

Variable		Type of farm LC	HC	p-value
Ins. / service period[1]	Qt1[2]	1.57	1.52	> 0.10
	Qt2	1.60	1.57	> 0.10
	Qt3	1.58	1.69	0.09
	Qt4	1.62	1.79	0.006
Calf-to-calf interval, d		381	393	<< 0.001
Calving to 1. AI, d		81	90	<< 0.001
Calving to last AI, d		107	118	<< 0.001
Milk production, kg		7,536	6,640	<< 0.001
Average lactation number		2.51	2.54	> 0.10
Mean no. of cows/herd,		28.8	36.8	<< 0.001

[1] Only INS/SER showed an interaction between level of milk production and farm type.

[2] Production levels between quartiles: 6,582; 7,154; and 7,684 kg

Effects of BVDV on BMSCC

There was a statistically significant difference between the two types of farms regarding level of antibodies against BVDV, showing that the HC farms were 3 times more likely to have had high titres of antibodies in the 1993 survey (confidence interval: 1.26-7.11), at any given level of the other variables (herd size and milk yield). If area was introduced into the model, however, the difference disappeared and BVDV-status became statistically non-significantly different between the two types of farms (p= 0.11). All variables in the full model had a significant effect ($p < 0.05$) according to Wald's test. None of the interactions tested were significant.

Discussion of descriptive statistics

When one tries to analyze differences between these two types of farms - both differences of disease incidence and the managerial differences - one must bear in mind that this material comprises the endpoints of dairy farmers in Sweden at least as far as udder health, as measured by BMSCC, is concerned. The LC farmers have managed to have low cell counts for a period of seven years or more and the HC farmers have done the same at their end of the scale. This result is not accidental but is the result of the owner's priorities and work for several years. Farmer characteristics, management decisions and strategies will be discussed in following chapters. There is, however, also a large variation both regarding incidence of treatment and prevalence of mastitis, as can be seen in Figures 1 and 2. During the control year 1990/91, ten percent of the HC farmers did not have a veterinarian to treat a single case of mastitis, while the highest incidence of treated cows on a single farm was over 95 cases/100 cowyears at risk. The corresponding figure for LC farms was 66.7. The AIDs at the 90th percentile were rather similar, however, or 39.3 and 38.5 for LC and HC farms, respectively. Part of the difference in incidence of mastitis treatment reflects management practices rather than true differences in incidence of disease.

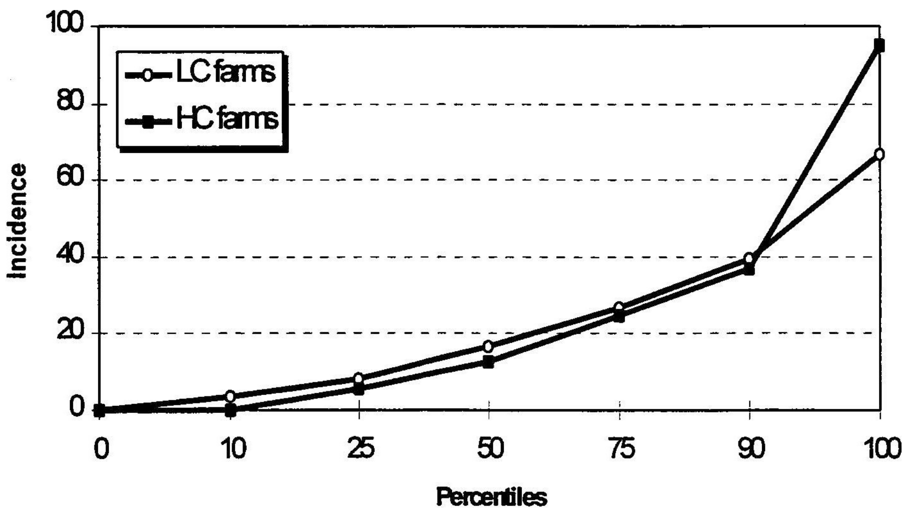

Figure 1. Incidence (cases/100 cowyears at risk) of treatments of mastitis on low cell count (LC) and high cell count (HC) farms.

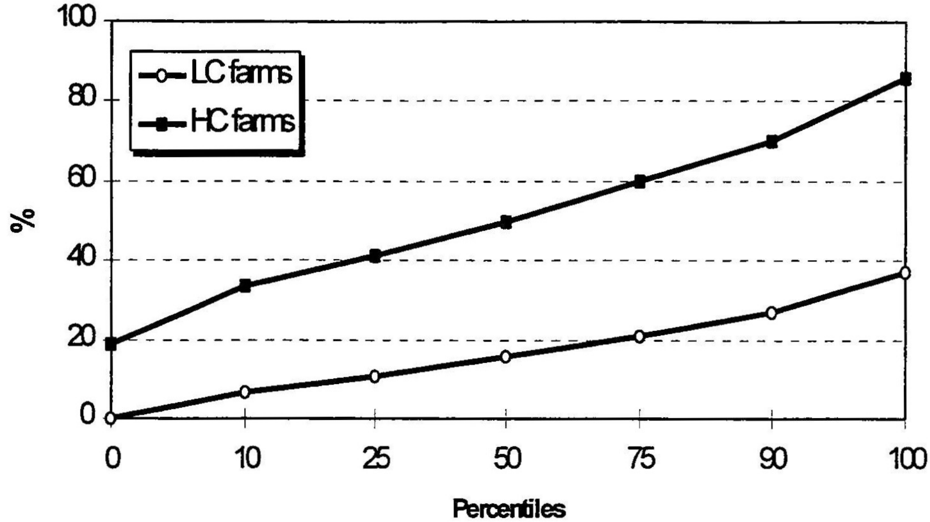

Figure 2. Percent cows / herd with udder health class 6-9 (60 -90 percent chance/risk of infectious mastitis) on low cell count (LC) and high cell count (HC) farms.

Risk or chance of treatment of disease

The figures on disease incidence in Table 3 and Figure 1 can not be regarded as giving the true incidence of a certain disease of cattle in Sweden but give an indication of the incidence of treatments of different diseases. From the moment a cow contracts a disease until she becomes a figure in the national statistics there are many steps and some of the more important relate to management on the farm. First of all the farmer has to recognize that the cow is ill, which then has to lead to a decision on his part to call a veterinarian or perform some other act, such as culling or treating. If a veterinarian is called to the case, he/she then has to report the case to the proper database. It is reasonable to regard these incidences as not only a risk of being ill but also that cows on certain farms have a greater chance of being treated. This is definitely true for "diseases" such as lack of oestrus, which, in Sweden, is a diagnosis linked to a treatment for stimulation of heat, or mastitis. For other diseases such as milk fever (Paresis puerperalis), that do not allow as much choice of "to treat or not to treat" on the farmer's part, no statistically significant differences between LC and HC farms were detected in this study.

The disease incidences are calculated as annual incidence densities as described above. Since no data were available on individual cows it was not possible to adjust assessments of the respective AIDs to duration of disease or repeated periods of disease. This might lead to an underestimation of AID, especially for diseases, such as mastitis or ketosis, that are associated with greater risks of recurring during lactation. The level of underestimation (or possibly overestimation) should, however, apply equally to the two types of farms, which means that the comparison in AID between them should not be significantly affected.

The total culling rate on LC farms is not statistically significantly different from culling rates on HC farms or the average association farm. This may indicate that culling is not the major strategy to keep BMSCC low at the LC farms.

Multivariable analysis

Breed traits, region, production level and lactation number can be expected to influence the differences seen in disease incidence and fertility parameters (Østergaard, 1980, Lindström et al., 1981; Eberhart et al., 1982; Jones et al., 1984; Bendixen, 1988; Schukken, 1990[a]; Deluyker et al., 1993). Multivariable analyses - linear and logistic regressions - were therefore used in order to adjust for possible confounding variables.

Fertility parameters

Fertility parameters are generally regarded as good indicators of management (Esslemont, 1974; Barr, 1975; Jansson, 1980). In this study, the fertility parameters CFI, CLI, CCI & INS/SER are all highly statistically significantly different between LC and HC farms, with longer time spans and more inseminations, at least in the highest production quartile, on the HC farms (Table 6). This indicates a less than optimal management of these farms. One may speculate as to the reason for the numerically lower values for INS/SER in the lower two production Qts on HC farms. One reason might be that it is easier to get the cows pregnant with lower production demands, but then that should apply equally to the LC farms. Another possibility is that the HC farmers simply do not perform pregnancy checks. This is not improbable, especially when considering that the national average INS/SER was 1.76 (SHS, 1992). It would be difficult to accept that the HC farmers were significantly better in this aspect of fertility when they were significantly worse in all the others.

Of the disease-related fertility parameters, "cystic ovaries" and "heat stimulation" showed a difference between breeds. HC farms with SLB or BLB had fewer treatments for cystic ovaries than LC farms. HC-SRB-farms had a higher incidence of treatment for lack of oestrus, which is the only fertility parameter where there is a higher incidence, or a greater chance, of being treated for a fertility ailment on HC farms. Historically, the SRB cow has not had such clear oestrus signs as the SLB (Jansson, 1980; SHS, 1992 & 1997), which might have influenced the HC farmers or it might be possible that the lower feeding intensity, mirrored by the lower production, causes more anoestrus or silent heats in SRB-HC herds.

Disease incidences

Breed traits are known to influence disease. Thus Bendixen (1988), when investigating risk factors for different diseases in Swedish dairy cattle, showed that the SRB has a higher risk of contracting parturient paresis and ketosis and the SLB is at greater risk of getting retained placenta, mastitis and trodden teats. Ekesbo (1966), Lindström et al. (1981), Brolund (1985) and Emanuelson (1988 & 1996[b]) have shown that the SLB is more prone to contracting subclinical and clinical mastitis, and Schukken (1990[b]) has reported that the red Dutch cow has a higher incidence of mastitis than the Dutch Friesian cow. Differences in disease incidence between HC and LC farms due to breed are listed in Tables 5 a and b. It is noteworthy that the incidences are lower on the HC farms for all diseases except ketosis. From other studies of disease incidence in Sweden, it is known that the incidence of many diseases, mastitis being one of them, is directly related to BMSCC when all farms are sampled (Emanuelson, 1996[a]). For the HC farms in this study that does not apply, which indicates that management of, and attendance to, sick animals was less than optimal and definitely not as good as on the LC farms. As regards ketosis, it appears to be the one exception from the rule, at least for SRB and BLB herds. One explanation might be that - since the feeding regimes and the quality of feed on the HC farms also are suboptimal (Chapter 5) - the cows on HC farms do not eat as well as LC cows and hence contract more ketosis. Since a cow that does not eat does not produce, the farmers on HC farms are "forced" to call for veterinary help to remedy the ailment.

Levels of Milk Production

Incidence of clinical mastitis is positively related to level of milk production (Bakken, 1982; Barnouin et al., 1986[b]; Schukken et al., 1990[b]; Emanuelson, 1996[a]). Since the LC farms have significantly higher milk production, the higher incidence in treatments for clinical mastitis is plausible, although contradicted by the observation that treatments increase in response to rising BMSCC (Emanuelson, 1996[a]). In this study, the difference remains after correction for level of milk production, which indicates that the LC farmers call for a veterinarian to treat cases of mastitis more often than the HC farmers. This extra attention, contact with veterinarians and attendance of cows, indicate better management on LC farms. In this context, it should be noted that the LC farms do not have a higher treatment incidence of mastitis than the average for the local livestock association (Table 3).

As was the case regarding influence of breed, the incidences of all diseases except ketosis were lower on the HC than on the LC farms when the results were related to production (Table 5 a and b). However, regarding ketosis and claw disorders this does not apply for all production levels. The differences disappear (become non-significant) in the highest (regarding ketosis) or two highest (regarding claw disorders) production levels. This indicates that with increasing demands on management to achieve higher milk production, some managerial differences between LC and HC farms disappear.

Trodden teats are more common on HC farms in the highest producing quartile. Trodden teats is not a disease, even though it frequently leads to mastitis (Bendixen, 1988), but is, among other things, an effect of insufficient bedding (Ekesbo, 1966; Lindström, 1983; Miller & Bartlett, 1991) and is therefore an indication of less than optimal management on the HC farms.

Incidence of subclinical mastitis and culling

Although some authors (Hogan et al., 1988; Emanuelson, 1996[a]) have found a direct relationship between BMSCC and incidence of clinical mastitis on the herd or national level, respectively, other authors have come to the opposite conclusion (Booth, 1995). Others report an inverse relationship between BMSCC and incidence of clinical mastitis on the farm level (Jasper et al., 1975; Eberhart & Buckalew, 1977; Marr, 1978; Erskine et al., 1988; Hoblet et al., 1988). Different etiologies of clinical and subclinical mastitis (as measured by SCC or CMT) have been demonstrated by several authors (Lindström, 1983; Barnouin et al. 1986[b-c]; Østerås, 1990; Bartlett et al., 1992[a & c]). The occurrence, in this study, of a lower incidence of cows with high UHC on LC farms concurrently with a significantly higher incidence of treatments for mastitis and a higher milk yield, is in accordance with Bakken (1982), who, in a study of 328 Norwegian tie stall dairy farms, came to a similar result.

The incidence of cows with UHC 6-9, *i.e.* they have a 60-99 percent probability of having infectious mastitis (Brolund, 1985 & 1990), was statistically significantly higher for all breeds and on all production levels on the HC farms. The method of selection of farms would have been a failure if this had not been the case. The placing of a cow in an UHC is an objective assessment of her udder health, based on the analysis of milk samples that the farmers send to the laboratory (Brolund, 1990). The incidence of cows with high UHC is therefore a better and more objective measurement of udder disease than treatment incidence and one that is better correlated with BMSCC.

As can be seen in Figure 2, there is fairly big variation regarding incidence of cows with high UHC within the two types of farms, with some degree of overlapping. The incidence of cows with high UHC on LC farms varies from 0 % to

37 % and on HC farms from 19 to 86 %. It is obvious that the risk of new IMI increases if, on average, 50 % of the cows have high udder health classes as compared with 16 %. The overlap between the two groups is more intriguing, however. How can it be that about 25 % of the LC farms have more than 20 % (20.8 - 37 %) of their cows in the high UHC and still manage to remain LC farms? And how can 10 % of the HC farms have less than 33 % of the cows in UHC 6-9 and remain HC farms? The main reason must be managerial measures that compensate for the increased risk of spreading or maintaining infections on the LC farms with high incidence of cows with high UHC or the lack of such measures on the HC farms. The prompt treatment of clinical cases of mastitis is one such action (Dodd et al., 1969; Dodd & Neave, 1970). Other differences in management leading to these effects on BMSCC and incidence of high UHC will be discussed in Ch. 4-9.

In the multivariable analysis there was no statistically significant difference as regards overall culling rate between LC and HC farms related to level of production. This again indicates that culling is not the major strategy to keep BMSCC low at the LC farms.

Effects of BVDV on BMSCC

BVDV infection causes a herd syndrome characterized to a significant extent by its effect on reproduction. The virus has also been shown to induce immunosuppression which may be involved in the general unthriftyness seen among calves and young stock, effects on growth-rate, and in the increased incidence of infectious diseases seen in affected herds (Meyling et al., 1990). High levels of antibodies in bulk tank milk indicate recent or current infection, whereas undetectable or low levels show that the herd has not been exposed to the virus for approximately 3 years (Lindberg & Alenius, 1997). If BVDV infection contributes to the impaired udder health on HC farms it may be expected that HC herds are more likely to be found in BVD class 3 than LC herds, which was also the case in the initial model. However, when geographical region was introduced, this association was no longer statistically significant. Thus area appears to be a classic confounder, associated both with the risk of having BVDV and of being an HC farm. It is well known that the prevalence of BVDV is highly associated with geographic region, with the highest incidence and prevalence in south-east Sweden at the time of the survey (Lindberg, 1995). There was no association between area and incidence of cows with UHC in the LC/HC material, however. It should also be noted that the overlap in time between the 1993 BVDV-survey and the observation period of BMSCC on LC and HC farms only concerns the last 1.5 years of the latter. We do not know how long herds in BVD class 3 in 1993 have been infected, only that they have had an active infection during some period in the 2-3 years preceding the survey. Furthermore, it was not possible to evaluate the effects of management on level of infection with the data available. It is not unlikely that the personality profiles of farmers having persistently high BMSCC and high BVDV herd titres are similar. Based on this material it can not be concluded that the udder health situation on the HC farms was influenced significantly by infection with BVDV.

It was not possible to check the LC and HC farms against a record of incidence of Bovine leucosis virus (BLV) because no national tank milk survey for BLV was done at a suitable time with respect to the recording period for the farms studied.

Conclusions

LC herds are smaller than HC herds and the milk production/cow is higher on LC than on HC farms. Generally there are higher AID of treatments on LC farms. Differences in AID between LC and HC farms indicate differences in quality of management. Level of milk production affects AID of treatments such that the differences disappear or decrease at the highest levels of milk production. Some differences in quality of management remain even in the highest milk production quartile as indicated by number of inseminations/service period. The incidence of cows with subclinical mastitis, as indicated by UHC, is statistically significantly higher on HC than on LC farms.

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Chapter 4.

Environmental factors affecting udder health

Introduction

In the Nordic countries, Ekesbo in Sweden (1966), Bratlie (1966), Bakken (1981 & 1982), Simensen (1974 & 1981[a]) and Østerås & Lund (1988[a]) in Norway, Saloniemi (1980) and Lindström (1983) in Finland, Schmidt-Madsen (1978) in Denmark, and Johannesson (1994) on Iceland have published investigations demonstrating effects of various environmental factors on udder health. Many other studies also indicate influences of environment on udder health (Grommers et al., 1972; Pearson et al., 1972; Goodhope & Meek, 1980; Le Du et al., 1985; Barnouin et al., 1986[b-c]; Hutton et al., 1990; Schukken, 1990[a]; Howard et al., 1991; Miller & Bartlett, 1991; Bartlett et al., 1992[a]). Implicated environmental factors related to housing range from the amount of light 30 cm above the barn floor (Johannesson, 1994) through the amount, kind of, or cleanness of, bedding (Le Du et al., 1985; Barnouin et al., 1986; Hutton et al., 1990; Schukken, 1990[a]; Howard et al., 1991; Miller & Bartlett, 1991; Bartlett et al., 1992[a]), to the width and length of stalls and presence or absence of insulating windows (Grommers et al., 1972; Bakken 1982; Østerås & Lund, 1988[a]). External factors (outside buildings) that have been shown to influence udder health are, for example, the amount of rainfall and temperature during summer (Simensen, 1974; Barnouin et al., 1986[c]) and the conditions on pasture or in holding areas (Barnouin et al., 1986[c], Bartlett et al., 1992[c]; Hillerton et al., 1995).

Housing conditions are subject to change. The early works by Ekesbo (1966), Grommers et al. (1972), Karlsson & Gustafsson (1978), Schmidt-Madsen (1978), Bakken (1978) and Saloniemi (1980) clearly demonstrated the adverse effects of open manure gutters with grids and electrical cow trainers but also the effects of other physical factors such as stall length and width, presence or absence of partitions, amount of litter in the stall and type and amount of play in the neck tie, etc. This led to technical solutions, that did not take basic or behavioral needs of animals into consideration, being prohibited in new stalls and hence the physical environment surrounding the cow has gradually improved. One indication of this is that Østerås (1990), when investigating risk factors for udder health on 676 randomly selected Norwegian dairy farms, could not identify a single "traditional" stall constructional risk factor. Only management-related variables, such as clipping of haircoat, trimming of claws, having a night light, etc., appeared as explanatory variables.

The aim of the present chapter is to identify environmental factors related to the physical surroundings of the cow, such as barn and stall construction, amount and quality of bedding, ventilation etc., that might adversely affect udder health, as measured by BMSCC.

Material and methods

The results in this chapter are based on data from 52 LC and 30 HC farms and collected by the technicians on the records described in Chapter 2, Materials and methods.

A total of 49 variables were selected from the records, TecGen and TecAni, and included in the analysis. One of the management-oriented variables - DipTeat - from the milking technique record (TecMiT) was also included in the analysis in this chapter. Dipping of teats was, in light of the research by Schukken (1990[a]) and Lam (1996[a]), considered to be part of the environment.

The data were first analyzed univariably, with type of farm as the dependent variable, to screen for differences between LC and HC farms. The statistically significant (p-value: ≤ 0.2), environmentally related variables in Table 7, were then included in a stepwise, backward elimination logistic regression (Statistixs, 1996), again with type of farm as the dependent variable. The 3 or 4 scored variables were dichotomized as described in Ch. 2. In this process one variable - the score for the stalls/barns of the young stock - shifted from being marginally significant to non-significant. A more extensive description of the statistical analysis is given in Chapter 2.

Results

Univariable analysis

Results of the univariable analysis are shown in Table 7. Variables, type of variable, type of statistical test, p-values and indication of odds of being an LC or an HC farm are included in the table. The variables have been translated from their abbreviated Swedish form into English.

General aspects of barn

The records of the technicians detected a difference regarding the number (CowNum, Table 7) and breed of cows in the barns on the two types of farms. The HC farmers kept significantly more cows of the SLB or mixed breeds than the LC farmers.

There was a tendency for the barn to be kept in better condition at the LC farms: 69 % of the LC barns received the top score of 3, vs. 53 % of the HC barns; 10 % of the HC barns received the lowest score as compared with 3.8 % of the LC farms (BarnStatus, p: 0.09).

There was no difference between the two types of farms regarding whether it was run by an owner-farmer or a tenant-farmer, or as to what year the barn was built (Ownership, BarnBuildingYear). The average year for building or doing a major renovation of the barn was 1970 for the LC and 1967 for the HC farms. In both groups, there was one farm with no major change since 1901. Four LC and 2 HC barns had been renovated in 1990-1992.

Table 7. Results of the univariable analysis of variables related to environment. Abbreviations are explained at the bottom of the table

Variables*:		
Statistically significant	**0.05 < p-values ≤ 0.20**	**Statistically NS**
General		
CowNum, ct, KW: 0.007, -	BarnStatus, 3 sc, KW: 0.09, +	Ownership
SRB, dc, Yc: << 0.001, +		OtherAnimals
SLB, dc, Yc: << 0.001, -		BarnBuildingYear
Indoor climate		
Daylight, 3 sc, KW: 0.03, +	Insulation, 3 sc, KW: 0.14, +	Artlight, Nightlight
	NoDraft, 3 sc, KW: 0.2, +	Lightscore
		Airin, Airout
		Ventscore
		Humidity
		Climatescore
		NH_3-good, -bad
Properties of stall, etc.		CO_2-good, -bad
Stallnotslipp, dc, Yc: 0.008, +	Urinedrain, 3 sc, KW: 0.06, +	Stallength, -width
Rubbermats, dc, Yc: < 0.001, +	YStie, dc, Yc: 0.1, +	Stallpercent
Strawamount, 3 sc, KW: < 0.001, +	YSstallscore, 4 sc, KW: 0.19, +	Stalltype
Strawbedding, dc, Fe: 0.02, +	Calfbarn, dc, Yc: 0.16, -	Tietype, Frontgate
Drycowstall, 4 sc, KW: 0.02, +	Waterbowls, 3 sc, KW: 0.10, +	Stallpartitions
Calfstallscore, 4 sc, KW: 0.025, +		Manureout
Milkingorder, 3 sc, KW: <<0.001, +		YSbarn, -pen
DipTeat, dc, Yc: < 0.001, +		YSslattfloor
Faultnum: ct, KW: << 0.001, -		Calftie
		Calfpen

* Variables with p-values ≤ 0.2 are described in Appendix 3.

Abbreviations used in Table 7: + : indicates increased odds of being an LC farm, -: indicates increased odds of being an HC farm, ANOVA: analysis of variance, artlight: artificial light, ct: continuous , dc: dichotomous, Fe: Fisher exact test, KW: Kruskal-Wallis, num: number, sc: score, Yc: Yates corrected, YS: young stock

Ventilation, insulation and light

More daylight could enter through the windows on LC farms than on HC farms (Table 7). This was the only climatic factor that was statistically significantly different between the two types of farms. Insulation and NoDraft were different on the 20 % level, with p-values of 0.14 and 0.2 respectively. The amount of artificial light, having a light on at night, amount of air let in or out by the ventilation system and signs of humidity on walls or windows were not significantly different.

The technicians were instructed to measure the concentrations of ammonia (NH_3) and carbon-dioxide (CO_2) at the two places in the barn that they subjectively felt had the best and the worst quality of air (see Appendix 2). There was, over all, a statistically significant difference between these two measurements (p: << 0.001). There was no difference between LC and HC farms, however. The mean, median and range of measurements for NH_3 and CO_2 can be seen in Table 8.

Table 8. Mean and range for measurements, in PPM, of NH_3 and CO_2 on LC and HC farms

	NH_3-best		NH_3-worst[1]	
Type of farm	LC	HC	LC	HC
Mean, PPM	4.2[a*]	3.6[a]	6.4[b]	6.5[b]
Range, PPM	0.0-11.0	0.2-12.0	0.8-15.0	1.0-17.0

	CO_2-best		CO_2-worst[1]	
Type of farm	LC	HC	LC	HC
Mean, PPM	1,118[c]	1,177[c]	1,645[d]	1,708[d]
Range, PPM	100-2,400	300-2,000	100-3,500	300-3,700

* a statistically significantly different from b; c statistically significantly different from d; *aa*: p: << 0.001.

[1] The upper legal limits in Sweden for NH_3 and CO_2 in barn air are 10 PPM and 3,000 PPM, respectively.

Stalls: size, construction, bedding and cleanness

Nine variables on the TecGen record concerned stall size, construction and condition. Of these only two, the nonslipperiness of the floor and the surface of the stall, *i.e.* whether rubber mats were installed or not, came out statistically significantly different, increasing the odds of being an LC farm (Table 7). Neither the width nor the length of the stalls were different between the two types of farms (Tables 7 and 9). None of the variables: type of front gate, type of stall, construction of tie or presence or absence of partitions between every second stall were different. Nineteen (36.5 %) of the LC and fourteen (46.7 %) of the HC farmers had short stalls. The difference was not statistically significant. Only one farm, an LC, had a cubicle housing system. All the rest were longbed tie-stalls with a front gate.

