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# Relation of Milk Production Loss to Milk Somatic Cell Count

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**Koldeweij E, Emanuelson U, Janson L: Relation of milk production loss to milk somatic cell count. Acta vet. scand. 1999, 40, 47-56.** – Milk production loss was studied in relation to increased somatic cell count (SCC). Available data were weekly test-day milk yields and SCC (in 1,000 cells/ml), and mastitis incidences. In total, 18,131 records from 274 cows were used. Production loss was determined for test-day kg milk, kg protein, and kg energy-corrected milk. Least-squares analysis of variance was used to estimate the direct effect of $Log_{10}$(SCC) on production. The recorded measures of production were first corrected for fixed effects, with adjustment factors estimated from a healthy data-set.

The average daily milk yield was 19.7 kg/day in first lactation and 22.0 in later lactations. The geometric mean of SCC was 63.1 in first lactation and 107.2 in later lactations. The incidence of clinical mastitis treated by a veterinarian was 19.8% of the lactations-at-risk. Linear relationships were found between the production parameters and $Log_{10}$(SCC). Quadratic and cubic effects were evaluated, but were found to contribute little to the overall fit of the models. The individual milk yield loss was 1.29 kg/day for each unit increase in $Log_{10}$(SCC) for cows in first lactation. Milk yield decreased by 2.04 kg/day per unit $Log_{10}$(SCC) for older cows. Corresponding values for protein yield were 0.042 and 0.067 kg/day for first and later lactations, respectively.

***dairy cows; mastitis; milk loss.***

## Introduction

Efficient herd management is of great importance on the modern dairy farm, especially when there is a surplus of dairy products on the market and production limits are set. In an efficient dairy enterprise it is necessary to minimize costs and maximize returns. Disease management is important in this context since many diseases are known to affect production costs and probably the most serious is mastitis. Costs entailed by diseases can be attributed to veterinary treatment, production losses, reduced slaughter value, and available production factors being idle (*Schepers & Dijkhuizen* 1991). The financial losses caused by reduced milk yield due to diseases, in general, have been calculated in only a few studies. One exception is mastitis, on which many studies have been conducted to estimate the production losses attributable to either clinical (e.g. *Lucey & Rowlands* 1984, *Houben et al.* 1993) or subclinical (e.g. *Dentine & McDaniel* 1983, *Nielen et al.* 1993) disease.

One difficulty in estimating production losses attributable to mastitis is the interrelationship between the incidence of the disease and production level (*Erb* 1987). The problem of estimating production loss is that a measure of milk production is needed that is free from the direct effect of the disease. Therefore, a predicted production measure free from disease or an adjustment of the actual 'diseased' production towards an unaffected measure needs to be obtained (*Solbu* 1988). *Lucey & Rowlands* (1984) used the relationship between consecutive lactations of the same cow, where pairs of lactations in which one was diseased were compared with pairs which were disease-free. *Solbu* (1988) and *Firat* (1993) also used a pairwise comparison of lactations to determine the production losses caused by mastitis. The obvious disadvantage of this approach is that cows with one – or only part of one – lactation, are excluded from the analysis. If there is a relationship between, say, the severity of mastitis and culling, some bias could be introduced. Another method is to use residuals, defined as the difference between the actual and a predicted production (*Lucey et al.* 1986, *Heuven* 1987), where 'abnormal' residuals are used to determine the effect of mastitis. The main problem concerning this method is in selecting the threshold for 'abnormality' as well as getting reliable estimates of the predicted production.

In most studies, monthly production records have been used and production loss was determined on the basis of yield in kg milk. There is considerable variation between different estimates of production losses caused by mastitis. These differences are partly attributable to the origin of the data, e.g. higher losses were found on farms with mastitis problems (*Schepers & Dijkhuizen* 1991). Furthermore, only a few studies (e.g *Houben et al.* 1993) have considered milk component concentrations in relation to production loss.

The objective of the present study was to use weekly records to estimate the decrease in milk production and content, correlated to increased SCC. The production loss was to be determined not only for test-day kg milk, but also for test-day kg protein, and energy corrected milk.

## Materials and methods

### *Data*

Data for this study were collected from cows in the experimental herd of the Department of Animal Breeding and Genetics, Uppsala, Sweden. Only cows with calvings between January 1, 1985 and September 1, 1992 were considered, but production data were available up to August 1993. The breeds concerned were Swedish Red and White (SRB), Swedish Friesian (SLB), and Swedish Jersey (SJB).

Milk yield and composition (fat and protein analyzed by Milkotester/Promilk, Foss Electric, Denmark), and milk somatic cell counts (SCC; analyzed by Fossomatic, Foss Electric, Denmark) and