The technicians assigned 4 point scores, where 4 was the top score, to the quality, cleanness and suitability of the stalls for dry cows, young stock and calves in accordance with the specially designed record, TecAni, described in Chapter 2. The dry cow and calf stalls scored statistically significantly higher on the LC farms. There was a trend (p: 0.19) towards the same effect regarding the stalls of the young stock (Table 10).

Table 9. Mean and range for stall measurement variables at LC and HC farms. No statistically significant differences was found between farms

	Type of farm			
	LC		HC	
Variable	Mean	Range	Mean	Range
Stall length, long stall, cm	216.8	200-230	215.4	200-220
Stall length, short stall, cm	170.8	150-185	170.5	160-180
Stall width, cm	115.7	100-120	115.1	100-120
Stall area, % of norm*.	95.2	77-113	94.6	76-103

* According to the Swedish animal welfare law (SJVFS, 1993); longbed: 220X120 cm; shortbed: 170X120 cm.

Table 10. Quality, cleanness and suitability of the stalls for the dry cows, the young stock and the calves. For type of statistical test and p-values see Table 7

Stalls of		Dry cows		Young stock		Calves	
		Type of farm					
		LC	HC	LC	HC	LC	HC
Percent score:	1	8.5^{a*}	16.0^{b*}	0.0	3.0	0.0^{a}	10.0^{b}
	2	17.0^{a}	36.0^{b}	19.6	17.8	21.1^{a}	33.3^{b}
	3	70.2^{a}	48.0^{b}	52.9	53.6	69.2^{a}	50.0^{b}
	4	4.2^{a}	0.0^{b}	27.4	17.8	9.6^{a}	6.7^{b}

* series a and b statistically significantly different, p: ≤ 0.025.

According to the judgment of the technicians, the LC farmers used significantly more bedding of better quality - Strawamount - than the HC farmers. The LC farmers also used straw instead of sawdust to a higher extent (Strawbedding, p: 0.02, Tables 7 and 11).

Tying the recruitment heifers was more common on LC farms even if the difference was not statistically significant (YStie, p: 0.10, Table 7). There were no differences between the two types of farms regarding keeping recruitment heifers in a separate barn, keeping them together in pens or on slatted floors, neither were there any differences as to the practice of tying up calves or keeping them together in pens. There was a weak tendency that more HC farmers kept their calves in a separate barn (Calfbarn, p: 0.16, Table 7).

There was a strong trend that the effectiveness of the urine drainage system was better on LC than on HC farms (Urinedrain, p: 0.06, Table 7). There was no difference as regards the handling or function of the manure system.

Management related and miscellaneous variables

It was statistically significantly more common that the LC farmers arranged the milking cows according to some udder health parameter, such as SCC or UHC, and that they dipped the teats after milking (Milkingorder, p: << 0.001, DipTeat,

Table 11. Distribution of LC and HC farms as regards statistically significantly different, environmentally related variables. 3 is the top score

Variable	Type of farm	Percent score 1	2	3
Daylight	LC	5.8^{a}	23.1^{a}	71.0^{a}
	HC	10.0^{b}	43.0^{b}	47.0^{b}
Stallnotslipp	LC	0.0^{c}	7.7^{c}	92.3^{c}
	HC	6.7^{d}	26.7^{d}	66.7^{d}
Strawamount	LC	0.0^{e}	15.4^{e}	84.6^{e}
	HC	23.3^{f}	26.7^{f}	50.0^{f}
Milkingorder	LC	17.3^{e}	13.5^{e}	53.8^{e}
	HC	56.7^{f}	23.3^{f}	10.0^{f}
		Percent Yes	**No**	
Rubbermats	LC	55.8^{e}	44.2^{e}	
	HC	16.7^{f}	83.3^{f}	
Strawbedding	LC	98.1^{a}	1.9^{a}	
	HC	83.3^{b}	16.7^{b}	
DipTeat	LC	88.5^{e}	11.5^{e}	
	HC	53.3^{f}	46.7^{f}	

* series a and b - p: < 0.05, c and d - p: < 0.01, e and f - p: < 0.001.

p: < 0.001, Table 7). There was a tendency that the water bowls were generally better placed and had higher flow capacity on the LC farms (Waterbowls, p: 0.10, Table 7). Significantly fewer poor or low scores (Faultnum, p: << 0.001, Table 7) were recorded by the technicians on the LC farms. The relative numbers of LC and HC farms as regards environmentally related variables are shown in Table 11.

Multivariable analysis.

The variables, CowNum, Breed, Drycowstall, Calfbarn, Calfstallscore and Faultnum were not included in the logistic regression. CowNum, Breed, Drycowstall were highly correlated with other variables and the calf-related variables will be dealt with in the calf part of the chapter concerned with the animal variables. Faultnum is an index variable that sums up the environmentally related faults on the technician's record sheet (TecGen). Since Faultnum therefore would not add to the specificity of the analysis, it was dropped. The full and the final models are shown in Table 12 with coefficients, χ^2 and p-values.

Table 12. Full and final models of effects of environmental variables. Variables in final model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
Barnstatus2	Condition of the barn			
Daylight2 *	Amount of daylight let in.	1.9	4.2	0.04
Insulation2	Insulation of barn.	-3.1	10.5	0.001
NoDraft2	Less draft in barn.			
Stallnotslipp2**	Slipperiness of the stall surface.			
Rubbermats***	Rubber mats installed in stalls.	4.1	19.7	<< 0.001
Strawamount2***	Amount of straw used in stalls.	2.8	8.9	0.003
Strawbedding*	Straw or sawdust as bedding.			
Urinedrain2	Status of urine drainage system.			
YStie	Tying of recruitment heifers.			
DipTeat***	Dipping the teats after milking.	2.9	10.5	0.001
Milkingorder2***	Cows ordered according to udder health.	3.5	14.3	< 0.001
Waterbowl2	Placing and capacity of waterbowls.			

Deviance: 45.2; p-value: 0.99; degrees of freedom: 75, constant coefficient: -13.9

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

Removing the two managerial variables Milkingorder and DipTeat changes the deviance from 45.2 to 65.8, which gives them a χ^2 of 20.6 and a p-value of << 0.001. When these two variables are removed from the final model, Daylight shifts from being significant to being non-significant (p: 0.08) and Urinedrain and Waterbowl become significant on the 0.05 level (*aa* p: 0.02). This alternate model without management variables has coefficients ranging from -3 to 4.3, with a constant coefficient of -11.8 and only one true outlier, an HC-farm. It has, however, 6 marginal outliers on the 0.08 level, 4 HC and 2 LC-farms, which gives it a classification that is not as good as the proposed final model, that has 1 LC and 2 HC outliers, 91.5 % of the farms correctly classified and a Wilk-Shapiro index of 0.76. Neither herd size (CowNum) nor breed can enter the model due to co-linearity.

In order to correct for cow size and to check the effects of stall variables, including those with a p-value larger than 0.20, a second model was created (Table 13). The introduction of the size of the cows, Cowcirc, did not bring stall area into the model, nor any of the other stall variables that were non-significant in the univariable analysis. All four stall variables found statistically significant in the univariable analysis, turned out statistically significant in this model. This should be interpreted thus: LC farms have significantly less slippery stalls, they use more rubber mats and more straw than HC farms. The latter have larger cows and use sawdust, instead of straw, more often than the LC farms. The model has 2 LC and 1 HC outliers, 84 % of the farms correctly classified and a Wilk-Shapiro index of 0.85.

Table 13. Logistic regression model of stall variables and cow size. Variables in final model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
Cowcirc*	Heart girth.	-0.3	18.9	<< 0.001
Stallpercent	Percent of stall area relative to norm.			
Frontgate	Type of front gate			
Stallpartitions	Partitioning between cows			
Stalltype	Type of stall			
Stallnotslipp2**	Slipperiness of the stall surface	1.9	5.1	0.024
Rubbermats***	Rubber mats installed in stalls.	4.1	14.3	< 0.001
Strawamount2***	Amount of straw used in stalls.	3.2	14.7	< 0.001
Strawbedding*	Straw or sawdust as bedding.	-3.3	5.4	0.020

Deviance: 51.4; p-value: 0.99; degrees of freedom: 76, constant coefficient: 61.2

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

Discussion

General aspects

Herd size (Cownum) is a risk factor for elevated BMSCC in this study. Herd size as a factor affecting incidence of cows with clinical or subclinical mastitis and or increased BMSCC in dairy herds has been studied by several authors. Bodoh et al. (1976) found no association between herd size and BMSCC, whereas Østerås & Lund (1988) and LeDu et al. (1985) found that larger herds had fewer problems with mastitis. Neither of these two latter studies differentiate between risk factors for increased BMSCC and clinical mastitis, however. Bartlett & Miller (1993), when analyzing risk factors for intramammary infections (IMI) for different bacteria, found an association between larger herds and IMI with coagulase positive staphylococci (CPS). Berry (1994), when studying dairy farms with a 12 month rolling average BMSCC <70.000 cells/ml, found that those farms were significantly smaller than the average British dairy farm. Keller (1977) and Østerås et al. (1994), who studied the influence of environment on udder health of cows in free stalls and tie stalls, respectively, found that the incidence of veterinary treatments was higher in larger herds. The results of this study therefore are in agreement with Berry (1994) and Bartlett & Miller (1993). It seems likely that larger herd size is a risk factor for mastitis and other diseases in general (Keller, 1977) but it should be questioned if herd size *per se* really is one of the major risk factors for high BMSCC in this study or if it is just another indication that the HC farmers have more cows than they can handle.

The general condition of the barn and the age of the building has been associated with udder health in some other studies. Bratlie (1966) states that he found a tendency that cows kept in wooden houses had better udder health and that older buildings often were drafty and that this was disadvantageous. Saloniemi (1980) found no association between udder health and the framework or age of the building. Simensen (1981[a]), in a study of the climate in Norwegian dairy barns, found that age of the building, type of floor and manure gutter significantly affected the indoor temperature. Other authors (Saloniemi, 1980; Bakken, 1982; Østerås & Lund, 1988[a]) have related indoor temperature to udder health. The result in this study, a tendency in the univariable analysis, that HC farmers had barns that were not in as good general condition as on the LC farms, seems to be in agreement with the Norwegian studies. This study did not, in agreement with Saloniemi (1980), find any relation between age of building and udder health. This is an indication that the risk factor for udder health is not primarily the age or framework of the building. It is, instead, the regular upkeep and quality, the management of the building, that determines if it will serve its purpose.

Ventilation, insulation and light

The effects of ventilation, insulation[4] of farm buildings and draft and their effects on udder health have been studied in the Nordic countries (Bratlie, 1966; Schmidt-Madsen, 1978; Saloniemi, 1980[a]; Bakken, 1982; Lindström, 1983; Østerås & Lund, 1988; Østerås et al., 1994) but not so much in other countries (Schukken et al., 1991). As discussed above much of the early research showed a

[4] The construction of the walls, the fit of doors and windows and whether the windows are double (or triple) glazed or not.

relationship between open manure gutters, undulating temperatures and draft and a negative effect on both BMSCC and clinical mastitis. As a result, open manure gutters disappeared and Østerås (1990), in a more recent study of the environment in Norwegian dairy barns, could not detect any traditional environmental risk factors. A significant effect of draft on both IMI and BMSCC was, however, demonstrated by Lindström (1983) irrespective of manure handling system, and Schukken et al. (1991) have found that a specific technical construction of ventilation - letting the air in along the roof - was a risk factor for clinical mastitis induced by *S aureus*. The result of the multivariable analysis (Table 12), where Insulation entered into the final regression model although it was not statistically significant in the univariable analysis (most probably due to confounding with some other variable/-s), is thus supported by the literature.

Significantly more daylight was let in by windows on the LC farms (Tables 7 and 12). An effect of light on udder health has been shown by Johannesson (1994). Saloniemi (1980), however, could not statistically demonstrate an effect of light although numerically there was an association between good udder health and better lighting. The possible role for daylight would be to illuminate the udder and teats so that minor injuries or changes to the appearance of the milk can be detected and remedied. In the Nordic countries, however, the light in the barn during the winter period is only to a small part dependent on the daylight let in through the windows. The important light source during the stabling period is the light from the lamps in the barn and there was no statistically significant difference as regards the artificial light between the two types of farms. It is possible that more light let into the barn through the windows during winter could affect the general condition of the cows and also possibly increase their resistance to bacteria. A 16 hour light period per day in the fall and winter has been shown to stimulate feed intake and milk production in dairy cows (Tucker, 1985) and light and melatonin has, in the laboratory, been shown to influence the immune system in guinea pigs and rats (Poon & Pang, 1994; Cardinali et al., 1997). The amount of daylight let in through the windows may, on the other hand, only be an indication that the cleaning and condition of the barns are better on the LC farms.

Stalls: size, construction, cleanness and bedding

No variable related to stall size or construction came out statistically significant in either the univariable or the multivariable analysis in this study. Even after correcting for the larger cows on HC farms (Table 13) there are no differences between stall measurements or stall area between the two types of farms. Some early reports (Ekesbo, 1966; Nygaard, 1979; Schmidt-Madsen, 1978) found indications of positive effects on udder health from longer stalls. The stalls were generally much shorter than today, however. Nygaard found no stalls longer than 200 cm and Ekesbo compared stalls longer or shorter than 185 cm. These measurements are not applicable to the current situation. This is further illustrated by Grommers et al. (1972) who, in an early study on effects of housing factors on udder health, found no effect on length or width of stall on incidence of trodden teats. Bakken (1982) found that the incidence of clinical and subclinical mastitis (elevated SCC) decreased with longer stalls but that the incidence of clinical mastitis increased with wider stalls. Heifers, for instance, had significantly more clinical mastitis in wider stalls. Incidence of subclinical mastitis was not affected significantly by the width of the stall. Østerås & Lund (1988[a]) found similar complex associations between size of stall and udder health where they, among other things, found that the incidence of IMI with CNS increased with width of stall and that the incidence of IMI with *S a* showed a curvilinear pattern with the highest incidence in the intermediate measurements of stall width. The results of this study are in agreement with Østerås (1990), who did not find any statistically significant factors related to the design of the stalls.

Four variables - stall slipperiness, presence or absence of rubber mats, amount, quality and type of straw - related to stall comfort and function were statistically significant in the univariable analysis and two - rubber mats and amount of straw - remain in the final model. In the "stall model" presented in Table 13, all four were statistically significant. This indicates that stall comfort and function is indeed important for good udder health. Other authors have arrived at similar results. Ekesbo (1966), Karlsson & Gustafsson (1978), Lindström (1983), Schukken et al. (1991) and Bartlett et al. (1992[a]) found that amount and type of bedding influenced the incidence of trodden teats, cases of clinical mastitis and/or BMSCC. Miller & Bartlett (1991), when assessing economic value of different management practices, report that sufficient bedding is beneficial. Howard et al. (1991), on the other hand, found that the use of straw was associated with higher BMSCC. No note of amount or quality of the straw was made, however. Rubber mats could function in at least two ways: one is to provide a better foothold for the cows as they rise, thus causing less trodden teats, and the other would be to insulate the stall better, which would increase cow comfort. Nygaard (1979) showed that well insulated stalls cause 35 % less injuries to teats and udders than colder stalls and Østerås & Lund (1988) found rubber mats to be associated with better udder health. Schukken (1990[a]) found conflicting results regarding rubber mats - they were a risk factor for clinical mastitis in general but a protective factor in the calving area for post puerperal mastitis induced by *E coli*. The finding that the stall surface on LC farms was less slippery than on HC farms is in agreement with Nygaard (1979).
The result in this study that the use of long straw as bedding protects against high BMSCC is in agreement with many other authors who have found straw a protective factor against clinical mastitis and/or high BMSCC (Karlsson & Gustafsson, 1978; Lindström, 1983; Barnouin et al., 1986[b]; Faye & Brochart, 1986;

Bartlett et al., 1992[c]). Miller and Bartlett (1991) could not differentiate between the effects of long straw, sawdust or sand, although they were all good for udder health. Howard et al. (1991) found straw to be a risk factor for elevated BMSCC.

Management related and miscellaneous variables

The management related variables Milkingorder - arranging cows in a milking order according to udder health - and DipTeat - dipping the teats in an antiseptic solution (usually an iodine formulation) after milking - were statistically significant in the univariable as well as the multivariable analysis. The practice to milk the cows according to their udder health status has support in the literature from the first half of the century, as discussed in Chapter 1. More recent reports also support this practice (White, 1965; O'Shea, 1987; Hutton et al., 1990 & 1991; Wilson et al., 1995), although Fox et al. (1987) could not make it work on all farms. No doubt the segregation of chronically infected cows needs to be integrated with other mastitis prevention measures to be fully effective.

In this study, there was sufficient variation among LC and HC farms for DipTeat to be statistically significantly different between the two types of farms. Dipping teats after milking in a disinfecting solution has been a standard part of udder disease preventive programs for the last 25 years, as reviewed in Chapter 1. Its main effect is to kill gram-positive bacteria such as *S a* or streptococci on teats, reduce new IMI and thus lower BMSCC. It is evident that the HC farmers have not adopted this practice to the same extent as the LC farmers and yet they are in greater need of it. Recent research by Schukken (1991) and Lam (1996[a]) have shown that long-term dipping of teats may be a risk factor for clinical mastitis, especially mastitis induced by *E coli* and other gram-negative bacteria. It is possible that the increased incidence of clinical mastitis seen on LC farms in this study (Chapter 3, Table 5 a) in some cases is due to this phenomenon.

The removal from the final regression model of the two management variables brings two other variables into the model: Urinedrain and Watercup. The function of the urine drainage system is important for the cleanness of the cows. If they are allowed to dip their switching tails in the mixture of urine and manure in a non-functional manure gutter they can become incredibly dirty. That clean cows have better udder health has been shown by many authors (Nygaard, 1979; Østerås, 1990, Bartlett et al., 1993; Berry, 1994). A readily available source of freely running, fresh water is essential to the dairy cow. To be denied this to some extent could either impair the digestion of feed or cause the cows to become subclinically stressed, which might possibly affect the function and capacity of the immune system, thus predisposing for IMI and elevated SCC (Selye, 1936 & 1952; Johnson & Vanjonack, 1975; Lamb, 1975).

Conclusions

The structure and the condition of the stall surface is of great importance for cow comfort, for her ability to rise without treading on her teats, and for providing a clean and reasonably soft lying place. The results in this study indicate that these conditions are more important in Swedish dairy barns today than the construction or size of the stall or other technical components such as ties or partitions. These latter constructional details may not be perfect, but they do not provide enough variation between types of farms to become statistically significantly different. Rubber mats with ample amounts of long straw of good quality serve well if one wants to achieve low and stable BMSCC. In order to keep BMSCC low dairy farmers should arrange their cows in a milking order where the cows with low SCC are milked before those with bad udder health as indicated by higher SCC or UHC. The results of this study indicate that it is beneficial to long-term udder health, monitored as BMSCC, to dip teats after milking. It would also appear that the climate in the barn is of some importance, at least as regards avoiding poor insulation.

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Chapter 5.

Effects of feed, water and pasture

Introduction

The effects of feeding regimes on milk production in dairy cows have been studied extensively (Trimberger et al., 1972; Broster et al., 1978; Broster & Broster, 1984) but the effect of feeding on health has been relatively sparsely studied. In the extensive review by Broster & Broster (1984), for example, less than one page of a total of 47, or 26 references of 303 (8.6 %), deal with health aspects of feeding of dairy cattle. There is, however, solid evidence that a high ration of grain, often in combination with silage (especially corn silage) is a risk factor for milk fever (Paresis puerperalis), retained fetal membranes (RFM), ketosis, displaced abomasum (DA), laminitis and other claw and leg diseases, and some reproductive disorders such as cystic ovaries, metritis and endometritis. The effects are direct or indirect via other diseases or increased milk production (Emery et al., 1969; Thomas et al., 1970; Trimberger et al., 1972, Whitmore et al., 1974; Belyea et al., 1975, Broster et al., 1978; Carstairs et al., 1981; Coulon et al., 1989; Tillgren & Pehrson, 1997). Only very few authors report statistically significant effects of feeding regimes on udder health. Barnouin et al. (1986[b]), in an epidemiological study, found that a high level of energy in relation to protein was a risk factor for clinical mastitis. Johnson and Otterby (1981) found a weak (p: < 0.10) association between a dry period ration containing 47 % grain and higher CMT values as compared with a ration with 12 % grain. Klug et al. (1989) had statistically significantly more cases of clinical mastitis among cows and heifers fed a similar ration during lactation and Sommer (1980) found an association between higher levels of protein and carbohydrates and clinical mastitis. Some studies report numerical differences in mastitis incidence rates between different feeding regimes but due to too few cows no statistically significant results were obtained (Emery et al., 1969; Fronk et al., 1980; Olsson, 1996). Trials in university herds or experimental stations rarely mimic the complex situation of real life however, and three studies employing more advanced statistical methods on large field materials have been unable to demonstrate any associations between high levels of estimated or previous milk production, feed components or nutritional levels and increased rates of mastitis (Dohoo & Martin, 1984; Curtis et al., 1985; Erb et al., 1985). One result in the latter study was that first lactation heifers (FLH) with an estimated higher milk production did indeed have higher production but also a lower incidence of mastitis.

The influence of feeding during the dry period and lactation on production and health of the dairy cow is complex. Overfeeding with either protein or carbohydrates will lead to adverse chemical and microbiological reactions in the rumen, which will affect the cow's appetite, metabolism, production and well-being (Emery et al., 1969; Thomas et al., 1970; Trimberger et al., 1972, Whitmore et al., 1974; Belyea et al., 1975, Broster et al., 1978; Carstairs et al., 1981; Coulon et al., 1989; Hibbitt, 1984; Tillberger & Pehrson, 1997). On the other hand, not feeding enough energy, protein or fiber will also lead to increased incidences of diseases such as dystocia, RFM, ketosis, DA and possibly also mastitis (Sommer, 1980; Curtis et al., 1985). The aim of this chapter is to analyze the feeding plans and water supply, and related subjects such as use of pasture, at LC and HC farms to identify risk factors for high BMSCC.

Material and Methods

The results in this chapter are based on data collected by the technicians on the record called TecGen and on data submitted by the farmers in the questionnaire. These are described in Chapter 2. Fifty-two LC and twenty-nine HC farms completed the Q, but one HC farmer did not weigh any feed stuffs, and thus calculations of proportions, ratios and the like are based on 28 HC farms. Most farmers did not state the amounts of different feedstuffs in dry matter (DM). In order to compare feeding plans and make calculations of ratios between different feedstuffs, such figures were transformed. The transformation factor for big-bale and tower silage was 0.4 and for silage in bunker silos 0.33 (Bertilsson, 1996). The figure obtained was rounded off to the nearest 0.5 kg. In this chapter, the term "concentrate" will be used for grain alone or grain and "extra top-feed" together.

Nine variables from record TecGen and 59 variables from the Q were analyzed univariably using Epi-Info 6 (1994) with type of farm as the dependent variable, to screen for differences between LC and HC farms. Variables with a p value $\leq$ 0.20 were introduced to a stepwise logistic regression using Statistixs (1996) and processed as described in Ch. 2.

Results

Univariable analysis

Results of the Univariable analysis are shown in Table 14. Variables, type of variable (dichotomous, ordinal, continuous), type of statistical test, p-values, and indication of odds of being an LC or an HC farm are in the table. The variables have been translated from their abbreviated Swedish form into English.

Table 14. Results of the univariable analysis of variables related to feed, water and pasture. Abbreviations are explained at the bottom of the table

Variables:*		
Statistically significant	**0.05 < p-values ≤ 0.20**	**Statistically NS**
TecGen record.		
HayQual, 3sc, KW, p: 0.013, +	Silagefin, dc, Yc, p: 0.14, +	Conc/day
SilageQual, 3sc, KW, p: 0.015, +	Waterbowls, 3sc, KW: 0.10, +	Silageinfeed
PastureH_2O, 3 sc, KW, p: < 0.001, +		Watersource
		PastureCondition
		Forest, Pasture
Questionnaire		Grassleys, Fields
Mechanization		
	Concdisp, dc, Yc: 0.053, -	SilageTower
	Silagedisp, dc, Yc. 0.11, -	Big-balesilage
	Investnum, ct, *t*-test: 0.16, -	Bunkersilo
		Milkline
		ALFA-line
		ACR, AMR
		InvestmentOther
Conservation of feed		InvestmentLatest
Homeproduced, dc, Yc: 0.043, -	HayOnly , dc, Fe: 0.09, +	Silagetower
	Buytopfeed, dc, Fe: 0.18, +	Silage-bale, -loaf
		Silagebunker
		BuyConc, -Ruff
		Hay/SilageCow
Feeding regime		Hay/SilageHeifer
ConcLactFLH, ct, ANOVA: 0.005, +	Conc/RuffFLH, ct, KW: 0.10, +	Conc/RuffCow
ConcLactCow, ct, ANOVA: 0.04, +	Conc/day, ct, KW: 0.08, +	ConcDryHeifer
TDMCow, ct, t-test: 0.047, +		ConcDry Cow
TDMFLH, ct t-test: 0.01, +		DMRuffFLH
		DMRuff Cow
		Riskfeed
Supply of water		Minerals
Wellspring, dc, Fe: 0.043, -		SameWater
		Welldug, -drilled
		Wellpublic
		Waterana
		Watertreatment
		Watergood
Miscellaneous		Waterchange
Hayother, dc, Yc: 0.005, +	Hayvolume, dc, Yc: 0,19, -	Haystructure,
	Hayprot, dc, Yc: 0.07, -	HayHygiene
	Feedana≥3, dc, Yc: 0.12, +	HayProt, -Energy
	FeedinDM, dc, Fe: 0.09, +	Stabledate
		Pasture, -days

* Variables with p-values ≤ 0.2 are described in Appendix 3.

Table 14, continued

Abbreviations used in Table 14: + : indicates increased odds of being an LC farm, -: indicates increased odds of being an HC farm, ACR: automatic cluster remover, ALFA-line: rail for clusters, ana: analysis, AMR: automatic manure remover, ANOVA: analysis of variance, ConcDryHeifer/ -Cow: kg of concentrate/day fed heifers and cows in the dry period, ct: continuous, dc: dichotomous, DMRuffFLH/ -Cow: total dry matter of roughage/day fed the FLH and cows, Fe: Fisher exact test, FLH: first lactation heifers, KW: Kruskal-Wallis, sc: score, Yc: Yates corrected.

Roughage

The roughage fed to the cows was either only hay (10 LC and 1 HC farms), only silage (1 HC farm) or a combination of hay and silage. Fourteen LC and three HC farms used silage for part of the winter season. The silage used was hay-crop silage except for one HC farmer who also used corn silage. Some beet-silage was also used as a complement to other feeds by both LC and HC farmers, primarily in the Kalmar region. The percentage of LC and HC farms receiving scores from 1 to 3 for the quality of hay and silage are shown in Table 15.

Table 15. Percentage of LC and HC farms and their quality scores for hay and silage. Three is the top score. Number of farms in parenthesis

		Type of roughage			
		Hay		Silage	
		LC (52)	HC (30)	LC (33)	HC (26)
Percent of score	*1*	0.0^{a*}	6.7^{b}	3.0^{c*}	19.2^{d}
	2	2.0^{a}	10.0^{b}	15.2^{c}	27.0^{d}
	3	98.0^{a}	83.3^{b}	81.8^{c}	53.8^{d}

* Series a and c statistically significantly different from b and d, $p < 0.02$.

LC and HC farms fed about equal amounts of roughage to their cows and first lactation heifers (FLH) (p: 0.4). The mean amounts fed were about 10 kg DM to FLH and 11 kg DM to cows, with a range of 4.5 to 17 kg DM. The proportion of hay in the roughage fed to cows and FLH on farms that used silage ranged from 0 % - one HC farm fed only silage - to 80 %. On six HC and one LC farm less than 15 % of the dry matter roughage fed to the cows was hay (p: 0.007) and 6 HC and 2 LC farms fed less than 20 % of the dry matter roughage as hay to the FLH (p: 0.02). The proportion of hay in the roughage, on farms feeding hay and silage, is shown in Figure 3. The difference is, on average, not statistically significant.

The farmers were asked, in the Q, to state what qualities they thought were important in a good hay. They were given four alternatives (that were not mutually exclusive), high protein value, large volume, good structure or other quality.

The HC farmers preferred a high protein hay with large volume (p: 0.07 and p: 0.19, respectively, Table 14). The LC farmers, to a higher degree than the HC farmers, did not accept the three given suggestions but argued for something

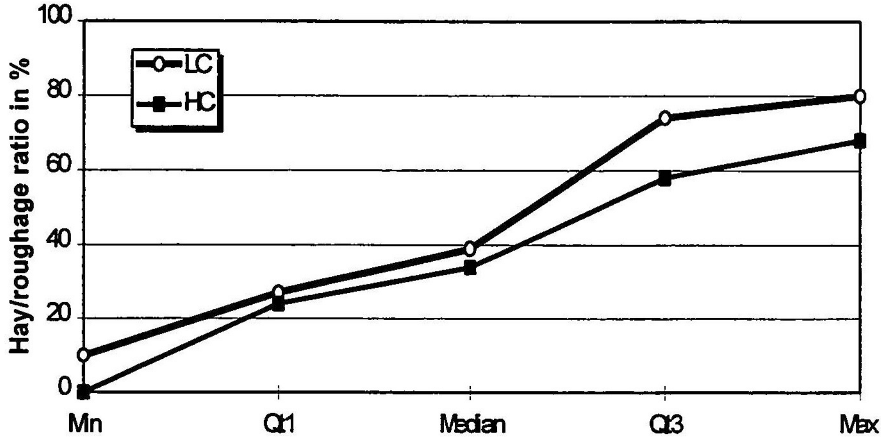

Figure 3. Proportion of hay in the roughage dry matter fed at LC and HC farms; Qt designating quartile.

"other", which usually was high energy content. An "other" alternative was advocated by 17 of the 52 LC farmers (32.7 %) compared with only one (3.4 %) of the HC farmers. The difference was highly statistically significant (p: 0.005). None of the answers regarding the corresponding qualities of silage was different between the two types of farms. Neither was there any difference as regards method of conservation of silage.

Concentrate

The dry period

Eleven LC and four HC farmers did not feed any concentrates to their heifers two months before calving (ConcDryHeifer, p: 0.6, Table 14). Seven HC and six LC farmers gave more than 2 kilos of concentrate to their heifers at this time (p: 0.21) The average amounts given to LC and HC heifers were 1.28 and 1.54 kilos, respectively. The difference is not statistically significant. The cows received similar rations of concentrate two months before calving (ConcDryCow). Eighteen LC and five HC farmers did not feed any concentrates to their cows at this time. The difference was not statistically significant (p: 0.16). Five LC and six HC farmers fed their cows more than 2 kilos of concentrate (p: 0.19). The average amounts of grain fed to the cows were 1.0 and 1.3 kilos, respectively (p: 0.17).

Peak lactation

All farmers fed concentrate to their cows and FLH during peak lactation. 86.5 % of the LC farmers fed concentrate 3 or more times per day compared with 65.5 % of the HC farmers (Conc/day, p:0.052, Table 14). The LC farmers fed statistically significantly more concentrate to their FLH and cows during peak lactation (Figure 4 and Table 14).

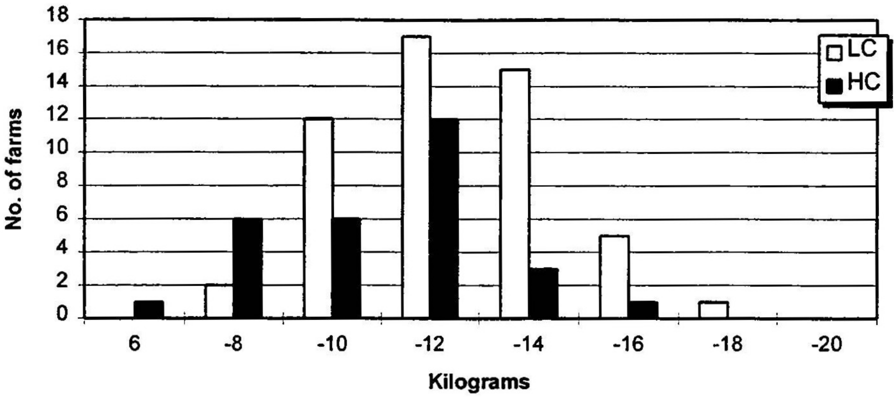

Figure 4. Kilograms per day of concentrate fed to first lactation heifers (FLH) during peak lactation at LC and HC farms (p: 0.005).

Mainly because of the greater amounts of concentrate fed to FLH and cows on LC farms, the total dry matter (TDM) fed at peak lactation was also statistically significantly different between the two types of farms, with p-values of 0.047 for cows and 0.01 for FLH.

Mechanization of feed handling, milking and related work

There was a fairly strong tendency that the HC farmers had mechanized the handling of the feed to a higher extent than the LC farmers. An automatic concentrate dispenser was used by 65.5 % of the HC farmers as compared with 40.4 % of the LC farmers (Concdisp, p: 0.053, Table 14). The same proportion of HC farmers had invested in an automatic silage dispenser compared with 44.2 % of the LC farmers (Silagedisp, p: 0.11, Tables 14 and 16). Six each of LC and HC farmers, 11.5 and 20.7 %, respectively, used airtight silage towers for conservation of roughage (p: 0.33, Table 14). On average HC farmers had done 4.3 mechanizing investments compared with 4.0 by the LC farmers (Investnum, p: 0.33, Tables 14 and 16). If the number of investments are corrected for the smaller herds on LC farms there is still no statistical difference between the two types of farms. The median year for the latest investment was 1989 on LC and 1988 on HC farms (p: 0.23). For these and other investments in mechanization, see Table 16.

Table 16. Degree of mechanization on LC and HC farms. Percentages of 52 LC and 29 HC farms

Type of investment	Type of farm LC	HC	Type of test	P-value
Autom. Concentrate dispenser	40.4	65.5	Yc	0.053
Autom Silage dispenser	44.2	65.5	Yc	0.11
Silage tower	11.5	20.7	Fe	0.33
Bunker silo	42.3	48.3	Yc	0.77
Big-bale silage	36.5	20.7	Yc	0.22
Automatic manure disposer	92.3	93.1	Fe	1.0
Milk line	98.1	100.0	Fe	1.0
ALFA-line*	13.5	3.4	Fe	0.25
Automatic cluster remover	1.9	3.4	Fe	1.0
Other investments	21.1	13.8	Yc	0.60
Average number of investments	4.0	4.3	KW	0.33
Median year for latest investment	1989	1988	KW	0.23

* Rail for clusters

Pasture

Two LC and one HC farmer did not let their cows out on pasture. The technicians interviewed the farmers about the general conditions on the pastures, whether they were natural meadows or cultivated fields, etc. The conditions were scored in the usual manner from 1 to 3. Five HC and one LC farm received the bottom score of 1 (p: 0.09). The average score for condition of pasture was not statistically significantly different between the two types of farms. There was no difference between LC and HC farms regarding days on pasture or mean date when the cows where stabled again in the fall. Eight LC and one HC farm stabled the cows in August (p: 0.14). Two HC farms stabled their cows in the beginning of November.

Water supply

The technicians subjectively judged the water in the pastures to have a higher quality and pose less of a threat to udder health on LC than on HC farms: 90.4 % of the LC farms received the top score for "pasture water supply" compared with 46.7 % of the HC farms. The difference was highly statistically significant (PastureH_2O, p: < 0.001, Table 14).

In the Q, the farmers were presented with 4 different ways of providing water in the barn to the animals. The alternatives were, 1: dug well, 2: drilled well, 3: public or 4: other. Three HC farms reported that they had some "other" type of water supply (Wellspring, p: 0.043, Table 14). There were no other differences as regards water supply between the two types of farms. A large majority of both types of farms had the same water for humans and animals, LC 82.7 % and HC 78.6 %. Over 90 % of both LC and HC farmers did not think that the water in the barn posed any threat to the health of the animals. Only seven LC and two HC farmers wrote in the Q that something was not quite right with their water. Four LC and one HC farmer reported that surface water sometimes seeped into their wells. Three LC farmers said that they had a problem with iron deposits, sand or some other similar problem and one HC farmer reported that he sometimes had high bacterial counts. As discussed in the previous chapter, the technician's assessment of the water supply in the barn to the cows was that it was marginally better at the LC farms (Waterbowls, p: 0.10, Table 14). This assessment concerned the number, placement and function of the water bowls.

Miscellaneous feed related variables

There was a tendency that the LC farmers sent samples of their feed - roughage as well as grain - for analysis more often than the HC farmers (Feedana≥3, p: 0.12, Table 14). The latter claimed that they produced more of their feed on their own farm (Homeproduced, p: 0.04, Table 14). The answers to the corresponding questions regarding purchase of feed was only marginally different between the two types of farms, however, (Buytopfeed, p: 0.18, Table 14) or not significantly different (BuyConc, BuyRuff, Table 14). Ten (19.2 %) LC and one (3.4 %) HC farmer gave the information about weight of different feedstuffs as DM instead of kilograms of feed (FeedinDM, p: 0.09, Table 14). The Q did not ask any question specifically about minerals and vitamins. Eight LC and two HC farmers volunteered information on this matter. The difference was not significantly different. There were no differences between the two types of farms as regards the use or size of the land (Forest, Fields, Grassleys, Pasture, Table 14).

Multivariable analysis

The feed-related variables in Table 14 were included in a multivariable analysis using logistic regression as described in Materials and Methods, Chapter 2. The variable SilageQual - quality score of silage - was eliminated due to too many missing values; 19 LC and 3 HC farms. TDMCow, ConcLactCow, ConcLactFLH were not included due to high correlation with TDMFLH. Silagedisp and Silagefin (having silage only for part of the winter season) were not included due to high correlation with Concdisp and HayOnly, respectively. For the full and final feed model A, see Table 17.

Of the 16 variables in the full model 6 remain after the stepwise logistic regression. LC farms feed less silage, have better water at pasture, have more and other views on a good hay, feed more DM to their first lactation heifers at peak lactation, and describe their feeding plans more often in DM. The HC farmers claim to have more home-produced feedstuffs. If Silagefin is introduced instead of HayOnly it becomes statistically significant but the p-value of TDMFLH increases to 0.06. Neither of the variables TDMCow, ConcLactFLH or ConcLactCow tests into the final feed model A.

Table 17. Full and final model A of effects of feed, water and related variables. Variables in final model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
HayQual2 *	Hygienic quality of hay			
HayOnly	Feeds only hay as roughage	2.9	5.8	0.016
PastureH$_2$O2* **	Quality of water at pasture	1.8	8.4	0.004
Concdisp	Concentrate dispenser in barn			
Silagedisp	Silage dispenser in barn			
Hayother**	Has other opinion about good hay	2.0	4.3	0.038
Hayvolume	Wants lots of hay			
Hayprot	Wants high protein content			
Homeprod *	Produces feed on farm	-1.6	4.3	0.038
Buytopfeed	Buys top feed			
Conc/RuffFLH	Ratio of conc/roughage fed FLH			
TDMFLH**	TDM/day to FLH at peak lactation	0.2	4.0	0.045
Conc≥3/day2	Feeds conc 3 or more times/day			
Feedana≥3	Analyses feedstuffs ≥3 times/season			
FeedinDM	States amount of feed in dry matter	2.2	4.9	0.027
Wellspring *	Spring as water source to animals			
Waterbowls	Placing and capacity of waterbowls			

Deviance: 64.2; p-value: 0.76; degrees of freedom: 73; constant coefficient: -6.5

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

In an attempt to include only relevant feeding variables, a second model was constructed. The variables concerning preferences of hay are nonsense variables in the context of trying to find feed-related protective or risk factors for elevated BMSCC, because they are reflections of the knowledge of the farmer and do not address the primary question. If the hay variables related to knowledge and the ones concerning the presence or absence of concentrate or silage dispensers are removed the first final model changes, see Table 18. This final feed model B has only three statistically significant variables: HayOnly, PastureH$_2$O2 and TDMFLH. ConcLactCow, ConcLactFLH and TDMCow are all exchangeable with TDMFLH, *i.e.* they can replace TDMFLH without making any other variable statistically non-significant. TDMFLH is thus a general indicator of feeding level. Silagefin is exchangeable with HayOnly. The final feed model B has fewer outliers - 1 LC and 3 HC - than model A that has 2 LC and 3 HC outliers. Feed model B does not contain any nonsense variables, 76.5 % of the farms are correctly classified (86.5 % of the LC farms) and the Wilk-Shapiro index is 0.94 as compared with 0.90. The interpretation of the second model is that LC farmers have better water at pasture, feed their FLH and cows more concentrate and DM at peak lactation and do not use silage to the same extent as the HC farmers. The knowledge variable, FeedinDM, can enter the model but then the feeding variables are no longer exchangeable and the fit of the model does not improve. Waterbowl receives a p-value of 0.08 if introduced.

Table 18. Feed and water model B when the owner-related variables concerning preferences of hay, stating feed in DM and presence or absence of silage or concentrate dispensers have been removed. Variables in final model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
HayQual2 *	Quality score of hay			
HayOnly	Hay only - no silage	2.3	5.3	0.021
PastureH$_2$O2* **	Quality of water at pasture	1.8	11.0	< 0.001
Conc/RuffFLH	Ratio Conc/Ruff: Heifers			
TDMFLH **	TDM/day to heifers at peak lact.	0.2	6.6	0.010
Conc≥3/day	Feeds conc. 3 or more times/day			
Feedana≥3	Analyses feed 3 times or more			
Wellspring *	Has spring as water source.			
Waterbowl	Function of waterbowls in barn	(1.2	3.1	0.08)

Deviance: 82.3; p-value: 0.3; degrees of freedom: 77; constant coefficient: -6.8

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

Discussion

Roughage

It is quite possible that the transformation from kg of feed to kg DM of feed has overestimated the DM content of the silage. This is more likely the case regarding the feeding plans of the HC farms, since the technicians judged the hygienic quality of both the silage and the hay to be worse on the HC than on the LC farms (SilageQual, p: 0.015; HayQual, p: 0.013; Table 14). Water content is an important factor that determines the quality of the silage (Sargison, 1993). It is therefore possible that some Type 2 errors have been introduced in the comparisons of use of silage on the two types of farms. It is unlikely that this method has induced any Type 1 errors, however.

The difference between the two types of farms in hygienic quality of both the hay and the silage, that was observed in the univariable analysis, disappeared in the multivariable analysis. There is universal agreement that feed and water should have a high hygienic quality- *i.e.* that there should be few bacteria and no toxic substances. Feed and water hygiene is regulated by law (SFS 1988:534 & SJVFS 1993:129). Systematic research into the effects of poor quality feed and water is sparse, however, and most reports are anecdotal in nature (Funke, 1968; Olsen, 1968; Häggblom, 1990). Even if one would question the subjective assessment of the technicians, poorer quality roughage and water should be noted as a possible risk factor for the high BMSCC at the HC farms (Schukken, 1991).

The feeding regimes of HC farms contain silage both more often and in higher ratios (Table 18 and Figure 3). Feeding plans rich in silage have been noted as a risk factor for disease in dairy cows in general (Thomas et al., 1970; Belyea et al., 1975; Coulon et al., 1989) and for disturbances of udder health, notably elevated SCC, in particular (Johnson & Otterby, 1981). The result in this study that a feeding regime without silage or one with silage fed only during part of the year is a protective factor against high BMSCC is thus supported by the literature. There may be several explanations why a diet rich in silage might induce disease in dairy cows. One is the high demands on hygienic quality of feed that was discussed above and that is necessary with the current demands of high milk production on the dairy cow. It is often difficult to get good quality silage and the farmer has to be particular about how the grass is harvested, predried, transported and packed for the silage process to be optimal (Sargison, 1993). This may indicate that it is not the silage *per se* that is the risk factor for elevated BMSCC but that there is some difference between LC and HC farms in the way of processing or keeping the silage that the study has not detected. One indication that this might be true is that the majority - 73 % - of LC farmers use silage during the full winter season and manage to keep BMSCC low for at least seven years. Another explanation, reported by one author, might be that cows fed silage can have a lower consumption of roughage DM (Thomas et al., 1970). It is possible that some underfeeding of nutrients and energy might occur if this is not compensated for by an alert farmer. Such underfeeding can induce a variety of diseases, particularly in early lactation (Curtis et al., 1985).

The variables describing owner preferences about a good hay (Hayvolume, -prot, -other) are interesting because they say something about the farmers that have given the answers. They are not interesting from an udder health point of view, however, since there is no causality between them and udder health. The same can be said for the variables Concdisp, Silagedisp and FeedinDM. This is the reason why they were removed from the first logistic regression model. Some of these variables will be discussed in a following chapter dealing with the farmers.

Concentrate

The LC farmers produce more milk per cow than the HC farmers (Table 3, Ch. 3). They do this by giving their cows more feed more often than the HC farmers. They give their cows and heifers less concentrate during the dry period, although the difference is only numerical, and more at peak lactation and there is a strong tendency, in the univariable analysis, that they feed concentrate more times/day than the HC farmers (Conc/day, p: 0.08, Table 18). Dividing the concentrate ration and feeding it in several small portions has been shown to increase milk production (Gustafsson et al., 1993). The cows on LC farms receive more treatments for clinical mastitis but have less subclinical mastitis than the cows on the HC farms (Table 5 and Figure 1, Ch. 3). There are thus no indications from the results in this study that the higher plane of nutrition (TDMFLH, Table 18) on LC farms should induce high BMSCC. The possibility exists, however, that the higher ration of concentrates fed the cows, and especially the FLH, could contribute to the higher incidence of clinical mastitis. This would then be in agreement with Sommer (1980), Barnouin et al. (1986[b]) and Klug et al. (1989).

From an udder health perspective, at least when monitored with BMSCC, it appears reasonable to recommend a feeding regime for mid-lactation FLH and dairy cows, respectively, comprising 12 (SD: 2.2) and 14 (SD: 2.7) kg of concentrate (grain and top feed)/day and with a proportion of concentrate relative to roughage of around 55 %. If silage of good hygienic quality is used the DM content ought not exceed 80-85 % of the total amount of roughage DM.

Pasture

No statistically significant differences between the practice of letting the cows out on pasture, the length of the grazing period or the date of stabling the cows in the fall were detected in the analyses. The only difference detected concerned the quality of the water on pasture. The variable PastureH_2O was statistically significantly different between LC and HC farms in the uni- as well as in multivariable analysis (Tables 15 and 19). It must be stressed, however, that the assessment of the technicians is based almost entirely on the anamnestic information given by the farmer. Only very few assessments have been confirmed by actual observations since the visits were made during the stabling period. Nevertheless, the statistical association is very strong ($p < 0.001$), with 40 (77 %) of the LC farms receiving the top score as compared with only 11 (37 %) of the HC farms. There can be no doubt that the quality of water at pasture is important for the health of the cow in general (Gillingstam, 1984; Carlsson, 1991) and for incidence of clinical mastitis in particular (Funke, 1968; Schukken et al., 1990[b]). These studies thus support the result of the present study, albeit not unconditionally since the etiologies behind clinical and subclinical mastitis differ. This result is, however, an indication that the quality of water at pasture may affect BMSCC.

Water

What has been said above about quality of water on pasture applies equally to the water supply in the barn. Three types of water supply - dug well, drilled well or public water were equally distributed between LC and HC farms. Three HC farms reported that they had a natural spring ("other") as water supply. Of these constructions public water generally is the most hygienic with drilled and dug wells being ranked second and third while a natural spring is comparable with surface water (Gillingstam, 1984).

Tied dairy cows may get lower milk production if the flow rate of water in the water bowls is low and if they are not placed correctly (Andersson, 1984). The placement and function of the waterbowls, as assessed by the technicians, are marginally better at the LC farms in both the uni- and the multivariable analysis. The possible risks associated with a watering system that functions sub-optimally have been discussed in Chapter 4.

Miscellaneous

There was a tendency in the univariable analysis that the LC farmers sent feed samples for analysis more often. This fits well with the higher milk production on LC farms because such a practice would make it possible for them to design better feeding plans, as would the practice of using DM for calculations of amounts of different feedstuffs.

Conclusions

A roughage diet consisting mainly of silage is a risk factor for high BMSCC, at least on the HC farms in this study. Good quality water at pasture appears to be important for good udder health as measured with BMSCC. The level of feeding on LC farms does not appear to be a risk factor for elevated BMSCC. It is possible that the higher consumption of concentrates on the LC farms may contribute to the higher incidence of clinical mastitis seen on these farms.

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Chapter 6.

Animal factors and management of animals

Introduction

Animal factors and care of animals have been shown to influence udder health of dairy cows. Grommers et al. (1971), Karlsson & Gustafsson (1978) and Lindström (1983) showed that characteristics of the udder such as shape, distance from teat to floor, teat length and distance between teats influenced incidence of trodden teats and/or SCC and infection rate. Østerås & Lund (1988[b]), Østerås (1990), Østerås et al. (1990) and Johannesson (1994) showed that better sheared and cleaner cows with better trimmed claws had better udder health. Ledin and Lema (1997) and Seabrook (1984) have demonstrated that having an interest in dairy cows and their welfare and generally taking good care and treating them well is associated with higher milk production. Hemsworth et al. (1981) demonstrated higher production performance in pigs that were treated well.

The aim of Chapter 6 is to identify animal and management factors that contribute to keeping BMSCC at low levels.

Materials and Methods

The results in this chapter are based on data collected by the technicians on the record called TecAni and on data submitted by the farmers in the questionnaire. These records are described in Chapter 2. Thirty-two variables from record TecAni and 70 variables from the Q were analyzed univariably using Epi-Info 6 (1994), with type of farm as the dependent variable, to screen for differences between LC and HC farms. Variables with a p value ≤ 0.20 were made available to a stepwise logistic regression using Statistix for Windows (1996). Ordinal and some continuous variables were dichotomized and correlations between variables checked as described in Ch. 2. Variables with very small numbers of either LC or HC farmers, such as hired hand B variables, were excluded from the multivariable analyses due to low explanatory value and to prevent the false identification of putative causal factors based on only a few farms (Dohoo et al., 1984[a]).

Results

Univariable analysis

Results of the univariable analysis are shown in Table 19. Variables, type of variable (dichotomous, ordinal, continuous), type of statistical test, p-values and indication of odds of being an LC or an HC farm are listed in the table.

Table 19. Results of the univariable analysis of variables related to animals and care and rearing of animals. Abbreviations are explained at the end of the table. When two p-values are shown the first is derived from ANOVA and the second from a Kruskal-Wallis equation

Variables:		
Statistically significant	**0.05 < p-values ≤ 0.20**	**Statistically NS**
TecAni record		
Calves		
Calfstallscore, 4 sc, KW: 0.025, +	Calfbarn, dc, Fe: 0.16, -	Calftie, Calfpen
Calfclean, 5 sc, KW: 0.04, +	CalfNumber, ct, KW: 0.07, -	CalfBS,
MilktoCalf, 4 sc, KW: 0.003, +		Calfclaw
Young stock		
YSclaw, 5 sc, KW: 0.007, +	YStie, dc, Yc: 0.1, +	YSBS
YSNumber, ct, KW: 0.046, -	YSshear, 5 sc, KW: 0.09, +	YSclean
Cows		
3teated, ct, KW: 0.009, -	CowCalm, dc, Fe: 0.059, +	
Teattiphurt, 3 sc, KW: 0.008, -	Teathurt, ct, KW: 0.075, -	
CowClaw, 3 sc, KW: << 0.001, +		
Dry cows		
DCclaw, 5 sc, 0.01/0.01, +	DCshear, 5 sc, KW: 0.16, +	DCNumber
DCclean, 5 sc, 0.002/0.002, -		DCBS
TecAni record		
Measurements on sampled, lactating cows		
AveClaw, ct, KW: 0.003, +		AveBS
AveClean, ct, KW: 0.006, +		
AveShear, ct, KW: 0.04, +		
AveTeatF, ct, KW: 0.005, +		
AveTeatR, ct, KW: 0.003, +		
AveFloorF, ct, KW: 0.004, +		
AveFloorR, ct, KW: 0.03, +		
AveCirc, ct, KW: 0.015, +		
Questionnaire, *Husbandry and diseases*		
Calves		
ColotoCalf, dc, Yc: 0.008, +	CowMilkDays, ct, KW: 0.13, +	MilktoCalf, Calf-
Deworm, dc, Yc: 0.002, +	CalfOwnB, dc, Yc: 0.08, +	CalfWean
DewormNum, 4 sc, KW: < 0.001, +	CalfHireHB, dc, Fe: 0.13, -	CalfPastureMo
FemaleTendCalf, dc, Yc: 0.003, +		CalfOwnA

Table 19, continued

Cows		CalfHireHA
CowTend, dc Fe: 0.007, +	MastVet, dc, Yc: 0.07, +	Milkout
PPturn, dc, Yc: 0.013, +	CowGroom, 4 sc, KW: 0.08, +	CalvingPenA-D
CowTrim, 4 sc, KW: 0.003, +	CowShear, 4 sc, KW: 0.2, +	DiseaseadviceA-F
CowWell, dc, Yc : 0.02, +		ParturitionDeck
Organization of work		ParturitionPen
BothMilk, dc, Yc: < 0.001, +	HireHand, dc, Yc: 0.18, -	TendCowHHA
HireHGroom, dc, Fe: 0.014, -	HireHNum, ct, KW: 0.06, -	HeatCheckA-E
	OwnBGroom, dc, Yc: 0.11, +	WhoGroomA-F
	OwnATrim, dc, Yc: 0.07, -	WhoTrimB-E

* Variables with p-values ≤ 0.2 are described in Appendix 3.
Abbreviations used in Table 19: + indicates increased odds of being an LC farm, - indicates increased odds of being an HC farm, ANOVA: analysis of variance, ave: average, BS: body score, ct: continuous , dc: dichotomous, DC: dry cow, Fe: Fisher exact test, KW: Kruskal-Wallis, mo: months, NS: non-significant, sc: score, Yc: Yates corrected, YS: young stock.

Animal factors

Table 19 shows that almost all variables indicating good care of animals are statistically significantly different between the two types of farms. Invariably the comparison comes out in favor of the LC farms, regardless whether the data come from the Q or from the TecAni record. The only variables where there are no (or only marginal) statistical differences are for the body score (BS), the score of calf claws and cleanness of the young stock. The animals generally are cleaner on LC farms, as can be seen in Figures 5 a and b, but the difference is smallest for the young stock.

That the cows were cleaner on the LC farms is supported by the farmer's own statements regarding frequency of grooming (CowGroom). Twenty-five percent of the LC farmers state that they groom some cows per day or week compared with only ten percent of the HC farmers. The difference borders on being statistically significant (p: 0.08). Seventy-three percent of the LC and eighty-three percent of HC farmers groom their cows "sometimes" or "when they get too dirty". It is likely that these words mean different degrees of dirtiness to the two types of farmers.

Thirty-five and seventeen percent, respectively, of the LC and HC farmers shear all cows more than once per stabling season (p: 0.16). The shearing of the milking cows is judged, by the technicians, to be statistically significantly better at the LC farms. (AveShear, p: 0.04, Table 19).

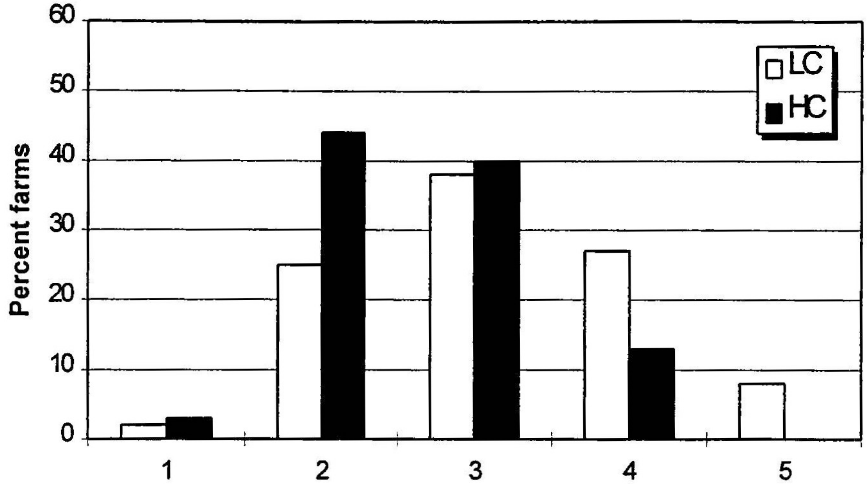

Figure 5 a. Scores given by the technicians for cleanness of milking cows. Five is the top score. Series statistically significantly different, p: 0.006.

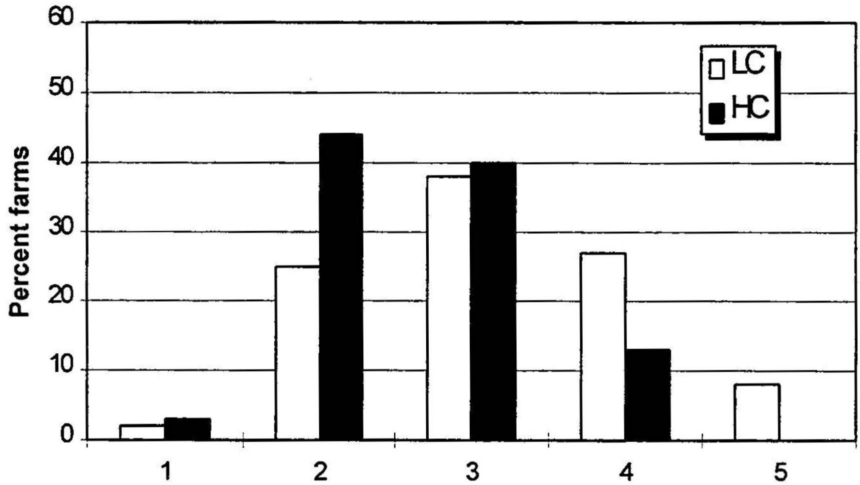

Figure 5 b. Scores given by the technicians for cleanness of calves. Five is the top score. Series statistically significantly different, p: 0.04.

The technicians judged the trimming of cows claws to be better on LC than on HC farms (AveClaw, p: 0.003, Table 19 and Figure 6). Trimming of claws was also performed more frequently on LC farms (CowTrim, p: 0.003, Table 19). According to the farmer's own statements in the Q, 15.4 % of the LC farmers trim the claws of their cows twice or more per year compared with none of the HC farmers. At the other end of the scale 7 % of HC farmers never trim claws compared with zero among LC farmers.

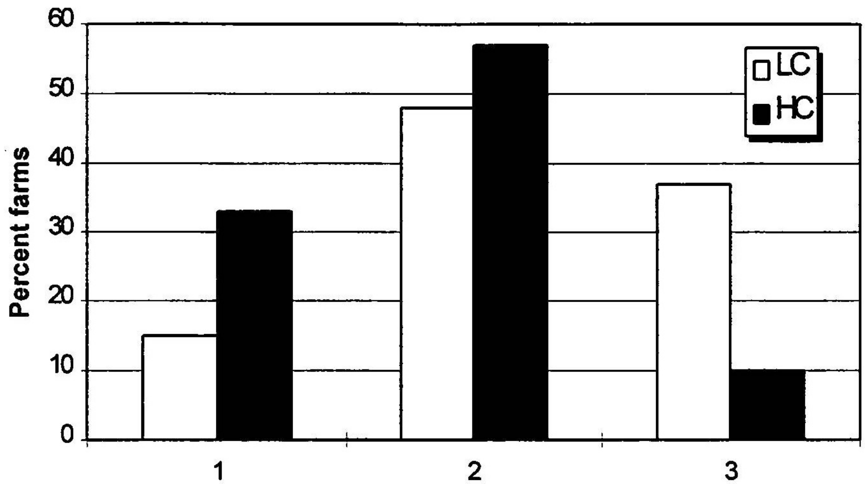

Figure 6. Scores given by the technicians for trimming of cows' claws. Three is the top score. Series statistically significantly different (p: 0.003).

The cows were bigger on HC farms and they had longer teats and greater distance between the base of the teats and the floor of the stall. This is demonstrated by the variables AveCirc - average heart girth, AveTeatF, -R - average length of fore and rear teats and AveFloorF, -R - average distance between fore and rear teats and floor (Table 20). Furthermore, the fore teats were statistically significantly longer than the rear teats ($p: < 0.001$) and the average distance from the fore teats to the floor was statistically significantly greater than that for the rear teats ($p: < 0.001$). When the average rear teat lengths, of the LC and HC farms, respectively, were subtracted from the values for average floor to "base of rear-teat" distance the average distance from the teat tip to the floor became 40.7 cm for the hind teats on LC farms and 41.4 cm for the same distance on HC farms.

Three variables indicate damage to teats, 3teated: percentage of three-teated cows in herd, Teathurt: percentage of cows with some trauma to a teat or teats and Teattiphurt: a 3 score variable scoring condition of teat-tips. The former two variables are largely related to trauma to the teat by the cow or by the environment, and the latter is largely an indication of the degree of trauma at milking. The variables 3teated and Teattiphurt were statistically significantly different,

Table 20. Average length of teats, base of teat-to-floor distance and heart girth for third or more lactation cows on LC and HC farms

	Type of farm							
	LC				HC			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max
AveTeatF, cm	5.6[a*]	0.6	4.3	6.6	6.0[b]	0.6	4.6	6.8
AveTeatR, cm	4.8[a]	0.6	3.8	6.1	5.3[b]	0.6	3.8	6.7
AveFloorF, cm	47.5[a]	3.6	40.9	56.2	49.1[b]	2.9	44.8	55.2
AveFloorR, cm	45.5[c]	3.6	39.2	55.2	46.7[d]	2.8	42.0	52.8
AveCirc, cm	195.4[e]	4.4	185.0	206.7	198.6[f]	6.3	187.0	218.0

* a - b, p: < 0.01; c - d, p = 0.03; e - f, p = 0.015.

with p-values of 0.009 and < 0.001, respectively, and Teathurt was marginally different (p: 0.075) between the two types of farm (Table 20).

Husbandry and attendance to animals

Calf rearing

Two-thirds, 67 %, of the LC farmers claimed that they gave their new-born calves colostrum within 1-2 hours after birth compared with only 34.5 % of the HC farmers (Colotocalf, p: 0.008, Table 19). Almost half, 44.5 %, of the HC farmers waited until the next morning to give colostrum to a calf that was born in the evening compared with 25 % of the LC farmers (p:0.11). Twenty-one percent of the HC farmers left the calf with the cow to eat at will, compared with 8 % of the LC farmers (p: 0.15). There was no difference as to the length of the period the calves were fed milk or milk replacer. On average, calves on both types of farms were weaned during the ninth week of life, with a range from 5-24 and 4-16 weeks on LC and HC farms, respectively (CalfWean, Table 19). Marginally significantly more LC farmers fed their calves whole milk throughout the milk period, however. Almost 30 % of the LC farmers fed whole milk for more than 5 weeks compared with only 11 % of the HC farms. The week when the shift from whole milk to milk replacer was made is shown in Figure 7.

Calves on LC farms were treated against intestinal parasites statistically significantly more often than calves on HC farms. Seventy-five percent of the LC farmers dewormed their calves at least once during the grazing period compared with only thirty-eight percent of the HC farmers (CalfDeworm, p: 0.001, Table 19) and 61.5 % of the LC farmers treated their calves twice or more, whereas only 14 % of the HC farmers dewormed this frequently (p: << 0.001). There were no differences regarding the age of the calves when they were let out on pasture.

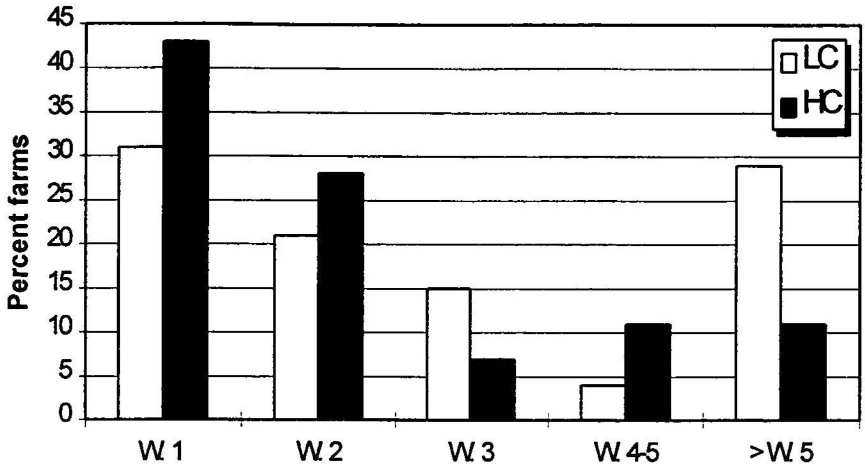

Figure 7. Week when shift from whole milk to milk replacer was made on LC and HC farms.

The attendance to diseased cows and related issues

The farmers were asked a number of questions, in different parts of the Q, about how they treated cows with mastitis during lactation or with milk fever or how they cared for cows during the peri-parturient period. When taking care of a case of mild clinical mastitis (no systemic symptoms), there was no difference between the two types of farms as to the frequency or practice of milking out the affected quarter (Milkout, Table 19). There was close to a statistically significant difference that the LC farmers were more willing to call a veterinarian for cases of mild clinical mastitis (MastVet, p: 0.07, Table 19). More LC farmers went out to check, at night before going to bed, on a cow that had calved during the evening chores, 73 % vs. 45 % (CowTend, p: < 0.001). The LC farmers turned a cow with milk fever over onto the other side three or more times during the day more often than the HC farmers (PPTurn, p: 0.013, Table 19). When giving a reason for why they let the cows out on pasture in the summer, the LC farmers, statistically significantly more often than the HC farmers, gave the answer that it was for the well-being of the cows (CowWell, p: 0.02), but also because it eased the workload during the summer (p: 0.06). Almost all - 98 and 93 %, respectively, of the LC and HC farmers ”always” or ”most often” covered the manure gutter with a mobile ”parturition deck” if they saw that a cow was about to calve and only very few, 8 and 3 %, respectively, used parturition pens (ParturitionDeck, -Pen, Table 19). Differences between LC and HC farms in management of dry cow therapy will be dealt with in Chapter 7.

The human side of husbandry

The human aspects of husbandry of dairy farms will be more extensively discussed in a later chapter. Here, only some results that have a direct bearing on the variables related to animal care will be mentioned. It was statistically significantly more common on LC farms that both husband and wife were present during morning and afternoon milking and took an active part in the milking and other chores (BothMilk, p: < 0.001, Table 19). There was a strong trend that HC farmers employed more personnel than LC farmers (HireHand, HireHNum, p: 0.18 and 0.06, respectively, Table 19). Five HC farmers and one LC farmer had two or more employees working with the animals (p: 0.02). The owner doing most of the milking is designated Owner A, and the second and third hired hands are called HireHandB (HHB or HireHB) in this study. On HC farms, where they had two or more hired hands, there was a trend that the HHB tended the calves (CalfHireHB, p: 0.13, Table 19), whereas on the LC farms there was a trend that one of the owners, Owner B, took care of the calves (CalfOwnB, p: 0.08, Table 19). On the LC farms a female statistically significantly more often took care of the calves, or 61 % vs. 24 % on HC farms (FemaleTendC, p: 0.003, Table 19). There was a tendency that Owner B groomed the cows on LC farms (OwnBGroom, p: 0.11) and that this was done by the HHB (HireHGroom, p: 0.014, Table 19) on the HC farms. There was no difference in routines when checking for heat between the two types of farms.

Multivariable analysis

The effect on BMSCC of variables related to animals and management of animals were analyzed in three somewhat overlapping models. In order to look only at the effect of animal variables, a general animal model comprising all animal - cow, calf, young stock and dry cow - variables was created. The general animal model was then divided into one cow and one calf model, in which relevant husbandry variables were introduced. The general animal model is shown in Table 22.

The results of the general animal model indicate that the cows were cleaner and the claws of the cows better trimmed on LC farms (AveClean, AveClaw). Moreover, the calves were cleaner and statistically significantly more LC farms had cows of the SRB breed. On HC farms there was a statistically significantly higher proportion of cows with traumatized teats and the herds were bigger (Teathurt, Cownum). No variables associated with young stock or dry cows were retained in the final animal model.

Table 22. Full and final model of all animal variables. Variables in final model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
DCclean2	Cleanness of dry cows			
YSshear2	Shearing of young stock			
YSclaw2*	Trimming of claws of young stock			
Calfclean2*	Cleanness of calves	2.76	9.4	0.002
3teated**	Percent three-teated cows			
Teathurt	Percent cows with traumatized teats	-0.31	12.8	< 0.001
Teattiphurt2**	Condition of teat-tips			
AveClaw**	Ave. score of sampled cows' claws	1.83	7.3	0.007
AveClean**	Ave. cleanness of sampled cows	1.67	8.5	0.003
AveShear*	Ave. shearing of sampled cows			
AveTeatF**	Ave. teat length of sampled cows			
AveFloorF	Ave. teat-floor distance of - " "-			
Floordistancediff	Difference fore and rear teats to floor			
AveCirc*	Ave. circumference of selected cows			
SLB***	Swedish Friesian ≥ 80 % of herd			
SRB***	Swedish Red ≥ 80 % of herd	4.00	24.6	<< 0.001
Cownum**	Number of cows in herd	- 0.07	6.6	0.01

Deviance: 46.3; p-value: 0.99; Degrees of freedom: 75; Constant coefficient: -11.8

Abbreviations: Ave.: average, diff: difference, F: fore, num: number.
*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

The cow variables of Table 22 were analyzed together with relevant cow husbandry variables, see Table 23. Only variables related directly to lactating cows were included in the analysis.

The variables Cownum, CowTend, CowGroom2 and BothMilk had to be excluded from the full model due to co-linearity . These variables were tried in the model when the number of variables had been reduced. Only BothMilk received a p-value low enough to enter the final model. The final Cow & Husbandry model in Table 23 has 1 HC and 3 LC outliers and 89.0 % of the farms are correctly classified. The Wilk-Shapiro index is 0.71 (0.88 if the outliers are omitted). PPturn can be replaced with CowTend, without major alterations of the final Cow & Husbandry model.

The interpretation of the results in Table 23 is that it is statistically significantly more common on LC farms that both husband and wife are present and take an active part in the work with the animals during milking (BothMilk). The cows on LC farms have better trimmed claws (AveClaw) and LC farmers call more often for a veterinarian when they have a case of mild clinical mastitis (MastVet). LC farmers turn a cow with milk fever over on the other side more times per day (PPturn) and they also go out to check on newly calved cows more frequently

Table 23. Full and final model of cow variables and relevant husbandry variables. Variables in final "Cow and Husbandry model" shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
3teated**	Percent three-teated cows	-0.31	7.6	0.006
Teathurt	Percent cows with traumatized teats	-0.32	8.5	0.003
AveClaw**	Ave. score of sampled cows' claws	1.65	4.5	0.034
AveClean**	Ave. cleanness of sampled cows			
AveShear*	Ave. shearing of sampled cows			
AveTeatR**	Ave. teat length of sampled cows	-3.51	11.2	< 0.001
AveFloorF	Ave. teat-floor distance of - " "-			
AveCirc*	Ave. circumference of sampled cows			
CowGroom2	Frequency of grooming of cows			
CowTrim2*	Frequency of trimming of claws			
Cowshear2	Frequency of shearing of cows			
CowTend**	Tending to a newly calved cow at night			
PPturn*	Frequent turning of cows with PP	2.23	6.5	0.011
BothMilk***	Husband and wife takes part in work	1.96	5.3	0.021
HiredHand	Having employees working with cows	-3.64	11.0	< 0.001
OwnATrim	Owner A trimming cows' claws	-2.84	7.1	0.008
MastVet	Calling for Vet for mild mastitis	3.31	11.5	< 0.001
SLB***	Swedish Friesian ≥ 80 % of herd			
SRB***	Swedish Red ≥ 80 % of herd			

Deviance: 39.1; p-value: 0.99; degrees of freedom: 71; constant coefficient: 14.1

Abbreviations: Ave.: average, F: fore, PP: paresis puerperalis (milk fever), Vet: veterinarian.

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

than HC farmers (CowTend). There are statistically significantly more three-teated cows and cows with traumatized teats on HC farms than on LC farms (3teated and Teathurt). The cows on HC farms also have longer teats (AveTeatR, -F). It is statistically significantly more common that HC farmers trim the claws of their cows by themselves (OwnATrim) and there are more often employed personnel on HC farms (HiredHand). Neither breed nor herd size enters into the final model.

The results of the analysis of calf and calf-related husbandry variables are shown in Table 24.

Table 24. Full and final model of calf and calf-related husbandry variables. Variables in final "Calf and Husbandry model " shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
Calfbarn	Calves kept in separate barn			
Calfstallscore2*	Condition of calf stalls			
ColotoCalf*	Colostrum to calf within 2 hours			
Milktocalf**	Care when making milk to calves			
Deworm≥2* **	Deworm more than once	3.0	18.1	<< 0.001
CalfClean2*	Score of calf cleanness	2.6	9.0	0.003
CowMilkDays	Num. of days calves fed whole milk	3.0	8.2	0.004
CowTend**	Tending to newly calved cows	3.9	8.1	0.004
FemaleTendC***	Female tending to calves	1.5	5.1	0.024

Deviance: 39.1; p-value: 0.99; Degrees of freedom: 71; Constant coefficient: 0.04

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

Of the nine variables in the full Calf & Husbandry model, five remain after the stepwise logistic regression. TendCalfOwnB (Owner B tends to calves) can not replace FemaleTendC but BothMilk and FemaleMilk (a female is responsible for and does most of the milking of the cows) can. The proposed final Calf & Husbandry model in Table 24 has zero LC and two HC outliers. The overall proportion of farms that are correctly classified is 84.0 %. The Wilk-Shapiro index is 0.71. Two cow variables related to parturition were included in the full model, CowTend and PPturn. PPturn can replace CowTend in the final model. Herd size (Cownum) can be introduced to the model without making any of the other variables statistically non-significant. There is no statistically significant influence of breed.

The results shown in Table 24 indicate that calves are cleaner and receive whole milk for a longer period of time on LC farms (CalfClean2, CowMilkDays). Calves are treated against intestinal parasites statistically significantly more frequently than on HC farms (Deworm≥2) and it is more common that a female tends to the calves or that both spouses are active in the work with the animals (FemaleTendC, BothMilk). Furthermore, newly calved cows or cows with milk fever are tended to more frequently on LC farms (CowTend, PPturn). These differences between types of farms remain after being corrected for herd size and breed.

Discussion

It is not easy to quantify the effect of good care of animals on udder health. The problem is partly one of causality and partly because so many other factors influence udder health. Furthermore, udder health can be measured both as incidence rate of clinical mastitis, which is not one disease but several, and as BMSCC, which adds to the complexity. Some animal and animal care factors are truly important for good udder health but may be confounded by other factors such as culling, treatment rate or keeping a milking order, and some animal and care factors are mere indicators of good husbandry and may have less impact on disease incidence and propagation.

Cows and husbandry of cows

Better and more frequent trimming of claws and keeping the cows clean are associated with better udder health in this study (Tables 23 and 24). This is in agreement with results by other authors (Østerås & Lund, 1988[b]; Østerås, 1990; Østerås et al., 1990; Bartlett et al, 1993; Johannesson, 1994). The described mechanism regarding cleanness is that clean cows have fewer sores on legs, abdomen, etc., that can be infected with potential udder pathogens such as *Sr dysgalactiae* and *S aureus* (Oz et al., 1985). Bartlett et al. (1993) found dirty udders to be a risk factor for IMI with CPS.

The correlation index between score for shearing of cows (AveShear) and score for cow cleanness (AveClean) is high (0.6) in this study. This is reasonable since it is easier to keep sheared cows clean. AveShear cannot replace AveClean in the Cow & Husbandry model, however. Because of the high correlation between these variables and because AveShear was statistically significant in the univariable analysis it may be of importance for udder health. Shearing of cows has also been shown to influence dissipation of body heat. High-producing dairy cows produce a lot of heat through increased metabolism (Ehrlemark, 1991). Sheared animals lose more body heat by radiation instead of sweating. Shearing of cows thus improves cow comfort and may reduce stress (Ehrlemark, 1991).

The proportion of cows with teat-treads is less on LC farms than on HC farms (Table 23). One reason for this is that the claws are better trimmed on LC farms, which makes it easier for the cow to rise correctly (Østerås et al., 1990). Untrimmed claws cause the cow pain (Bergsten, 1995). Chronic pain may suppress the immune system (Selye, 1936 & 1952) and might thus predispose for clinical or subclinical mastitis and other diseases. A high incidence of trodden teats may also be an indication of less than optimal stalls, as discussed in Ch. 4. It appears that it is not advantageous for the cows on HC farms to have their claws trimmed by their owners.

The sampled cows on HC farms had longer teats than the ones on LC farms. This is in agreement with other studies of Swedish dairy cows (Ral et al., 1988). Longer teats are a risk factor for trodden teats (Grommers et al., 1971) and subsequent mastitis. The greater distance between the floor and the teats on HC farms disappears in the multivariable analysis and it does not seem to protect the cows from treading on their teats. Other authors have claimed that a distance from the teat apex to the floor of less than 40 cm significantly increases the risk of teats being trampled (Grommers et al., 1971; Saloniemi, 1980). In this study, the floor-to-teat distance was measured from the base of the teats and not from the tips. Only one farm, an LC farm, had a floor to "base of the teat" distance that was less than 40 cm. When the mean rear teat length was subtracted from the mean teat-to-floor distance of the two farm types, 19 LC and 6 HC farms had an average rear teat apex-to-floor distance of less than 40 cm. The difference was not statistically significant. In this study, it therefore appears that the longer teats on cows on HC farms, possibly in combination with less straw and less rubber mats, predispose for trodden teats and traumatized teats, and that this is not compensated for by a greater teat-to-floor distance.

The farmers on LC farms were more willing to call a veterinarian for mild cases of clinical mastitis (Table 23). Treating clinical cases of mastitis - induced by contagious udder pathogens - with antibiotics will reduce cell counts (Dodd et al., 1969; Neave et al., 1969, Dodd & Neave, 1970), especially if combined with other udder health promoting measures, as discussed in previous chapters.

There were no statistically significant differences between BS of animals on LC and HC farms (Table 19) . There were, however, no indications that the HC farmers generally mistreated or severely underfed their animals, see Chapter 5. It could therefore be expected that BS would not differ between the two types of farms.

The most common form of ownership of farms in Sweden is within a family (Nitsch, 1987). On the LC farms it was statistically significantly more common that both husband and wife shared the work with the milking and feeding of the cows and other animals (BothMilk, $p: \ll 0.001$). This is in agreement with other authors (Bakken, 1978; Tarabla and Dodd, 1990). It is reasonable to assume that it would be easier to achieve good results if both spouses do the work with the animals together. This is, however, no guarantee for good udder health, as spouses shared the work on 14 % of the HC farms. The work also has to be performed in a knowledgeable way and it has to be structured to be successful. More personnel were employed on HC farms (HiredHand, $p: < 0.001$). The results of the univariable analysis showed that certain parts of the work done by the owners on LC farms, such as tending to calves and grooming of cows, quite often were done by employed personnel on HC farms, and then often by number 2 in rank. It is reasonable to assume that many hired hands may not show a level of interest in the work that fully matches that of the owners. Herd size (Cownum) is an intervening variable in the comparison of the number of staff on LC and HC farms, and should therefore not be included in that analysis (Martin et al., 1987).

Calves and calf rearing

Calves were cleaner on LC farms (Figure 6 b and Tables 20 and 25). Calves on Swedish dairy farms generally are kept single in pens and therefore depend on Man to supply them with clean straw in order to keep free of urine and manure. The calfstalls on LC farms were statistically significantly cleaner (Table 7, Chapter 4), which probably is the main reason why calves were cleaner on LC farms. Calves were also dewormed more often and more frequently on LC farms. Deworming of calves has been associated with higher milk production later in life (Sykes, 1994).

Calves on LC farms are statistically significantly more often tended by a woman, notably the farmer's wife (Table 24). This is an interesting result in view of results by Hartman et al. (1974) and Losinger and Heinrichs (1997) showing that preweaned heifer-calves have a higher mortality rate if tended by a male. It is possible that women are more patient or care better for pre-weaned animals than men. It should be noted, however, that the variable BothMilk can replace "female tending calves" in the final Calf & Husbandry model. The most common circumstance on LC farms was that both spouses were present in the barn, actively participating in the work, and that the females generally had greater responsibility for taking care of the calves.

The results, in the uni-and the multivariable analyses (Tables 20 and 25), concerning feeding of colostrum and length of the whole milk period are interesting not only because of the possible beneficial effects manifested as increased growth rate (Odde, 1986; Robinson et al., 1989), a decreased death rate (Losinger & Heinrichs, 1997) and higher milk production later in life (DeNise et al., 1989), but also because the LC farmers, with significantly fewer cows with subclinical mastitis (Table 5, Ch. 3), also have less high cell count milk available for feeding calves. In view of the udder health situation on the HC farms, the opposite result would not have been unreasonable. It is reasonable to expect a behavioral link between the practice of feeding colostrum to a calf within 2 hours and tending extra to a newly calved cow and possibly also to more frequent turning of a recumbent cow with milk fever. This was the reason for including two variables related to parturition in the Calf & Husbandry model. The result that LC farmers statistically significantly more often go out an extra time to check on a newly calved cow (CowTend, p: 0.002), or turn a recumbent cow with milk fever onto its other side more frequently (PPturn, p: 0.038), are yet other indications that they care more about the welfare and well-being of their animals than the HC farmers do. Attitudes towards animals will also be discussed in a following chapter.

When discussing the results concerning rearing of calves one must address the issue of causality. Is it possible that cleaner calves that receive whole milk and that are dewormed more frequently can have better resistance against udder pathogens later in life? In this context, it should be noted that no variables related to young stock became statistically significant in the multivariable analysis. Some studies have shown beneficial effects on milk production after antiparasitic treatments and the feeding of colostrum and whole milk as discussed above, but none has shown any effect on disease resistance. It is biologically possible that these actions by LC farmers could have positive effects on udder health, but it could also be just another indication of the better care of animals that prevail on LC farms.

Conclusions

The attendance to and rearing of cows and calves on LC farms is superior to that on HC farms. Keeping cows clean and with well-trimmed claws assist in keeping BMSCC low, as does treating clinical cases of mastitis with antibiotics. "Working in family" and having a female milker are also protective factors against elevated BMSCC. Treating calves more frequently against intestinal parasites, keeping them clean, and feeding whole-milk for a longer period of time may reduce BMSCC. Long teats are a risk factor for trampled teats and elevated BMSCC. Long teats act in concert with environmental factors, such as absence of rubber mats and low amounts of bedding, to increase the incidence of trodden teats on HC farms. It appears urgent to find ways of motivating employed personnel to take care of animals and tend to their needs in such a way as to benefit animal health and productivity.

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Chapter 7.

Milking machine and milking technique

Introduction

The meeting of technology in the form of the milking machine, the dairy cow, pathogenic bacteria and man, creates a truly multifactorial background for the etiology of mastitis (IDF, 1987; IDF, 1994; Woolford, 1995). The milking machine can act as a vector to spread pathogens between cows (Fox et al., 1991; Bramley, 1992; Baines, 1993) and within cow (Hamann et al., 1980; Woolford et al., 1980; IDF, 1987; Isaksson & Åström, 1988; Baines, 1993). Bacteria can be propagated through the teat canal due to impact (Thiel et al., 1969; O'Callaghan et al., 1976) or reverse pressure gradients (RPG) (Galton et al., 1990; Mein, 1990; Rasmussen et al., 1994; Woolford, 1995). The milking machine can also traumatize the teats or the teat canals and thus either impair defense mechanisms and/or furnish the bacteria with better living conditions (IDF, 1987; Bramley, 1992; IDF, 1994). Improper milking technique, such as letting in air at application or removal of the teatcups or through liner slip, can make even a well-designed milking system infect the cow at milking (IDF, 1987; Mein, 1990; Baines ,1993; IDF, 1994; Woolford, 1995).

Many epidemiological studies have demonstrated effects of milking technique and milking machine on udder health (Pearson et al., 1972; Moxley et al., 1978; Goodhope & Meek, 1980; Le Du, 1985; Barnouin et al., 1986[a]; Faye & Brochart, 1986; Østerås & Lund, 1988[b]; Howard et al., 1991; Schukken et al., 1991; Bartlett et al., 1992[b-d]; Johannesson, 1994). The results of these studies regarding generally well accepted advice to dairy farmers, vary considerably. The practice of checking foremilk before milking, which is required by the EEC "Milk directive" (1992), can be mentioned as an example. Three studies find that checking the foremilk is either associated with more cases of clinical mastitis (Schukken et al., 1991; Bartlett et al., 1992[c]) or lower BMSCC (Goodhope & Meek, 1980), and 4 found no effect of checking foremilk on udder health (Pearson, et al., 1972; Hueston et al., 1987; Howard et al., 1991; Hutton et al., 1991). That the incidence of clinical disease might be influenced by diagnostic acts, such as checking of foremilk, is not difficult to understand; it is more difficult to explain the effect on subclinical disease (Goodhope & Meek, 1980). Another example of equivocal results regards the use of an individual cloth or paper towel/cow when cleaning the udder before milking. Two French studies claim that using one towel/cow when cleaning the udder before milking is a protective factor against clinical mastitis during lactation (Barnouin et al., 1986[b]) or post-partum (Faye & Brochart, 1986), while Bartlett et al. (1992) claim that a shared wash cloth and an individual drying cloth reduces the incidence of mastitis induced by environmental streptococci. Six studies found no statistically significant differences in udder health due to the use of shared or individual wash cloths (Pearson et al., 1972; Moxley et al., 1978; Lindström, 1983; Hueston et al., 1987; Howard et al., 1991; Hutton et al., 1991).

Overmilking is found by 4 studies to raise BMSCC (Pearson et al., 1972; Le Du, 1985; Johannesson, 1994; Østerås & Lund, 1988[b]). This is the only factor that is not contradicted by any other of the epidemiological studies, yet in controlled studies overmilking *per se* has not influenced udder health (Olney & Mitchell, 1983; Mein, 1990; Baines, 1993; Hamann et al., 1994). These examples illustrate the complexity of the problem. This chapter is an attempt to sort out which of the factors related to milking and the milking machine that contribute to keeping BMSCC low.

Material and methods

The results in this chapter are based on data from 52 LC and 30 HC farms and collected by the technicians on the records described in Chapter 2, Materials and methods.

From the records TecMiT, TecMiM and the Q, 77 variables were included in the analysis. One variable (Teattiphurt) from TecGen was also included. The condition of the teat tip was considered to be an important indicator of milking machine function and milking technique (IDF, 1987; IDF, 1994).

From the TecMiM a number of indexes for various functions of the milking machine were created. One such index is the MilkmachScore, which is a summation of the faults of the milking machine. The higher this index or score, the worse is the milking machine. Another index is the PulsIndex (pulsator index). This is a summation of the number of faults found by the technicians on the pulsators relative to the number of pulsators on the farm. The higher this index, the more faults have been found on the pulsators. A third index, from the TecMiT, is the number of faults in milking technique given the milkers by the technicians - more faults yield a higher index.

The methodology of the study of the milking technique caused much debate in the team that designed the study. It was finally agreed that the milking technique should not be studied openly. Instead, the technicians were instructed to study the work of the farmer "out of the corner of his or her eye" as the technician appeared busy taking measurements of the interior of the barn. It was felt that since the technician was not there at the owner's request the knowledge of being studied with a stop-watch and record probably would alter the farmer's usual routines. This method of study has not yielded precise results on certain aspects of milking technique, such as variations of "prep-time" or machine-on time, but it has given a good general insight in variations of milking technique between farmers on LC and HC farms.

The data were first analyzed univariably, with type of farm as the dependent variable, to screen for differences between LC and HC farms. The statistically significant (p-value: ≤ 0.2) variables in Table 24 were divided in two sets: one with variables related to the milking machine and one with variables related to milking technique and other managerial aspects of milking. The full models thus created were processed in a stepwise, backward elimination logistic regression (Statistixs, 1996), again with type of farm as the dependent variable. The ordinal (3 or 4 scored) variables were dichotomized. For a more extensive description of the statistical analysis, see Chapter 2.

The terminology used is the one suggested by Bramley et al. in Machine Milking and Lactation (1992).

Results

Univariable analysis

Results of the univariable analysis are shown in Table 24. Variables, type of variable (dichotomous, ordinal, continuous), type of statistical test, p-values and indication of odds of being an LC or an HC farm are in the table. The variables have been translated from their abbreviated Swedish form into English.

Milking machine

All farmers had pipeline milking machines except one LC farmer who used bucket milking. All pipeline milking machines were of the highline type except on one LC farm, where they milked in a milking parlor.

There were no statistically significant differences between the vacuum level or the reserve capacity of the vacuum systems, even though numerically more HC farms had underdimensioned vacuum systems, 27 % compared with 21 % of the LC farms. There was, however, a statistically significant difference between the dimensioning of the vacuum airline between the two types of farms

Table 24. Results of the univariable analysis of variables related to milking technique and milking machine. Abbreviations are explained at the bottom of the table. When two p-values are shown, the first is derived from ANOVA and the second from a Kruskal-Wallis equation

Variables **Statistically significant**	**0.05 < p-values ≤ 0.20**	**Statistically NS**
***TecMiM**, General*		
ServTime, ct, KW: 0.009, -		Machinetype
CowNum, ct, KW: 0.005, -		VacuumLevel
Clusternum, ct , KW: 0.01, -		
MilkmachScore, ct, < 0.001/< 0.001, -		
Vacuum and milk transport systems		
Vaclinescore, 3 sc, KW: 0.004, -	Risers, dc, Yc: 0.17, -	Reservliters/min
Milklinem, ct, << 0.001/<< 0.001, +		Reservcapacity
Pulsators		Undulations
PulsIndex, ct, KW: 0.002, -	Pulsmean, ct, KW: 0.12, +	Pulsmax
Pulsdiff, ct, 0.04/0.04, -	Massadiff, ct, KW: 0.18, -	Massamean
Pulsmin, ct, KW: 0.02, -	Limpmean, ct, 0.06/0.07, -	Massamax, -min
Limpmax, ct, 0.03/0.02, -		Massalft, -rht
Limpdiff, ct, 0.02/0.01, -		Massalrdiff
***TecMiT**, Milking Technique*		Limpmin
Drygood, dc, Yc: 0.015, +	Cows/cluster, ct, AN: 0.06, -	Stimulation
Stripcup, dc, Yc: 0.04, +	Checkcluster, dc Fe: 0.07, +	Stimmedsec
Airscore, 3 sc, KW: 0.02, -	Cowcalm, dc, Fe: 0.06, +	Stimrange
OntimeMax, ct, KW: 0.003, -	Man&CowWell, dc, Fe: 0.14, +	PrepMax, -Min
DipTeat, dc, Yc: < 0.001, +		PrepRange
Milkingdiff, dc, Fe: < 0.001, -		Cleancloth, No-
Milktqindex, ct, KW: << 0.001, -		Sharedcloth, etc.
Disturbwork, dc, Fe: 0.03, -		MachineOntime
HireHMilk, dc, Fe: 0.03, -		Udderempty
		Workwhenmilk
TecGen		Talktocow, Pat-
Teattiphurt, 3 sc, KW: 0.008, -		
***Questionnaire**, General*		
DCTno, dc, Fe: 0.02, -	DCTmastitis, dc, Yc: 0.15, +	DCTall, DCT6-9
DCTother, dc, Fe: 0.02, +	DCTselective, dc, Fe: 0.10, +	
Organization of work	MastVet, dc, Yc: 0.07, +	
BothMilk, dc, Yc: < 0.001, +	HireHand, Yc: 0.18, -	TendcowHHA
MrsMilk, dc, Yc: 0.005, +	HireHNum, ct, KW: 0.06, -	TendcowOwnB
FemaleMilk, dc, Yc: 0.04, +	TendCowOwnA, dc, Fe: 0.12, +	
MilkersNum, ct, KW: 0.03, -	MilkOwnA, Fe: 0.2, +	
	MilkHireHA, dc, Yc: 0.06, -	
	MilkHireHB, dc, Fe: 0.12, -	
	TendcowHireHB, Fe: 0.13, -	

Table 24, continued
Attitudes towards cows and dairying
LikeCow, 5 sc, KW: 0.02, +
LikeMilking, 5 sc, KW: 0.008, +
LikeSum, ct, KW: 0.003, +

* Variables with p-values ≤ 0.2 are described in Appendix 3.

Abbreviations used in Table 24: + indicates increased odds of being an LC farm, - indicates increased odds of being an HC farm, AN: analysis of variance, ct: continuous, DCTall: DCT to all cows, DCT6-9: DCT to cows with udder health score 6-9, dc: dichotomous, diff: difference, Fe: Fisher exact test, KW: Kruskal-Wallis, Massa: massage, Prep: preparation before milking, Stim: stimulation, Yc: Yates corrected.

(Vaclinescore, Table 24). Less than 10 % (9.6 %) of the LC farms had underdimensioned vacuum airlines compared with 36.7 % of the HC farms.

The milklines on the HC farms were generally severely underdimensioned (Milklinem, p: << 0.001, Table 24), *i.e.* the diameter was too small relative to the length of the milkline and the number of clusters used. On average, the milkline was 20 meters too long on HC farms while the milklines on the LC farms could have been 19 meters longer, according to the Nordic norm (Statens Maskinprovningar, 1988), see Table 25.

Table 25. Descriptive statistics of length of milkline in meters relative to the Nordic norm. Minus meters means that the installed milkline was longer than the Nordic norm and plus meters that the diameter of the milkline and number of clusters used at milking would have allowed the stated extra meters of milkline

Type of farm	Mean	Min	25 %-ile	Median	75 %-ile	Max
LC	19[a]	-48	-10	16	31	140
HC	-20[b]	-85	-46	-22.5	0	70

* a and b statistically significantly different, p: << 0.001

The farmers on HC farms had more milking clusters than LC farmers. When this result was corrected for herd size the difference disappeared.

The minimum, maximum, mean and median of the pulsation rate, the pulsation cycle and degree of limping[5] of the pulsators were compared between the two types of farms. The differences between pulsators within farm was also analyzed and compared between farms. The condition and function of the pulsators were statistically significantly better at the LC farms (Pulsindex, p: 0.002, Table 24). The differences between pulsation rates of pulsators within farm was statistically

[5] The two pulsation cycles generated by the pulsator are not equal.

significantly larger on HC farms than on LC farms (Pulsdiff, p: 0.04, Table 24) and there was a trend to the same effect regarding the average rate of pulsation cycles (Pulsmean, p: 0.12, Tables 24 and 26).

Table 26. Mean, median, quartiles and range of frequency of pulsation cycles/minute on pulsators on LC and HC farms

Type of farm	Mean	Min	25 %-ile	Median	75 %-ile	Max
LC	57.7	40.7	57.0	58.5	60.0	61.7
HC	56.9	45.6	56.2	57.5	59.0	61.8

There was statistically significantly more limping of the pulsators on HC farms (Limpmax, -diff, -mean) and there was a weak tendency that there was a greater difference between the massage phase (the d-phase) of different pulsators on HC than on LC farms (Massadiff, p: 0.18, Table 24). Descriptive statistics of the d-phase of the pulsators on the two types of farms are in Table 27.

Table 27. Descriptive statistics of the massage phase (d-phase) of the pulsators on LC and HC farms. The numbers express % of full cycle

Type of farm	Mean	Min	25 %-ile	Median	75 %-ile	Max
LC	31.4	24.8	28.0	32.4	34.3	38.7
HC	31.1	26.7	28.5	29.5	33.7	43.1

There were no differences between farms regarding undulations of the milkline and only a very weak tendency that the LC farmers had fewer "risers" (the milk-line is bent 90° upward, to pass some construction detail in the barn). On 16 LC and 10 HC farms undulations were recorded and 9 LC and 10 HC farms had "risers" of the milkline (Undulations and Risers, Table 24). The milking machines on the HC farms had statistically significantly more faults in the overall score than the ones on the LC farms (MilkmachScore, p: <0.001, Table 24).

Milking technique

When judging the milking technique the technicians recorded statistically significantly more clusters on HC than on LC farms. There was a strong tendency that the HC farmers milked more cows with the same cluster (Cows/cluster, p: 0.06, Table 24). When the variable Cows/cluster was dichotomized at 9 cows/cluster there was a statistically significant difference between the two types of farms (p: 0.007), with 1 (2 %) of the LC farms and 5 (17 %) of the HC farms milking more than 9 cows with same cluster.

The LC farmers generally had a better milking technique than the HC farmers (Milktqindex, p: << 0.001, Table 24). There were, however, no differences between the two types of farms as regards stimulation of the milk-let-down reflex or time for preparation of the cow before milking. The LC farmers were statistically significantly more careful when cleaning the udder and teats before milking, however (Drygood, p: 0.015, Table 24). A stripcup was used regularly by 32.7 % the LC and by 10 % of the HC farmers (Stripcup, p: 0.04, Table 24). There were no differences as to the use of separate or shared wet or dry papers or cloths or any other method of cleaning cows teats before milking (Table 28).

The average time the clusters hung on the cows were not statistically significantly different between types of farm (MachineOntime, Table 24). Even though the study of the milking technique was not a true time-study, the technicians were instructed to note when farmers deviated from what is generally considered a reasonable routine. The maximum machine-on time exceeded 11 minutes on any one cow on 3.8 % of the LC and 23.3 % of the HC farms (p: 0.01). The longest machine-on time recorded in this study was 25 minutes on one HC farm (OntimeMax, Table 24).

Table 28. Frequency of method of cleaning udders and teats of cows before milking on LC and HC farms. 52 LC and 30 HC farms

	Type of farm		
Method of cleaning	LC	HC	p-value
One dry or wetted paper or cloth/cow	56 %	50 %	0.8
One cloth or paper per 2 cows	2 %	3 %	1.0
Shared cloth or paper	17 %	17 %	1.0
Straw	2 %	0 %	1.0
Hand alone	17 %	23 %	0.7
No cleaning	2 %	7 %	0.5
Other method	4 %	0 %	1.0
	100 %	100 %	

The human side of milking

There was a strong trend that the LC farmers checked the milking process better than the HC farmers (Checkcluster, p: 0.07, Table 24). They also let in statistically significantly less air when attaching or detaching the clusters (Airscore, p: 0.02, Table 24). There was no difference between the two types of farms as regards whether the milker/-s worked with other things, such as feeding calves or fetching fodder, during milking (Workwhenmilk). It was the subjective opinion of the technicians, however, that the extra work done disturbed the milking process less at the LC farms (Disturbwork, p: 0.03, Table 24). There was also a tendency that the cows were calmer and that "man" and cow worked better together during milking on LC than on HC farms (CowCalm, Man&CowWell, Table 24). The technicians did not detect any differences between the LC and HC farmers in how they talked to or patted the cows during milking.

There were statistically significantly more people and more employed personnel involved milking cows on HC farms (MilkersNum, p: 0.03; HireHMilk, p: 0.03), while the difference in technique and routines between milkers was statistically significantly less on LC farms (Milkingdiff, p: < 0.001, Table 24).

The information obtained by the technicians regarding number and status of people milking cows was corroborated by the owners' statements in the questionnaire. The Q also yielded other more specific information in relation to milking of cows. It was statistically significantly more common that both spouses took part in the work with the animals, both milking and feeding, at the LC farms (BothMilk, p: < 0.001, Table 24). It was also more common on LC than on HC farms that the wife was the person responsible for milking the cows (MrsMilk, p: 0.005). Since some employed personnel, especially on HC farms, were women, the difference between LC and HC farms as regards female milkers was somewhat reduced, although still statistically significantly different between types of farm, if gender of the milker was made the determining factor (FemaleMilk, p: 0.04). The distribution of these variables on LC and HC farms is shown in Table 29.

The LC farmers generally liked cows and the milking of cows more than the HC farmers did (LikeCow, p: 0.02; LikeMilking, p: 0.008; LikeSum, p: 0.003, Table 24). LikeSum is the summation of LikeMilking and LikeCow, see Figure 8. In the figure it can be seen that almost 70 % of the LC farmers are in the three highest scores (8-10) whereas only 37.9 % of the HC farmers rate cows and milking of cows that highly. That difference between farms is statistically significant (p: 0.012).

Table 29. Conditions regarding martial status, gender and employment of persons involved in milking cows on LC and HC farms. 52 LC and 29 HC farms. Figures in percent

	Type of farm		
Personal status or activity	LC	HC	p-value
Both spouses working with animals	55.8	13.8	< 0.001
The wife generally milks the cows	38.5	6.9	0.005
A female generally milks the cows	38.5	13.8	0.04
Hired hand A generally milks the cows	23.1	33.3	0.06

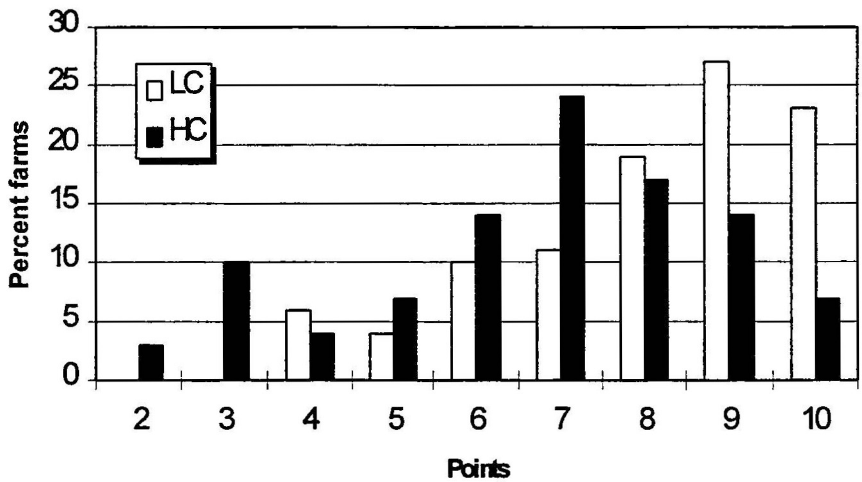

Figure 8. Summation of points given for liking and milking cows by milkers on LC and HC farms. Series statistically significantly different (p: 0.003).

Treatment of mastitis and dry cow therapy

Management of mild cases of mastitis during lactation has been discussed in Ch. 7. There were some differences between the two types of farms regarding the way they treated cows at drying-off. The farmers were presented with a series of suggested measures when drying-off cows that included: use of a long-acting, antibiotic, intramammary preparation (DCT) at drying-off to all cows or to none of the cows and various selective treatments such as using DCT if the cow had had clinical or subclinical mastitis (UHC 6-9) during lactation. The results concerning treatment of cows at drying-off are shown in Table 30. The answers to questions about measures at drying-off were not mutually exclusive.

Table 30. Percentages of LC and HC farmers taking various measures at drying-off. Actions not mutually exclusive. 52 LC and 29 HC farms

Variable	Type of farm LC	HC
DCT* to all cows	7.7	6.9
DCT to no cows	1.9[a]	17.2[b]
DCT to cows treated for mastitis	53.8	34.5
DCT to cows with udder health class 6-9	69.2	72.4
Other action at drying-off or other use of DCT	17.3[a]	0.0[b]

Figure a statistically significantly different from b (p: < 0.02).
* DCT: dry cow treatment with a long-acting, intramammary antibiotic preparation.

Only a minority of farmers treat all cows at drying off. Five HC farmers (17.0 %) and one LC farmer (1.9 %) did not use DCT and statistically significantly more LC farmers suggest some other measure or combination of measures at drying-off than the ones presented in the Q.

Multivariable analysis

The multivariable analysis of variables associated with milking machine and milking technique is divided in two parts. The first model, presented in Table 31, will deal with variables related to the milking machine and the maintenance of it and the second model with milking technique, the condition of teat-tips and the human aspects of milking cows, including treatments for clinical mastitis and at drying off.

Table 31. Full and final models of effects of variables related to the milking machine. Variables in final MiM-model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
Clusternum**	Number of clusters used at milking			
Vacline2**	Score for vacuum airline			
Milklinem***	Length of milkline relative to norm	0.03	17.0	<< 0.001
Risers	90° upward angle of milkline			
PulsIndex**	Index of faults on pulsators	(-0.02	2.8	0.09)
Pulsdiff	Difference in cycles between pulsators			
Pulsmean2	Average of cycle frequency			
Limpmean	Average limping of pulsators			
Massadiff2*	Difference in phase d of pulsation cycle			
ServTime**	Number of months since last service			

Deviance: 88.5; p-value: 0.22; degrees of freedom: 79, constant coefficient: 0.62

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. The asterisks refer to p-values in the univariable analysis.

As can be seen in Table 31, only one variable remains in the final milking machine model: the length of the milkline relative to its diameter and the number of clusters used at milking. The pulsator index gets a p-value of 0.09. All variables related to the milking machine in Table 24 that are not presented in Table 31 (such as Limpmax, Limpdiff and Pulsmin) are too highly correlated with the variables in this latter table. They have been tested into the model when their correlate has been eliminated. Introducing herd size (CowNum) into the model does not alter the model significantly. The model has 4 HC but no LC outliers, a Wilk-Shapiro index of 0.87 and an overall classification of correctly classified farms of 75 %.

The second model in this chapter concerns milking technique, teat apex condition, and relevant human aspects, as mentioned above. The full and final MiT models are presented in Table 32.

MrsMilk and FemaleMilk (a female is responsible for the milking of the cows) are exchangeable in the final MiT-model. BMmilk becomes statistically significant if entered instead of any of these but evicts Cow8cluster2. LikeCow is exchangeable with LikeSum. The final MiT-model presented in Table 32 has 0 LC and 3 HC outlier, 90.1 % of the farms are correctly classified and the Wilk-Shapiro index is 0.78. Cownum has not been entered into the model since it is an intervening variable for MilkHireHA (hired hand A milks the cows). Disturbwork can not enter the model due to co-linearity.

The interpretation of the results presented in Table 32 is that LC farmers practice post milking teat dipping more frequently (DipTeat), that it is more common that the wife of the farmer milks the cows (MrsMilk) and that the spouses share the work with the animals (BothMilk). The LC farmers also like cows and like to milk cows more than HC farmers do (LikeSum). The cows on HC farms have more damaged outer orifices of the teat canal (Teattiphurt2) than the cows on LC farms. Employed personnel milk the cows statistically significantly more often at HC farms (MilkHireHA), the milking technique in general is worse on HC farms (Milktqindex) and more cows are milked with the same cluster (Cow8cluster2).

Table 32. Full and final model of effects of variables related to the milking technique, relevant human factors, teat tip condition, treatment of clinical mastitis and dry cow therapy. Variables in final MiT-model shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
Clusternum**	Number of clusters used at milking			
Cow8cluster2	> 8 cows / cluster	-2.3	4.3	0.038
Drygood**	Careful drying of teats			
Stripcup*	Inspection of milk by use of a stripcup			
Airlittle2	Small amount of air let in			
Airlot2	Large amount of air let in			
Milkingdiff	Difference in routines between milkers			
Ontime2_10	Average machine-on time ≥ 10 minutes			
Checkcluster	Checking clusters during milking			
DipTeat* **	Postmilking teatdip	4.0	10.5	0.001
Man&CowWell	Man & cow work well together			
Cowcalm	Cows are calm during milking			
Disturbwork*	Milking is disturbed by other work			
Milktqindex* **	Number of faults in milking technique	-2.6	15.6	<< 0.001
MrsMilk* **	The wife milks the cows	7.0	17.9	<< 0.001
MilkHireHA	Employee A milks cows	-3.2	6.4	0.011
Milkers≥3_2**	≥ 3 milkers			
Teattiphurt2 **	Condition of teat-tips	3.6	10.9	< 0.001
MastVet	Calling for vet. for mild mastitis			
DCTno*	No DCT to cows			
DCTmastitis	DCT if cow has had mastitis			
DCTselective	Selective use of DCT			
DCTother*	Suggests other DCT			
LikeSum **	Likes cows and to milk cows	0.6	6.2	0.013

Deviance: 34., p-value: 1.00, degrees of freedom: 73, constant coefficient: -6.5

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of univariable analysis.

Discussion

Vacuum fluctuations, especially in combination with liner slip, have been shown to increase infection rate through impact or RPG (Thiel et al., 1969; Thiel et al., 1973; O'Shea et al., 1975; O'Callaghan et al., 1976; O'Shea et al., 1976; Hamann et al., 1980; O'Shea, 1987; Mein, 1990; Baxter et al., 1992, Woolford, 1995). Several conditions, mainly underdimensioned milklines, but also too narrow vacuum airlines on HC farms, predispose for vacuum fluctuations (Statens Maskinprovningar, 1988; Mein, 1990). To the less-than-optimal physical conditions of the milking machine on HC farms is added inadequate milking technique with, among other things, letting in more air when attaching or detaching the clusters, disruption of milking routines because of other work being done during milking, and differing milking routines between milkers (all statistically significant in the univariable analysis). Improper milking technique has been associated with increased rates of IMI both in experiments and under field conditions (O'Shea et al. 1976; Griffin et al., 1982; O'Shea, 1987; Østerås & Lund, 1988[b]; Mein, 1990; Baxter et al. 1992; Baines, 1993). Furthermore statistically significantly more cows, with a higher incidence of subclinical mastitis (Table 5 a, Ch. 3), were milked with the same cluster (Cow8cluster2) without a milking order (Table 12, Ch. 4). This would increase the risk of spreading contagious bacteria to uninfected cows at milking. There was also overmilking on some HC farms, which might have added to the risk factors on these farms.

In this study, pulsator function did not appear as a major contributor to high BMSCC on HC farms (Pulsator index, p: 0.09). This is in accordance with other studies (Erskine et al., 1987; Hueston et al., 1987). Others, however, have found significant effects of pulsator function on cell counts (Hoare et al., 1979; Østerås & Lund, 1988[b]; Hutton et al., 1991). Hoare et al. (1979) found pulsation cycle to significantly influence BMSCC, and Hutton et al. (1991) and Østerås & Lund (1988[b]) associated frequent cleaning and correct rate of regulator cycles with low SCC and low rates of clinical mastitis.

Use of a strip cup did not contribute to low BMSCC on LC farms although it was statistically significant in the univariable analysis. This is in contrast to results of Goodhope & Meek (1980) but in agreement with others (Pearson, et al., 1972; Hueston et al., 1987; Howard et al., 1991; Hutton et al., 1991). The results by Goodhope & Meek (1980) are difficult to explain, as mentioned in the introduction. One possible mechanism is that by finding cows with clinical disease and either putting them at the end of the milking order or treating them with antibiotics or taking some other step to reduce the risk of infecting other cows, one might have an effect on subclinical mastitis. No such actions by the farmers are reported by Goodhope & Meek, however. On the other hand there is the risk, associated with the use of a strip cup, of contaminating the milker's hands with pathogenic bacteria and spreading them to other uninfected cows (IDF, 1987). It is reasonable to expect a low impact on BMSCC of the practice of inspecting the foremilk. The detection level for clinical signs in the milk is well above the level for bacterial contamination due to subclinical mastitis. This has been demonstrated by Meaney (1994), who found that cows often did not show clinical signs of mastitis although they had SCC above 10×10^6 cells/ml.

The effect of post-milking teat-dipping to reduce the prevalence of contagious pathogens such as *S aureus* and hence BMSCC is well documented in the literature (Moxley et al., 1978; Hoare et al., 1979; Lindström, 1983; Hueston et al., 1987; Dargent-Molina et al., 1988; Hutton et al., 1991; Howard et al., 1991; Miller & Bartlett, 1991; Fenlon et al., 1995). The findings in this study that the LC farmers use post-milking TD more frequently than the HC farmers is thus in agreement with the literature. Not all LC farmers teat dip, however. Six, or 11.5 %, of the LC farmers do not practice TD. Since these farmers have a low annual incidence of treatments of clinical mastitis - 5 of them ≤ 10 % and the sixth has an incidence of 13.6 % - and since five of them reduce the risk of new IMI by keeping a strict milking order, it is reasonable that they do not see any need to teat dip. It is quite probable that other LC farmers do not need to teat dip either, but that they do it as an insurance against IMI and/or because they believe in the advice they have been given.

The condition of the teat tips, notably the outer orifices of the teat canals, on cows on HC farms received a statistically significantly lower score than the teat tips on cows on the LC farms. Bad (= low) scores were given for severe smooth or rough hyperkeratotic rings, all degrees of eversion of the teat canal as well as other signs of trauma to the teat canal such as cracks. These symptoms have been associated with overmilking, vacuum fluctuations, increased vacuum levels, faulty liners, high pulsation ratios and insufficient hoof trimming (IDF, 1987; Spencer, 1989; Østerås et al. 1990; Hamann et al., 1994). Most of these conditions, or prerequisites for them - underdimesioned air and milklines for instance - have been shown, either in the uni- or the multivariable analyses, to be present on HC farms. Damaged teat ends, faulty milking technique and malfunctioning milking machines have been associated with increased IMI and elevated cell counts (IDF, 1987; Spencer, 1989; IDF, 1994). The condition of the outer orifices of the teat canals therefore acts as an index for all of these circumstances, plus possibly some that have not been analyzed in this study, such as rough removal of cluster (Griffin et al., 1982).

The influence on udder health by gender of the milker is intriguing. Other authors have found that "working in family" (≈ BothMilk) leads to lower cell counts (Bakken, 1978; Tarabla & Dodd, 1990) although they have not specified the gender of the milker. It is possible that females, through a generally more caring approach to milking and cows, can achieve better results as regards udder health. This would then parallel results by Losinger & Heinrichs (1997) regarding females raising calves better than males, as discussed in the previous chapter. This does not apply to all females or males milking cows, however, as slightly more than 60 % of milkers on LC farms are male and 13 % of milkers on HC farms are female. MrsMilk can be replaced by BothMilk in the final MiT-model (Table 32). Further studies into the deeper psychological characteristics and mechanisms behind these results are warranted. In this context, it should also be noted that the milkers on LC farms like cows and milking more than HC farmers do. It is not hard to understand that a positive attitude towards one's work yields better results. The result in this study that a positive attitude towards cows and milking is linked to better udder health, as expressed by BMSCC, is in agreement with results by Tarabla and Dodd (1990). This positive attitude towards milking by the LC farmers may also be partly responsible for the higher milk production seen on LC farms. Such an association has been demonstrated by other authors (Seabrook, 1984; Tarabla and Dodd, 1990).

It is more common that an employee milks the cows on HC farms. The importance of good milking routines and of employee performance at milking is stressed by several authors (Erven, 1990; Baines, 1993; Sanders, 1993). Motivating employees to consistently do a good job, especially when milking, is a major task for managers of dairy farms (Maddox, 1988; Erven, 1990).

All effects of variations of DCT on the odds of being an LC or HC farm disappeared in the multivariable analysis. It can be seen in Table 30 that very few farmers gave DCT to all cows at drying off. This is not in accordance with recommendations in the 5PP (Dodd et al., 1969; Dodd & Neave, 1970), but is in agreement with Swedish and Danish recommendations (Olsen, 1971; Olsen, 1975; Funke, 1988). Most LC and HC farmers practice selective use of DCT in accordance with these recommendations, either as a sequel to having treated a case of clinical mastitis during the past lactation or because of high cell counts as expressed by UHC. Five HC farmers (17.0 %) don't use DCT at drying off, at least not to an extent that comes close to being regular. This is noteworthy considering the incidence of cows with high cell counts on these farms (Figure 2, Ch. 3). It is likely, however, that this omission does not influence the udder health of the community of HC farmers, even though it most probably affects udder health on the individual farms. It is yet another indication of the level of enlightenment of this group of farmers. That one LC farmer does not use DCT regularly is less surprising. It is also indicative of the level of interest and education that only LC farmers suggested treatments or actions that were not listed in the Q. Treatment of cases of clinical mastitis with mild symptoms have been discussed in Ch. 6.

Conclusions

The milking machines should be well dimensioned to keep BMSCC low. This applies in particular to the diameter of the milkline. It appears to be advantageous to have a greater diameter of the milkline than the current Nordic recommendation. Well functioning regulators are probably helpful if one wants to keep BMSCC low.

A good milking technique is essential in order to achieve low BMSCC. Post-milking TD is a protective factor against elevated BMSCC. It is advantageous to have a female milker and that both spouses actively share the work with the animals. Liking cows and liking to milk cows contribute to keeping BMSCC low. An underdimensioned milking machine and an improper milking technique cause teat lesions that lead to elevated BMSCC. Having employees do the milking is also a risk factor for elevated BMSCC.

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Chapter 8.

The human factor of management of dairy farms

Introduction

Even though most researchers agree that personal abilities, motivations and preferences are paramount for the results obtained on a farm (Muggen, 1969), only very few studies have analyzed the effects of these or of the farmer's psychological traits and/or personality - in short "the human factor" - on BMSCC or other udder health parameters. Dohoo et al. (1984[a]) associated the technically oriented farmer with higher BMSCC and the farmer oriented towards animal care and herd well-being with higher milk production, more services per conception, more digestive disorders and more ketosis. Berry (1994), in a study of low cell count dairy herds, observed" greater care in management standards and extra attention to detail ... in all herds", and Fenlon et al. (1995) found that "Management of high BMSCC herds showed less commitment to implementing mastitis control practices than herds with a consistently low BMSCC." Even if these statements are not very specific about farmer psychology, they say something about the farmers' attitudes towards issues related to udder health.

Farmer education and willingness to attend informational meetings have been associated with udder health. Mein et al. (1977) observed that farmers who were knowledgeable about subclinical mastitis had lower BMSCC. Hutton et al. (1990) and Tarabla & Dodd (1990) found that farmers who attended dairy information meetings or had a general information-seeking behavior, respectively, had lower BMSCC. Socio-demographic factors, such as "working in family" (all or most members of the family take part in the work) the, have been shown to lower BMSCC (Bakken, 1978; Tarabla & Dodd, 1990), as discussed in earlier chapters, whereas the age of the farmer does not seem to influence udder health (Muggen, 1969; Tarabla & Dodd, 1990).

Ravel et al. (1996) observed that the personality of the stock person influenced preweaning mortality and number of piglets weaned, where good results were associated with high self-discipline and low farm performance with exaggeratedly self-assured or sensitive stockpersons. Seabrook (1984) reported that the personality of the dairyman can influence production, but no reference to BMSCC or other udder health parameters is given.

One reason for the relative lack of knowledge about how the psychology and personality of the farmer affects health of his animals is, of course, that it is a complex and therefore elusive factor to measure, as has been discussed by Muggen (1969). This chapter is an attempt to associate various farmer traits and actions with BMSCC.

Material and Methods

The variables in this chapter come from the Q and from the evaluations of farmer/milker personality. The variables from the Q cover areas of socio-demography, organization of work, extent of education and farming experience, score on knowledge variables, reading habits, spare time activities, memberships and activities in associations, and attitudes towards cows and dairying. One-hundred and five variables from the Q and 22 variables from the records of personality profiles were included in the analyses.

In the univariable analysis of variables concerning socio-demographic factors, organisation of work, education/knowledge and attitudes towards cows and dairying the subset of persons mostly responsible for the care and milking of the cows (Owner A) were selected to represent the farm, except on HC farms with employed personnel. On these farms the owner who was regarded as the person responsible for farm policy was selected (52 LC and 29 HC). In the univariable analysis of subscriptions and reading habits, spare time activities and memberships and activities in associations all personal Q's completed by owners/milkers and milkers, 80 LC and 48 HC, were included. Differing results between these two datasets will be shown below. In the multivariable analyses, the subset of 52 LC and 29 HC owners/milkers was used.

The data were first analyzed univariably, with type of farm as the dependent variable, to screen for differences between LC and HC farms. The statistically significant (p-value: ≤ 0.2) variables were analyzed in a stepwise, backward elimination logistic regression (Statistixs, 1996), again with type of farm as the dependent variable. The ordinal (3 or 4 scored) variables were dichotomized. A more extensive description of the statistical analyses is given in Chapter 2.

The personalities of the farmers were scored using the paired personality traits of Seabrook (1984) independently by the technicians and the author. The scoring was done by marking the line between the words making up the pair, on the relative distances between the two words that the scorer thought best corresponded to the evaluated person's personality. The original 18 pairs of personality traits were reduced to 11, mainly because the personnel who interacted with the farmers were not trained to judge people professionally and some of the original pairs seemed too closely related for them to be easily differentiated.

Some, such as ability to persevere or degree of adaptability, seemed too hard to judge after only having talked to a person for some hours. The traits "Easy going", "Sociable" and "Easy to get on with" were called "Company" and were contrasted to "Not wanting company" and the pair "One who keeps quiet - One who speaks his/her mind" was removed in favor of "Not talkative - Talkative". In the Swedish language the pair "Forceful - Giving in easily" was called the English equivalent of "Hard to persuade - Easy to persuade". The technicians scored 41 LC and 24 HC farmers and the author 26 LC and 13 HC farmers. The reason why not all farmers were scored is that this part of the project was introduced during the second year.

The multivariable analyses of the technicians' and author's opinions of the personality profiles of the LC and HC farmers were done separately from the analysis of other variables. The analysis of the results by the technicians followed the usual procedures (Ch. 2). When analyzing the personality profile variables evaluated by the author, only two variables could be present in any one final model. Several different models were therefore tried for p-values of variables and goodness of fit of different models as estimated by overall classification of farms and number of outliers.

Results

Univariable analysis

Results of the univariable analysis are shown in Table 33. Variables, type of variable (dichotomous, ordinal, continuous), type of statistical test, p-values and indication of odds of being an LC or an HC farm are in the table. The variables have been translated from their abbreviated Swedish form into English.

Table 33. Results of the univariable analysis of variables related to the human factor, including socio-demographic, work-related variables and variables describing farmer personality. Abbreviations are explained at the end of the table

Variables:		
Statistically significant	**0.05 < p-values ≤ 0.20**	**Statistically NS**
Socio-demographic variables and organization of work (52 LC & 29 HC)		
OwnAMan, dc, Fe: 0.046, -	HiredHand, dc, Yc: 0.18, -	OwnBornYear
Kidnum, ct, KW: 0.049, +	HiredHNum, ct, KW: 0.06, -	Maritalstatus
BothMilk, dc, Yc: < 0.001, +	TendCowOwnA, dc, Fe: 0.12, +	HHBornYear
MrsMilk, dc, Yc: 0.005, +	MilkHireHA, dc, Yc: 0.06, -	HHMaritalstatus
FemaleMilk, dc, Yc: 0.04, +	MilkHireHB, dc, Fe: 0.12, -	HHKidnum
MilkerNum, ct, KW: 0.03, -	TendcowHireHB, dc, Fe: 0.13, -	TendcowHHA
Milkers≥3_2, dc, Fe: 0.005, -	Reliefreg, dc, Yc: 0.11, +	BarnhoursOwner
Table 33, continued		
ReliefD/Yr, ct, KW: 0.03, +	OthworkHr/Yr, ct, KW: 0.09, -	BarnhoursHH

CowNum, ct, KW: 0.007, -	OwnerVacation, ct, KW: 0.12, -	BarnhoursTotal
		Owneroffdays
		Farmowned
Education/Knowledge (52 LC & 29 HC)		Farmleased
Educ>½yr, dc, Yc: 0.009, +	Course90, dc, Yc: 0.11, +	EducationYear
Schooling, dc, Yc: 0.01, +	Breedother, ct, KW: 0.09, +	CowstartYear
Courselast, ct, KW: 0.04, +		BreedTemper
Breedgrowth, ct, KW: << 0.001, -		BreedMastitis
WordsinQ, ct, KW: 0.001, +		BreedProduction
Qwrong, ct, KW: << 0.001, -		BreedRepro
Unfilledbox, ct, KW: 0.006, -		Misspell
MisspellRatio, ct, KW: 0.017, -		
Attitudes (52 LC & 29 HC)		
Cowwell, dc, Yc: 0.02, +	Ownnegcom, ct, KW: 0.09, -	ProfSame
Milkdelivery, dc, Yc: 0.011, +		ProfForest
ProfShop, Fe: 0.043, -		ProfFactory
LikeSelf, ct, KW: 0.03, +		ProfOffice, -other
LikeCow, ct, KW: 0.02, +		LikeDairyProfit
LikeMilking, ct, KW: 0.008, +		LikeOtherJob
LikeSum, ct, KW: 0.003, +		LikeFood
Ownpluscom, ct, KW: << 0.001, +		LikeOpenLand
Ownneutcom, ct, KW: 0.003, +		Like5year
Tecpluscom, ct, KW: << 0.001, +		Tecneutcom
Tecnegcom, ct, KW: << 0.001, -		
Subscriptions and Reading habits (80 LC & 48 HC)		
	2ndNewspaper, dc, Yc: 0.11, +	1stNewspaper
	ReadLand, dc, Yc: 0.10, -	Agric.Magazines
		Other Magazine
		MagazineSum
		Read/week
		Readmore
		ReadBook
Evening and spare time activities(80 LC & 48 HC)		HUSDJUR A-D
Cultural, dc, Fe: 0.046, +		Newspaper
SpareTimeOther, dc, Yc: 0.04, +		TV, Instrument
		Cardplay
		Outdoor, Family
		Animals, Riding
Memberships and activities in associations (80 LC & 48 HC)		Sports, Hunting
LRF, dc, Fe: < 0.001, +	Dairyassoc, dc, Yc: 0.13, +	VariousFarmersA
Farmek/SCAN, dc, Fe: < 0.001, +	NatureProt, dc, Fe: 0.09, +	ForestA, STF
Livestockassoc., dc, Yc: 0.02, +	TrustPost, ct, KW: 0.2, +	SportsA, OtherA
AssocSum, ct, KW: 0.014, +		

Table 33, continued

***Personality profile** (n in M & M)*		
TecConsiderate, ct, KW: 0.014, +		TecCompany
AutConsiderate, ct, KW: 0.013, +		AutCompany
TecPatient, ct, KW: < 0.001, +		TecTalkative
AutPatient, ct, KW: 0.001, +		AutTalkative
AutIndependent, ct, KW: 0.004, +	TecIndependent, ct, KW: 0.054, +	TecNotWorry
AutCooperative, ct, KW: < 0.001, +	TecCooperative, ct, KW: 0.06, +	AutNotWorry
TecUnmodest, ct, KW: 0.046, +		TecLikeChange
AutConfident, ct, KW: 0.02, +		AutLikeChange
		TecHardpersuade
		AutHardpersuade
		AutUnmodest
		TecConfident

* Variables with p-values ≤ 0.2 are described in Appendix 3.

Abbreviations used in Table 33: + indicates increased odds of being an LC farm, - indicates increased odds of being an HC farm, A: association, Agric: agricultural, ct: continuous, dc: dichotomous, Fe: Fisher exact test, HUSDJUR: agricultural magazine of SHS, KW: Kruskal-Wallis, Like5year: will run a dairy farm in 5 years, STF: Swedish Tourist Assoc., Yc: Yates corrected.

Socio-demographic variables and organization of work

There were no statistically significant differences between age or marital status between the owners on LC and HC farms (OwnBornYear, Maritalstatus, Table 33). On average, the LC farmers had statistically significantly more children, who lived on the farm together with their parents (Kidnum, p: 0.049). There were no statistically significant differences between age, marital status or number of children of employed personnel on the two types of farms (HHBornYear, HHMaritalstatus, HHKidnum, Table 33).

As has previously been described (Ch. 6 & 7), statistically significantly more females (farmers wives) were involved with the animals on LC farms (OwnAMan, BothMilk, MrsMilk, FemaleMilk, Table 33) and were also registered as Owner A. There was a tendency that the HC farmers had more employees and that these were responsible for the milking and rearing of the animals (HiredHand, HiredHNum, MilkHireHA, -B, MilkersNum, Milkers≥3_2, Table 33). All 52 LC farmers registered as Owner A took an active part in the care of the cows and calves, whereas two HC owners did not (TendCowOwnA, p: 0.12, Table 33).

There was no difference between LC and HC farms in the numbers of hours spent working in the barn (BarnhoursOwner, BarnhoursHH, BarnhoursTotal). When the total number of hours-in-barn (BarnhoursTotal) was corrected for herd size (CowNum), however, there was a statistically significant difference, with more hours spent among the animals by the LC farmers/milkers. On average, cows on LC farms had 19 minutes of human contact per day compared with 15 minutes on the HC farms.

The farmers on LC farms used the "Relief service" (a substitute tends the cows and other animals for a couple of days per month) statistically significantly more than the HC farmers, 18.4 and 9.5 days/year, respectively. This did not result in more days off for the owners, however (Owneroffdays, Table 33). The LC farmers had marginally shorter vacations than the HC farmers (OwnerVacation, p: 0.12), 4.6 and 5.9 days/year, respectively. There was a trend that the HC farmers worked more hours off the farm than the LC farmers did (OthworkHr/Yr, p: 0.09, Table 33). There was no difference between the two types of farms depending on whether they were owned or leased (Farmowned, -leased, Table 33).

Education/Knowledge

If all milkers were included in the analysis (80 and 48, respectively) there was no difference in schooling or other formal education between the two types of farms. When only the milking owner or owner (Owner A) was selected to represent the farm, as described above, the LC farmers had statistically significantly more formal, agriculturally related education longer than half a year (Educ>½yr, p: 0.009, Table 33). They had also, to a higher extent, attended an agricultural school of some kind (Schooling, p: 0.01, Table 33). LC milkers had, if all milkers were included, attended an agriculturally related course statistically significantly more recently than the HC milkers (Courselast, p: 0.04). There was a trend that the LC milkers had attended such a course in the 1990s (Course90, p: 0.11, Table 33).

When asked to rank goals, five given and one of their own choice, for breeding dairy cows, the HC farmers statistically significantly more often ranked "high growth rate" higher than the LC farmers did (Breedgrowth, p: $\ll$ 0.001, Table 33), whereas there was a trend that the LC farmers more often suggested something else to breed for (Breedother, p: 0.09). There were no differences between the two types of farms regarding other goals for breeding (BreedTemper, -Mastitis, -Prod, -Repro, Table 33).

The LC farmers used statistically significantly more words in the Q to describe and motivate their actions (WordsinQ, p: 0.001, Table 33 and Figure 9). When the numbers of spelling errors was related to the number of words used in the Q it was seen that the HC farmers had a statistically significantly higher proportion of misspelled words (MisspellRatio, p: 0.017). The HC farmers made statistically significantly more faults and left more boxes empty when filling in the Q (Qwrong, p: << 0.001; Unfilledbox, p: 0.006). These mistakes were corrected as described in Chapter 2.

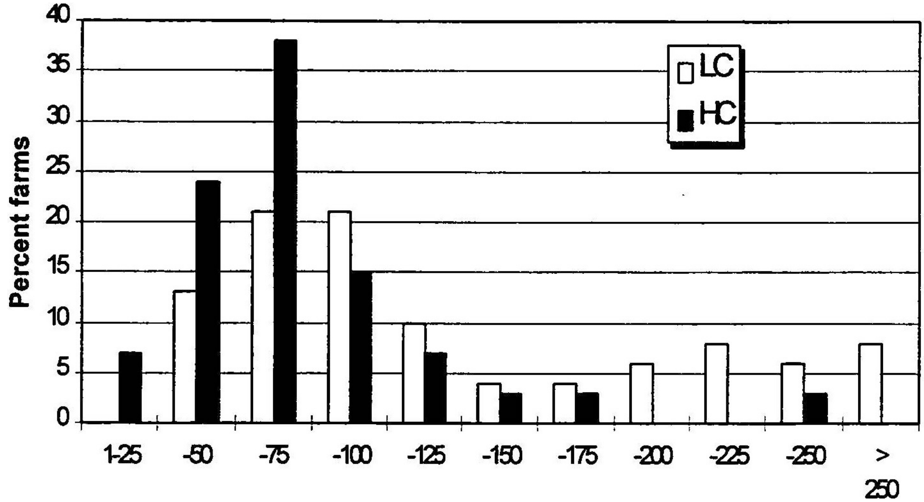

Figure 9. Number of words used in the questionnaire (Q) by 52 LC and 29 HC farmers. LC farmers used statistically significantly more words than HC farmers (p: 0.001).

Attitudes towards cows and dairying

The LC farmers statistically significantly more often than the HC farmers gave the reason that it was for the well-being of the cows that they were let out on pasture (CowWell, p: 0.02, Table 33). They also statistically significantly more often said that, after having treated a case of mastitis, they waited some time extra for the milk to become normal, before they let the milk into the tank (Milkdelivery, p: 0.011, Table 33).

The farmers (52 LC and 29 HC) were asked whether they would choose to become dairy farmers again if they were given the choice or if they would have preferred some other profession. Although the majority of both types of farmers, 89 % of the LC and 79 % of the HC farmers, said that they would have chosen to become farmers again, statistically significantly more HC farmers stated that they would have liked to work in some kind of shop instead of being farmers (ProfShop, p: 0.043, Table 33). They were also asked to grade, independently from 1-5, how they liked milking cows (LikeMilk), generally working with cows (LikeCow), how they rated being a food producer (LikeFood), to keep the landscape open (LikeOpenLand), to be able to decide about the day's work by oneself (LikeSelf), the profitability of dairying (LikeDairyProfit), and how much they would have preferred another job with a salary and regular working hours (LikeOtherJob). They were also asked whether they thought they would still be dairy farmers in five years (Like5year). The LC farmers rated the freedom to decide about the day's work, generally working with cows and milking cows, statistically significantly higher than the HC farmers (LikeSelf, p: 0.03; LikeCow, p: 0.02; LikeMilking, p: 0.008, Table 33). There was no difference regarding the views of the future of dairy farming between the two types of farmers (Like5year). When all milkers (80 LC and 48 HC) were asked the same questions, the results were almost the same. The most notable differences were that wanting another job was rated somewhat higher by the HC milkers (LikeOtherJob, p: 0.18) with 27 % of them giving this a rating of 4 or 5 compared with 14.5 % of the LC milkers, and that liking cows was no longer statistically significantly different (LikeCow, p: 0.07).

What the farmers had written regarding udder health, general management of animals, etc., in the Qs were rated as positive, negative or neutral comments by the author. The LC farmers had written statistically significantly more positive and neutral comments than the HC farmers (Ownpluscom, p: << 0.001; Ownneutcom, p: 0.003; Table 33).

Subscriptions and reading habits

There were only minor differences between the two types of farmers/milkers (80 LC and 48 HC) regarding number of newspapers or magazines that they subscribed to, or their reading habits. There was a trend that the LC milkers had 2 daily newspapers (2ndNewspaper, p: 0.11, Table 33). They were asked to state how many hours they spent reading different newspapers and agricultural magazines per week. There were no major differences between the two types of farmers in this aspect, although the HC farmers claimed to read an agricultural weekly magazine (ReadLand, p: 0.10) somewhat more frequently than the LC farmers/milkers.

Evening and spare time activities

Statistically significantly more LC farmers/milkers (80 LC and 48 HC) stated that they regularly took part in some cultural activity, such as an amateur theatrics society or painting, and the LC farmers/milkers also more often suggested some other activity that was not listed in the Q (Cultural, p: 0.046; SpareTimeOther, p: 0.04, Table 33). When only the owners were included in the analysis, hunting changed from being non-significant (Hunting, Table 33) to being borderline significant (p: 0.07). The ten most common spare time activities are listed in Table 34.

Memberships and activities in associations

The milkers and farmers (80 LC and 48 HC) on LC farms were statistically significantly more often members of agricultural associations, such as LRF (the farmers' union), Farmek and SCAN (farmer-owned slaughter co-operatives) or the local livestock association. They were also members of more organizations/associations, generally, than farmers and milkers on HC farms (AssocSum, p: 0.014, Table 33). When the subset of owners was analyzed, the differences concerning memberships in farmers organizations disappeared. There was a trend that the farmers/milkers on LC farms were members of some environmental or nature protection association to a larger extent than their HC counterparts (NatureProt, p: 0.09) and that they held more positions on boards and the like in the organizations/associations they were members of (TrustPost, p: 0.2).

Table 34. The 10 most common evening and spare time activities practiced by LC and HC farmers and milkers. The activities were not mutually exclusive. 80 LC and 48 HC farmers/milkers

	Type of farm		
Evening activity	LC	HC	p-value
Watching TV	51 %	56 %	0.71
Reading the newspaper	44 %	40 %	0.78
Reading HUSDJUR*	27.5 %	23 %	0.71
Cultural activity	10 %	0 %	0.046
Other evening activity	20 %	17 %	0.81
Spare time activity			
Sports	19 %	19 %	1.0
Doing something with animals, incl. riding	17.5 %	15 %	0.75
Hunting	14 %	17 %	0.84
Doing something with the family	12.5 %	8 %	0.66
Other spare time activity	57.5 %	29 %	0.003

* see legend of abbreviations, Table 33.

Personality profile

The personality profiles of the LC and HC farmers according to the judgment of the author are shown in Figure 10.

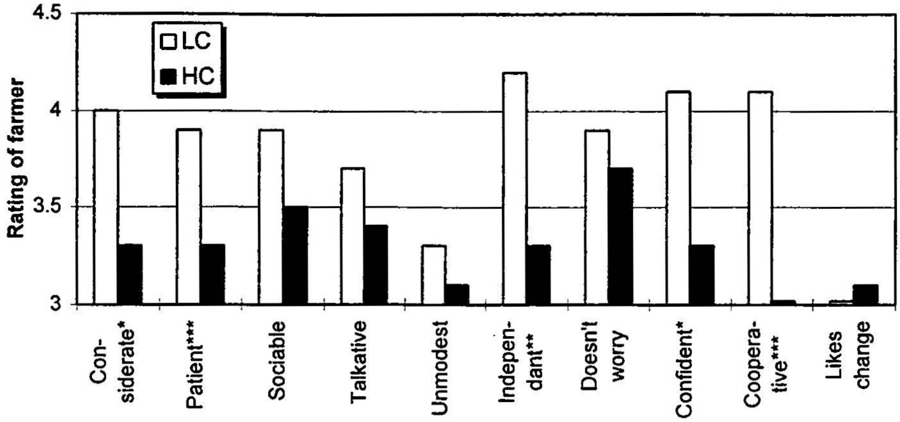

Figure 10. Personality profiles of LC and HC farmers according to the author. Score from 1 to 5. Asterisks refer to results of the univariable analysis.

All personality traits received average scores ≥ 3, which was the mid point between the pairs of words. This was true also for scores given by the technicians. Both types of farmers thus received average or positive scores for all of their personality traits.

Multivariable analysis

Human factors in general

The multivariable analysis of variables associated with the human factor is divided in two parts (Tables 35 and 36). The first model deal with socio-demographic and work-related variables and the second model with the rest of the variables in Table 33. The analysis of the personality profiles is presented below under its own heading.

The first "human factor model" is presented in Table 35. MrsMilk and FemaleMilk can replace BothMilk in the first final "human factor model" without altering it significantly. The first final model has 1 LC and 4 HC outliers. The Wilk-Shapiro index is 0.89 and 76.5 % of the farms are correctly classified. If CowNum is dropped from the model, Kidnum becomes statistically non-significant. Total hours spent in the barn (BarnhoursTotal) is also evicted from the final model and can almost be replaced by BarnhoursOwner, which receives a p-value of 0.054. BothMilk is, in this case, the only remaining variable (p: << 0.001). None of the employee variables can enter the model even in the absence of CowNum.

Table 35. Full and first final model of effects of socio-demographic and work-related variables on BMSCC. Variables in first final "human factor model" shown with coefficients, χ^2 and p-values and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
OwnAMan*	Owner A male			
Kidnum*	Number of children on farm	0.57	4.5	0.034
BothMilk***	Both spouses take part in work	2.32	13.1	< 0.001
CowNum**	Number of cows in herd	-0.12	18.6	<< 0.001
HiredHand	Having employees			
MilkHireHA	Employee A milks the cows			
Milkers≥3_2**	≥3 milkers			
ReliefD/Yr*	Number of days/year with relief staff			
BarnhoursOwner	Number of hours-in-barn/day of owner A			
BarnhoursTotal	Total number of hours spent in barn	0.23	5.9	0.015
OthworkHr/Yr	Number of hours/year on second job			
OwnerVacation	Number of days of vacation/year			

Deviance: 70.3; p-value: 0.66; degrees of freedom: 76, constant coefficient: 1.00

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of the univariable analysis.

The final model of the socio-demographic and work-related variables (Table 35) indicates that the larger number of children living on the farm, the fact that both spouses work together with the animals, and that they spend more time with each cow contribute significantly to the low cell counts on LC farms. Having a larger herd is a risk factor for elevated BMSCC.

The second "human factor model" is presented in Table 36.

The variable "Schooling" can not fully replace "Education for > ½ year" in the second human factor model. If entered, it receives a p-value of 0.051. The final model presented in Table 36 has 2 LC and 3 HC outliers, an overall correct classification of farms of 81.5 % and a Wilk-Shapiro index of 0.91.

The suggested interpretation of the second model is that LC farmers have more formal, agriculturally related schooling, that they have a wider variety of spare time activities and that they statistically significantly more often wait longer than the official withdrawal time, so that the milks looks normal before they send it to the dairy. The HC farmers had statistically significantly more faults in the Q.

Table 36. Second full and final models of effects of human factors on BMSCC. Analysis includes variables covering attitudes towards cows and dairying, reading habits and spare-time activities. Variables in second final model shown with coefficients, χ^2 and p-values

and indicated with bold font. The suffix 2 indicates that the variable has been dichotomized

Variable	Explanation of variable	*Coefficient*	χ^2	*p-value*
Education & knowledge				
__Educ>½yr__**	Agricultural education > ½ year	1.6	5.9	0.015
Course90_2	Taken an agricultural course within 2 years			
WordsinQ***	Numbers of words written in Q			
__Qwrong__***	Number of faults in Q	- 0.4	20.5	<<0.001
Unfilledbox**	Number of unfilled boxes in Q			
MisspellRatio*	No. of misspelled words/No. of words			
Attitudes				
Cowwell*	Pasture is good for cow's well-being			
__Milkdelivery__*	Wait longer if milk not normal	1.8	6.2	0.013
LikeSelf*	Appreciates to decide about working-day			
LikeSum**	Likes cows and milking			
Reading habits				
2:ndNewspaper	Has 2 daily newspapers			
ReadLand	Reads agricultural magazine at night			
Spare time activities				
__SpareTimeOther__*	Does something else in spare time	1.8	7.5	0.006
TrustPost	Holds position on board			
AssocSum*	Sum of memberships in associations			

Deviance: 64.0; p-value: 0.83; degrees of freedom: 76, constant coefficient: -1.61

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Asterisks refer to results of the univariable analysis.

If these two models are merged, only two variables become non-significant, Milkdelivery and SpareTimeOther. The remaining six variables, BarnhoursTotal, BothMilk, CowNum, Kidnum, Educ>½yr, Qwrong are all statistically significant with p-values ranging from 0.03 (Educ>½yr) to << 0.001 (Qwrong). The variables MrsMilk and FemaleMilk can replace BothMilk in this merged model without altering it in a major way.

Personality profiles

The full and final models of the personality profiles are presented in Table 37. In the "final model, technician" only one statistically significant variable remains in the end, TecPatient. TecConsiderate receives a p-value of 0.06 and thus borders on being statistically significant. This model, comprising only Patient, has 0 LC and 2 HC outliers and a Wilk-Shapiro index of 0.87.

Table 37. Full and final models of personality profiles of LC and HC farmers as evaluated by technicians and the author. The prefix "Tec" indicates evaluation by technician

and "Aut" evaluation by author. Variables in final models shown with coefficients, χ^2 and p-values and indicated with bold font

Full model, technicians			*Final model, technicians*		
Variable	Pair of words		*Coefficient*	χ^2	*p-value*
TecPatient* **	Patient -	Impatient	1.6	7.9	0.005
TecConsiderate*	Considerate -	Inconsiderate	(1.0	3.5	0.06)
TecCooperative	Co-operative -	Unco-operative			
TecIndependent	Independent -	Not Independent			
TecUnmodest	Unmodest -	Modest			

Full model, author			*Final model, author*		
Variable	Pair of words		*Coefficient*	χ^2	*p-value*
AutPatient* **	Patient -	Impatient	2.1	12.4	< 0.001
AutConsiderate*	Considerate -	Inconsiderate	2.5	14.5	< 0.001
AutCooperative	Co-operative -	Unco-operative			
AutIndependent**	Independent -	Not Independent	(2.8	10.1	0.001)
AutConfident*	Confident -	Apprehensive	1.9	6.7	0.001

*- p: < 0.05, **- p: < 0.01, ***- p: < 0.001. Number of asterisks refer to p-value of univariable analysis.

Three variables make up the final models in the evaluation of the farmers made by the author, AutPatient, AutConfident and AutConsiderate. Combinations of these three variables yield the best fitting models with the least outliers and the highest overall classification of farms. AutIndependent is also highly statistically significant when it is tried in the models, but the models containing AutIndependent have slightly more outliers and a lower proportion of correctly classified farms.

The interpretation of these result is that personal traits of the owner have influenced udder health as measured by BMSCC. It seems advantageous to be patient. Possibly LC farmers are also more confident, considerate and independent.

Discussion

Four socio-demographic and work-related variables remain in the first final model containing human factors, BarnhoursTotal, BothMilk, CowNum and Kidnum, (Table 35). Bartlett et al. (1992[c & d]) report that increased person-hours/cow increase the risk of IMI with coliforms and that decreased person-hours/cow reduce the incidence of clinical mastitis. These results may possibly apply to the findings concerning incidence of clinical mastitis on LC and HC farms in this study (Table 5 a, Chapter 3) but say nothing about possible effects on BMSCC. The author has found no study reporting effects of person-hours/cow on BMSCC. It seems reasonable, however, that increased contact with humans, if it is pleasant, could contribute to better udder health, in analogy with results by

Seabrook (1984) and Hemsworth (1981). The variable BothMilk again is strongly statistically significant in the analysis, which reinforces results from earlier chapters of the positive effects on BMSCC emerging from the circumstance that both spouses take an active part in the milking and caring of the animals (Chapters 6 and 7). Both of the variables MrsMilk and FemaleMilk can replace BothMilk in the final model. It therefore appears that the sex of the milker can affect udder health as measured by BMSCC. This is in analogy with observations of Hartman et al. (1974) and Losinger and Heinrichs (1997) that females induce less mortality in pre-weaned dairy calves. The result that the LC farmers are prepared to wait longer than the official withdrawal time after having treated a case of clinical mastitis, so that the milk looks normal again when they deliver it to the dairy, is yet another indication of the LC farmers' dedication to uphold high standards of quality and high attention to detail (Berry, 1994).

Number of dependents appears to be associated with udder health on LC and HC farms, with more children living on the farm on LC farms although the average age of the parental generation did not differ between farms. The children were not only younger dependents but also older, who, in some cases, took an active part in the work or were expected to take over the farm. It is not unreasonable that these circumstances can create a situation where the LC farmers feel better motivated in their work. This would be in accordance with a long-standing Swedish tradition of family farming (Nitsch, 1987). The effects of number of dependents on udder health were investigated by Tarabla and Dodd (1990), who could not demonstrate such a relationship, however.

In the review of effects of human factors on farm performance by Muggen (1969), level of education generally had a positive effect, as did years of farming experience and vocational training. Farming experience, measured as number of years of working with dairy cows, did not differ between the two types of farmers in this study (CowstartYear, Table 33), whereas formal, agriculturally-related education longer than 6 months did (Educ>½yr, Table 36). Since the LC farmers/milkers also, in the univariable analysis, had attended more short courses more recently than the HC farmers (Courselast, Table 33) it seems that they generally have a more information-seeking behavior than the HC farmers/milkers. The result that the LC farmers more frequently have a wider variety of spare time activities further reinforces this impression. Information-seeking behavior has been associated with lower BMSCC (Hutton et al., 1990), with higher milk yields, but not with lower BMSCC (Tarabla & Dodd, 1990), and generally with higher farm performance (Muggen, 1969).

The Qs returned by the HC farmers contained statistically significantly more faults than those of the LC farmers. These faults were corrected by telephone, as described in Chapter 2, except for the one Q by an HC farmer that was never returned. The results in the univariable analysis, that HC farmers had more spelling errors per word written, left more boxes blank and used fewer words than the LC farmers, support the general impression that the HC farmers were less interested in dairy farming in general and in taking part in this study in particular. It also supports the result concerning length of education. Furthermore, the results in Chapter 5 concerning HC farmers' opinions of good quality hay, and in this chapter about what would be important qualities to breed for in dairy cows, leave the impression that the HC farmer lack essential items of knowledge that possibly would improve the performance on their farms. Differences in the personalities of the two types of farmers have also been detected that might influence the basic ways in which they function in the environment of the dairy farm. The possibility that the personality of the farmers can influence the health of the cows and calves and the general performance of the dairy farms is in agreement with the results by other authors (Dohoo et al., 1984[a]; Seabrook, 1984; Bigras-Poulin et al., 1985; Tarabla & Dodd, 1990) and in analogy with results of studies on farming of other species (Hemsworth et al., 1981; Ravel et al., 1996).

Conclusions

Having consistently low BMSCC was associated with having more children living on the farm, having an agriculturally-related education longer than 6 months, spending more time with the animals, both spouses working with the animals and doing other chores during milking, and having a female do the milking. Having consistently high BMSCC was associated with less attention to detail, as evidenced by making more faults in the Q, and having a larger herd. Possibly personal traits such as patience, and maybe also being more confident, considerate and independent, help the LC farmers achieve their results.

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Chapter 9.

General discussion

Methodology and validation of results

The methodology of this project can be criticized for possible bias in data collection (information bias) since the technicians and the interviewer knew what kind of farm they were visiting. For practical reasons it is very difficult, if not impossible, to blind a study such as this. Possibly students could have collected the data but that would not have worked since the project needed the expertise and training of the technicians to get good quality data, not just unbiased data. As mentioned in Chapter 2, no other study of this type has been blinded (see also Table 1, Ch. 1). It was decided that it would be better to counteract the risk of information bias by actively discussing this risk with the technicians and to instruct them to act as similarly as possible on the two types of farms. Since the author made visits to the majority of the farms after the technicians had been there it was possible to compare the scoring of the two types of farms. The comparison of scores has not been made systematically for all variables, however, since the author visited the farms up to a year after the visit by the technician and sometimes during a different season of the year. The author has concentrated on the animal-related variables, cleanness, claws, etc., and the more stable of the environmental variables. Since it has not been possible to get estimates that were relevant to compare on a more systematic basis, most often only a subjective estimation of differences have been made. In this process underestimations of differences between types of farm have been detected (Type 2 errors). An example of this is that in one HC barn a wall was loose and threatened to cave in, yet the technician had scored the general status of the barn to be a 2 (Satisfactory) instead of an obvious 1 (Unsatisfactory). Another example is that the two technicians working in the south-western part of the country only had one farm, out of 23, with a low score (in the dichotomized version) of calf cleanness. The impression is that the technicians generally have been conservative with giving the lowest scores regardless of type of farm. No evidence that the technicians have overestimated differences between LC and HC farms has been detected (Type 1 errors).

In order to track systematic errors in scoring of data, a number of checks were built into the study. Some examples: The scoring of cleanness, claw trimming, shearing etc. was done both on individual animals and on different categories of animals judged collectively and on different records. Some scores were nonsense scores such as the one on calf claws (Table 19, Ch. 6). Furthermore, the data collected by the technicians could be checked against statements made by the farmers in the Questionnaire, and vice versa.

No dairyman pays any attention to the claws of the calves and the technicians did not detect a difference in this variable between LC and HC farms. Neither did they register statistically significant differences in body score in any of the categories of animals. Since there have been no indications of severe under- or overfeeding on the two types of farms, this is reasonable. These results and the one regarding cleanness of young stock (Tables 20 and 23, Ch. 6) add credibility to the scoring of the technicians and show that they have indeed practiced individual scoring of animals or categories of animals. Another indication that the technicians have been precise in their measurements and unbiased in their scoring is the result concerning gases (NH_3 and CO_2) in the barn. No statistically significant differences between type of farm were detected, although there were statistically significant differences in the concentration of gases between the two places in the barns that they judged to have the best and the worst quality of air (Table 8, Ch. 4).

Yet another indication that technicians have treated the two types of farmers similarly is the result that the number of neutral comments made by the technicians in their evaluations were not statistically significantly different between LC and HC farms (Tecneutcom, Table 33, Ch. 8).

To check for influence of technician on scoring, an ANOVA was performed on all scores and measurements, with technician as the independent variable. No scores except for the dichotomized versions of status of claws of dry cows (DCclaw) and of claw status in general (CowClaw) were significantly affected by technician. The p-value of technician on the average score of claws of cows sampled and evaluated individually (AveClaw) was 0.72, however. This variable was therefore used as an indicator of trimming of claws. There were no statistically significant differences as regards distribution of LC and HC farms between technicians. The above-mentioned possible overscoring of calf cleanness in one region did not have a statistically significantly effect on the influence of technician on calf cleanness, although that region had the highest average score for calf cleanness.

Selection of farms

The selection method served three purposes, 1: it made sure that the BMSCC had been either low or high for a period of 7 years or more, thus ensuring stable conditions on the farm, 2: a smaller number of farms was needed for the study since the material became polarized, and 3: making sure that an adequate number of farms with poor udder health were included in the study. The personal contact between the farmers and the technicians reinforced this latter effect. Stable farm conditions due to a long observation period of BMSCC were necessary since all farms were visited only once by the technicians. Stable farm conditions meant greater precision in estimates of farm conditions. The method of selection made sure that farmers with poor udder health, as measured with BMSCC, were included in the study in sufficient numbers. High drop-out rates of farmers with less good farm performance have been reported in other studies, as discussed in Ch. 1.

Multivariable analysis and level of statistical significance

Concern may be voiced over the possibility of interpretation and inference of results with so many variables being part of the analyses, as has been the case in the present study. Some statisticians have argued that when multiple comparisons are made one should increase the level of statistical significance, *i.e.* make α smaller in the $1 - \alpha$ expression (an $\alpha = 0.05$ yields a $1 - \alpha = 0.95$, which is the arbitrary level that is commonly accepted as the border between statistically significant and non-significant results). The argument is that this should be done because 5 % of the results (with the aforementioned value of α) obtained may be due to chance alone. Rothman (1986) argues against this way of reasoning, however, and claims that all results should be evaluated on their own merits regardless of whether they are obtained in uni- or multivariable analyses, or with his own words "Therefore, no adjustments for multiple comparisons should be made even if a larger number of comparisons are reported at one time, provided that it is clear how many comparisons have been made and that all 'negative' (that is 'non-significant') results have been reported along with the 'positive' or 'significant' results." In this study, all variables made available to the univariable analyses of data gathered on the LC and HC farms are presented as the first table in Chapters 4-8.

In the multivariable logistic regression some variables have shifted from being non-significant in the univariable analysis to becoming statistically significant. These variables are listed in Table 38. The reason these variables shift from being non-significant to statistically significant is most probably due to confounding with some other variable/-s that have masked their effects. When tried together with relevant group variables they become significant predictors of BMSCC, however. Teathurt is one such variable that interacts with the variables 3teated and Teattiphurt2 (Table 22, Ch. 6). Both of the latter variables become statistically non-significant in the logistic regression shown in Table 22, while Teathurt becomes statistically significant. The variable 3teated, correlates to Teathurt and Teattiphurt2 on the 0.3 level, and 3teated becomes statistically significant when

Teattiphurt2 is removed (Table 23, Ch. 6). Another example is BarnhoursTotal that becomes statistically significant when corrected for herd size (CowNum).

Herd size has emerged in many of the final models as a risk factor for elevated BMSCC. It may be more difficult to control or eradicate contagious pathogens in a herd with a greater reservoir pool. Also, as herd size increases, manure disposal and sanitation problems may make cows more dirty and hence more exposed and/or susceptible to various bacteria (Oz et al., 1985, Schukken et al., 1990[b]; Bartlett et al., 1992[c]). Alternately, herd size may be confounded with management procedures, which may be the true disease determinants.

Table 38. Variables that have shifted from being non-significant in the univariable analysis to becoming statistically significant in the multivariable analysis

Variable	Table/-s	Chapter	Sign of coefficient *
Insulation	12	4	+
HayOnly	17/18	5	+
FeedinDM	17	5	+
Teathurt	22/23	6	-
MastVet	23	6	+
OwnATrim	23	6	-
HireHand	23	6	-
CowMilkDays	24	6	+
Cows8cluster2	32	7	-
MilkHireHA	32	7	-
BarnhoursTotal	35	8	+

* + indicates increased odds of being an LC farm, - indicates increased odds of being an HC farm

The interview

The author interviewed the farmers as described in Chapter 2. No statistical analysis was done on this part of the study, but impressions will be presented in this chapter.

Differences between LC and HC farms

Almost all studies listed in Table 1, Chapter 1, that have compared high and low cell count farms have focused on problem herds. This study has tried to work from the opposite direction. The farms of interest are the low cell count farms and the hypothesis that, all aspects of the management of the farmers together with the environmental conditions on the LC farms result in low BMSCC. It might have been possible to work only with the low cell count farms, and this was suggested by researchers working with qualitative data. The comparison between farms has, however, added insights related to the management of high cell count farms and has made it possible to attach statistical significances to various actions and physical properties on the two types of farms.

All variables from Chapter 4 - 8 that have been statistically significant in the multivariable analyses, are shown in Table 39.

Table 39. All variables, statistically significant in the multivariable analyses in Chapters 4-8. The suffix 2 indicates that the variable has been dichotomized

Variable*	Explanation of variable	p-value	Sign of coefficient**
Environmental variables, Ch. 4			
Daylight2	Amount of daylight let in	0.04	+
Insulation2	Insulation of barn	0.001	+
Rubbermats	Rubber mats installed in stalls	<< 0.001	+
Strawamount2	Amount of straw used in stalls	0.003	+
Stallnotslipp2	Slipperiness of the stall surface	0.024	+
Strawbedding	Straw or sawdust as bedding	0.020	+
DipTeat	Dipping the teats after milking	0.001	+
Milkingorder2	Cows ordered according to SCC	< 0.001	+
Cowcirc	Heart girth	<< 0.001	-
Feed related variables, Ch. 5			
HayOnly	Hay only - no silage	0.021	+
PastH_2O2	Quality of water at pasture	< 0.001	+
TDMHeifer	TDM/day to heifers at peak lact.	0.010	+
Animal and management variables, Ch. 6			
3teated	Percent three-teated cows	0.006	-
Teathurt	Percent cows with traumatized teats	0.003	-
AveClaw	Ave. score of sampled cows claws	0.034	+
AveClean	Ave. cleanness of sampled cows	0.003	+
AveTeatR	Ave. teat length of sampled cows	< 0.001	-
BothMilk	Husband and wife takes part in work	0.021	+
HireHand	Having employees working with cows	< 0.001	-
OwnATrim	Owner A trimming cows claws	0.008	-
MastVet	Calling for vet. at mild mastitis	< 0.001	+
PPturn	Frequency of turning cow with milk fever	0.011	+
Cownum	Number of cows in herd	0.01	-
Deworm≥2	Deworm more than once	<< 0.001	+
CalfClean2	Score of calf cleanness	0.003	+
CowMilkDays	Whole milk to calves	0.004	+
CowTend	Tending to a newly calved cow	0.004	+
FemaleTendC	Female tending to calves	0.024	+

Table 39, continued

Milking machine and milking technique variables, Ch. 7			
Milklinem	Length of milkline relative to norm	<< 0.001	+
Cow8cluster2	> 8 cows / cluster	0.038	-
DipTeat	Postmilking teatdip	0.001	+
Milktqindex	Number of faults in milking technique	<< 0.001	-
Teattiphurt2	Condition of teat-tips < 0.001		-
MrsMilk	The wife milks the cows	<< 0.001	+
LikeSum	Liking cows and milking	0.013	+
MilkHireHA	Employee A milks cows	0.011	-
Socio-demographic, work related and other human variables, Ch. 8			
Kidnum	Number of children on farm	0.034	+
BothMilk	Both spouses take part in work	< 0.001	+
CowNum	Number of cows in herd	<< 0.001	-
BarnhoursTotal	Total number of hours spent in barn	0.015	+
Educ>½yr	Agricultural education > ½ year	0.015	+
Qwrong	Number of faults in Q	<< 0.001	-
Milkdelivery	Wait longer if milk not normal	0.013	+
SpareTimeOther	Does something else in spare time	0.006	+
Personality profile, Ch. 8.			
TecPatient	Patient - Impatient, technician	0.005	+
AutPatient	Patient - Impatient, author	< 0.001	+
AutConsiderate	Considerate - Inconsiderate, author	< 0.001	+
AutConfident	Confident - Apprehensive, author	0.001	+

* Variables with p-values ≤ 0.2 are described in Appendix 3.

** + indicates increased odds of being an LC farm, - indicates increased odds of being an HC farm

In an attempt to create one final model, all variables, except the personality traits, were processed as described in previous chapters. The final model had seven variables, number of cows (CowNum), rubber mats in stalls (Rubbermats), feeding hay only (HayOnly), grouping the cows according to udder health (Milkingorder2), frequent deworming of calves (Deworm≥2), dipping teats post milking (DipTeat) and amount of straw in stall (Strawamount2). A larger herd increases the odds of being an HC farm. The other six variables increase the odds of being an LC farm. These seven variables would be the ones that have the greatest influence on BMSCC. This final model does not have a very good fit, however. The coefficients range from -657.2 - for the equation constant - to 291.3 for DipTeat and the p-values vary from 0.03 to 0.64 in the default test (Wald's test), yet they are highly statistically significant when checked for contribution to deviance. The Wilk-Shapiro index is 0.19. The coefficients jump sharply when variables are taken out of the model. These are indications of co-linearity, which creates an unstable model. This also raises the question if it is meaningful to compare, for instance, number of children with length of milkline or teat dipping with deworming of calves. The grouping of variables done in the preceding chapters seems even more reasonable in the light of this result. The grouping of variables has been an attempt to structure them according to biologically plausible associations, and in order to give the results higher explanatory value in the search for protective factors and possible ways of keeping BMSCC consistently low.

Environmental factors, including dry cow treatments

Of the environmental variables (Table 39), 6 have p-values of less than or equal to 0.01. Of these Insulation may be questioned as to precision in scoring. The technicians had no objective way of measuring degree of insulation but judged it from secondary factors, mainly wet walls and/or water on the inside of windows, and on information from the farmers. The technicians did not visit all farms during similar weather conditions, which also gives space for errors. The slipperiness of the stall surface was also judged subjectively and has a considerable correlation with presence of rubber mats (0.31). The other variables are less affected by prerequisites for scoring errors. The six environmental variables of greatest importance in affecting BMSCC would then be: Rubbermats, Strawamount2, Strawbedding, DipTeat, Milkingorder2 and Cowcirc, the latter being the only variable directly related to higher BMSCC. Three of the six variables (four of seven if Stallnotslipp2 is included) concern different aspects of the stall surface. No variable related to stall area became statistically significant. It therefore appears that the condition of the stall surface, and the amount and quality of the straw are more important for good udder health and a low incidence of trodden teats than length and width of the stall, at least when the stalls are as big as the ones in this study. The possible effects of daylight on BMSCC have been discussed in Ch. 4.

To dip the teats in a disinfecting solution after milking has been a standard recommendation in udder health programs since Dodd & Neave (1970) formulated the Five Point Plan. Dipping of teats together with the other actions recommended has been most successful in reducing cell counts (Schukken et al., 1998). The result found in this study, that LC farmers dip the teats of their cows statistically significantly more frequently than the HC farmers, is thus in agreement with the literature and with current advice. Most of the LC farmers probably keep BMSCC low partly due to the practice of TD. Six (11.5 %) of them did not teat dip, however, yet still managed to keep cell counts low; and 16 (53.3 %) of the HC farmers practiced TD and managed to keep cell counts high. TD must be practiced together with other bacteria reducing measures to be effective (Dodd & Neave, 1970). One must, on the other hand, raise the question of how many LC farmers really needed to TD, since many of them had both a low incidence of clinical mastitis and low BMSCC (Figure 1, Ch. 3). It is tempting to speculate that some of them could have stopped this practice and still would have kept BMSCC low. Possibly this could also have led to a reduction in the incidence of clinical mastitis in accordance with results by Schukken (1990[a]) and Lam (1996). Discontinuation of teat-dipping may, however, lead to an increase in IMI with *S aureus* (Lam, 1996).

Another central element in the 5PP is the treatment of all cows ("blanket" treatment) at drying-off (Dodd et al. 1969; Neave et al. 1969; Dodd & Neave, 1970). Only 4 LC and 2 HC farmers, 7.7 and 6.9 % respectively, practiced blanket dry cow treatment at drying-off, however (Table 21, Ch. 7). The practice of the majority of farmers is thus in accordance with Swedish recommendations (Funke, 1988). One LC and five HC farmers did not practice DCT at all or very rarely (Fe, p: 0.020). Selective dry cow treatment is not statistically significant in the univariable analysis (KW, p: 0.07). All DCT-related variables disappear early in the multivariable analysis if the two management variables DipTeat and Milkinorder are included in the analysis. If these are not included, DCTselective becomes statistically significant, however. It therefore appears that the differences seen in the use of antibiotic treatment at drying-off is not a major factor contributing to the low BMSCC at LC farms and that post-milking TD and segregation of chronically infected cows are more important. Does this mean that we can stop DCT altogether? This study does not answer that question, since it only looks at the farms when they have reached a certain udder health status and does not explain how they got there. It is highly probable that one would have to use antibiotics both for treating suitable cases of clinical mastitis and at drying-off to achieve low BMSCC in a reasonable time and at a reasonable cost. Designing alternate programs to the 5PP in order to cost-effectively lower BMSCC and concomitantly reduce the use of antibiotics, therefore seems an urgent task for future research.

The result in this study, to place the cows with high cell counts so that they are milked last, is in agreement with long-standing advice to dairy farmers, although it was not included in the 5PP, as discussed in Ch. 1. Creating a milking order where the chronically infected cows are milked last is thus one way to reduce the spread of contagious bacteria in dairy herds, thereby lowering the incidence of new infections and then also the need for premature culling and treatment with antibiotics.

Feeding factors

The result that feeding only hay can act as a protective factor against elevated BMSCC, or the opposite - that feeding silage may be a risk factor for elevated BMSCC - is interesting and in agreement with reports in the literature (Johnson & Otterby, 1981). It is likely, however, that the quality of the silage is of importance since the technicians have subjectively judged the silage to be of inferior quality on HC farms. Another possibility is that the association of silage with HC farmers and elevated BMSCC is incidental and due to the personality of these farmers. Providing good quality silage or hay is sometimes a very trying business during Swedish summers. One comment to the question what farmers thought was most important during harvest of hay was "having fair weather".

The finding that the LC farmers could keep the BMSCC low and still feed more TDM and more concentrate, especially to their first lactation heifers, was somewhat of a surprise. It should be noted, however, that the average feeding regime on the LC farms is not very extreme as regards proportion of concentrate compared with some of the really high-yielding farms in Sweden. On average, the proportion of concentrate relative to TDM was around 54 % on LC farms.

The quality of the data concerned with water at pasture has been discussed in Ch. 5. If the technician's estimates of quality of water at pasture are correct it may be of importance to keep BMSCC low. This result is not corroborated by other research, however. In order to draw conclusions from epidemiological studies, support from other studies and plausible biological explanations are needed. One explanation might be that bad quality water induces subclinical mastitis (and sometimes clinical mastitis) via an impaired immune system. The result of the present study concerning effect of quality of water at pasture on BMSCC should, nevertheless, be regarded as hypothesis generating rather than being a definite result.

Animal factors and management of animals, including milking technique

The cows on HC farms obtained poor scores on all three teat parameters, indicating problems with the environment, mainly the amount of straw and condition of the stall surface, with the milking technique and milking machine (Ch. 7), and with teat length. Since the teat canal is probably the most important anatomical and "immune-functional" structure of the cow that protects her from bacterial infections (IDF, 1987; IDF, 1994), these results indicate that the HC farmers have to improve all the mentioned conditions that are within their control in order to improve udder health of their cows.

In the Q, the answers given by the LC farmers indicate that they call for a veterinarian to treat cases of mild clinical mastitis statistically significantly more often than the HC farmers. This is supported by the fact that LC farms have a higher incidence of mastitis treatments, (Table 5 a, Ch 3). It is very likely that the treatments with antibiotics help in shortening the duration of the IMI, thus reducing the risk of new infections, which would lead to lower cell counts (Dodd et al. 1969; Neave et al. 1969; Dodd & Neave, 1970; Funke, 1982; Funke, 1983).

Reducing the use of antibiotics in dairy farming has recently emerged as an urgent task for the veterinary profession (ASM, 1995; Ekman et al. 1995; Kruse et al., 1995; WHO, 1997). Alternate routes must therefore be tried to reach the goals of low BMSCC, low incidence of clinical mastitis, and a reduced use of anti-microbial agents, especially when antibiotics are used more for reasons of economy and production than for animal welfare.

More personnel that milk cows are employed on the HC farms (HiredHand) and the technicians have subjectively judged the milking techniques to differ between different milkers statistically significantly more (in the univariable analysis) on the HC farms. This impression is shared by the author. Results by several authors (Bigras-Poulin et al., 1984; Dohoo et al., 1984[a]; Seabrook, 1984; Ravel et al., 1996) indicate that the personality of the stockperson influences production, mortality and possibly also morbidity of animals. Some people may therefore be better suited to take care of and work with animals than others. This is in agreement with results of the present study, see Ch. 8.

In an attempt to assess the importance of calf management variables in relation to corresponding cow variables, a model was created with the statistically significant variables from both calf and cow management models (Tables 24 and 25, Ch. 6) plus some extra variables indicating good management of cows such as average scores for trimming of claws, shearing and cleanness of cows, as well as treating mild cases of mastitis and herd size. Seven of originally 14 variables remain statistically significant, CowTend, Calfclean2, CowMilkDays, Deworm≥2, Cownum, AveClaw and BothMilk. All these variables have p-values less than or equal to 0.01. Thus, three of the four calf-related variables stay statistically significant. It therefore appears worthwhile to try and establish if there are in fact any direct causal effects on udder health, as measured by BMSCC, of keeping calves clean, feeding them whole milk instead of milk replacer and treating them against intestinal parasites. There are reports that such actions can lead to higher production and better weight gain, as has been discussed in Chapter 6, but no results, as far as the author is aware, indicate effects on udder health.

The milkline

The milkline on the LC farms is, on average, oversized (Table 26, Ch. 7). The dimensioning of the milkline is the only milking machine parameter to stay statistically significant in the multivariable analysis. It is therefore very likely that this plays a major role in keeping BMSCC low on LC farms, as discussed in Chapter 7. It should also be noted that Milklinem stays statistically significant even when corrected for with production and herd size. This is a strong indication that the Nordic recommendations should be adjusted to the higher milk flows and higher production of the modern dairy cow.

The human factor, including the personality profile

The human factors, both the management and the personality of the farmer, obviously play a major role for the production achievements and the economic result of a farm. It is really quite remarkable that agricultural advisors and researchers did not realize this until the 1950s and early 1960s (Muggen, 1969). Some reports had been published earlier but did not have any particular impact (Muggen, 1969). In the present study, management related variables became statistically significant in all aspects studied (Ch. 4-8). In Ch. 4, analyzing effects of the environment, all variables except cow size, insulation and possibly daylight, are management related. Having rubber mats and making sure that they work to keep cows dry and non-slipping, reflects a decision on the farmer's part and his or her work with upkeep and daily cleaning. Furnishing the cows with lots of straw of good quality is management, and so is arranging a milking order and post-milking TD; all very important to protect the cow from trampled teats and new IMI. Even the amount of daylight let in through the windows probably is largely a consequence of the farmer's ambition and actions to keep the barn clean and well functioning. Feeding cows and calves are, of course, also forms of management - the level of feeding and the feedstuffs chosen depend on farmers' decisions. The importance of management could be exemplified from all other chapters, but the repetitious harangue would only bore the reader, and would not add further information.

Two managerial measures recommended by the 5PP are missing among the statistically significant results from the multivariable analyses: inspection of foremilk and treating the cows with antibiotics at drying off. Inspection of foremilk is, if one has access to individual cell counts, probably of lesser importance and not economically worthwhile (Pearson et al., 1972; IDF, 1987; Howard et al., 1991). Checking the foremilk also means opening the teat and possibly contaminating the milker's hands with bacteria from the teat cistern and teat canal. Inspection of foremilk is of no value to diagnose subclinical mastitis as cell counts can reach several million/ml before clinical signs are detected (Meaney, 1994). On the other hand, there is the concern that clinically altered milk of inferior quality would reach the consumer. Use of the strip cup has been identified as a risk factor for clinical and subclinical mastitis in an ongoing Swedish research project (Hallén Sandgren, 1998), and is currently not recommended in the udder health program of New Zealand (Emanuelson, 1998).

Another management factor that is missing among the statistically significant results and one that is often stressed in udder health work, is stimulation of the cow before milking. Of the 46 LC and 22 HC farms where the technicians obtained measurements on the length of pre-milking stimulation, the averages were 5.5 and 7 seconds, respectively. Ninety and seventy-seven percent of the LC and HC farmers, respectively, had stimulation times of less than, or equal to, 5 seconds. Lack of prestimulation has not affected BMSCC in this study. A relevant question, therefore, is if it is really necessary to stimulate today's high yielding, easily-milked cows before milking? One advantage with reduced handling of the cows udder is that spread of contagious bacteria will also be reduced, thus diminishing the risk of new IMI (IDF, 1987). Before such advice can be incorporated in national udder health programs, further research is needed to elucidate these issues.

The LC farmers like cows and like to milk cows. They often work as a couple when taking care of the animals and they spend more time with the cows. There are also more children living on LC farms. All of these circumstances interact to create a higher degree of motivation to do a good job. One common complaint of LC farmers is, however, that they do not receive any encouragement from society or their own organizations. Even if many of them have received diplomas for good quality milk, many would like a system with higher prices for higher quality milk.

The fact that females take such an active part in the work on LC farms is an interesting observation and one that ought to be followed up with research from specialists on psychology, inter-marital relationships, etc. Is it so that males on LC farms have more of a "female attitude" towards animals and caring for animals or is this something that they know or have learned from experience? Or, as one LC farmer said as he patted a calf on the head "This may prove to be time well spent sometime in the future." The care of the animals on LC farms is definitely not only motivated by a devoted love of all living creatures. Most often the behavior of the LC farmers is motivated by rationality.

Strategies of LC farmers

The farmers were interviewed as described in Ch. 2. There were several objectives with the visit to the farm and when conducting the interview, the three main ones being: to check the conditions on the farms at first hand, to check the milking technique of the farmers and to try and find the common denominator among LC farmers to answer the question on how they can keep cell counts consistently low. It was quite easy to interview the LC farmers as they were almost always polite, patient, interested in the study and in dairy cows and pleased that somebody took an interest in what they were doing and thinking on the subject. The LC farmers generally had a clearer understanding of the association between subclinical mastitis and high somatic cell counts and had an ambition to keep them as low as possible. The LC farmers often expressed concern that BMSCC had risen "significantly" - from for instance 60,000/ml to 90,000/ml - on certain occasions and often told stories about what they had done to get them down again. Several LC farmers said, without being provoked or asked, that they thought prevention of disease was important (this is probably one reason why they frequently went out in the evening to check on the cows, CowTend). Many LC farmers said that they thought it was important to keep the stalls dry and well bedded. Those that had hired personnel often emphasized the importance of a good and uniform milking technique.

Interviewing the HC farmers was much more difficult. They were often also patient and friendly but not as informative and hospitable as the LC farmers. The HC farmers rarely expressed concern about the high cell counts. Sometimes they were aware that they had a problem with udder health and either tried to explain the reason why in various ways or asked questions about why they had high cell counts and "if they were contagious". The HC farmers were a more heterogeneous group than the LC farmers and a number of different reasons why they were HC farms could be postulated. These ranged from ignorance and poor management to willfully keeping BMSCC high since "no money was lost". The heterogeneity of the HC farmers is reflected by the number of outliers in the final logistic regression models that were almost always greater than the number of LC outliers. The interviewer often volunteered to take samples for bacteriological analyses and therefore asked where the high cell count cows were (or in some other way tried to get the same information). The LC farmers invariably knew where the "culprits" were - generally at the end of the milking order - and knew where the records were to identify them. The HC farmers rarely knew which cows had high cell counts and quite often did not have their records in order, and generally had the high cell count cows spread throughout the barn.

Five strategies to keep cell counts low

Five strategies developed by LC farmers to keep BMSCC low were identified during the interviews (Ekman, 1994).

1. The "radical culling" method. Some of the LC farmers were prepared to cull 50 % of the cows if necessary to keep BMSCC low. One farmer hated having mastitis cows and said that he preferred to send them to slaughter at once rather than treat them for mastitis.

2. The "intensive treatment" method. Some LC farmers were very keen on calling for a veterinarian to come and treat a cow with antibiotics even for very mild clinical symptoms. About 10 % of the LC farmers treated more than 40 % of their cows for mastitis annually (Figure 1, Ch. 3). Not all of these voluntarily chose to

treat for mastitis, however. Some had a high incidence of cases of acute, clinical mastitis.

3. The "drying-off-infected-teats" method. Some LC farmers - not very many - practiced drying-off of chronically infected teats during lactation as a complement to other measures. They argued that this was a way to reduce the number of infectious glands (and cows) and since these glands did not produce very much milk, the loss of milk production was acceptable.

4. The "pedantry" method. Some LC farmers were very particular about how the cows were treated and milked. This meant, for instance, that they could not take a vacation or let the relief service take care of the animals because they did not trust anyone else to do the job correctly. One such farmer was aware of this dilemma and said, somewhat sadly, that he couldn't do anything about it and that it had meant that his children were not interested in dairy cows or dairying.

5. The loving-your-cows-and-spending-all-hours-among-them method. This is not a large group within the group of LC farmers but it exists. There are, however, some HC farmers that also "love their cows" but they don't have the knowledge or ambition to acquire low BMSCC. This attitude has to be accompanied by knowledge and skills to be effective - just loving cows is not enough.

The latter two strategies are closely linked with the personalities of the farmers and therefore not suitable to market as udder health control programs to farmers in general. Most LC farmers are a mixture of the first two, coupled with the managerial actions and physical factors that have emerged as statistically significant variables in the analyses described in the previous chapters. One other strong underlying reason for the LC farmers to have low cell counts is that they most often have the ambition to keep them low and sometimes have worked hard for many years to get there.

Final conclusions

Ten recommendations to a farmer who wants to keep BMSCC low would be:

1 Fill your barn with pure-bred SRB cows (preferably progeny of sires with a high breeding value for resistance to mastitis).
2 Install rubber mats in all stalls and install them correctly so that they keep dry.
3 Use large amounts of high quality straw and replenish twice daily, so that the bedding is clean and dry.
4 Group your cows in a milking order so that the healthy animals are milked first and the ones with high cell counts are milked last.
5 Base your feeding of roughage on hay. If you use silage be very careful with the harvest and conservation and still feed at least 15-20 % of the roughage DM as hay. Do not feed more than 55-60 % of the total DM as concentrates.
6 Keep your cows clean, well-clipped and with well trimmed claws.
7 Milk your cows with a simple yet physiological technique and keep it the same regardless of milker, time of year and cow.
8 Invest in an over-dimensioned milking system, especially the milkline, that can swallow all the milk from your high-producing cows.
9 Raise your calves well and keep them clean, well fed on whole milk and free of parasites.
10 Find a partner who likes cows and to milk cows and that wants to share the work with you. Raise many children.

But before you do all that take a good look at yourself and consider if you have the necessary interest in dairy cows and calves, and in keeping them healthy, and if you are a patient, confident and sufficiently considerate person.

Future research

Some lines of research have already been mentioned, such as the psychology of the good milker and how women work and interact with dairy cows and calves. Another area of interest is the effect of the health, feeding and well-being of the calf for the level of future performance as a dairy cow. One deficiency of the present study is that it does not address conditions and management of different loose-housing systems and their effects on udder health, preferably measured both as BMSCC and incidence of clinical mastitis. A study corresponding to this one, but looking at udder health of loose-housed dairy cows, is of some urgency. It is also urgent to "fine tune" the advice regarding the optimal milking technique. And then, finally, a new comprehensive udder health program has to be designed that has an holistic approach to udder health, the dairy cow and the dairyman/woman, and that aims at wholesome milk from healthy animals, that do not receive standardized treatments of antibiotics or other chemicals, and that yield good economic returns for their owners.

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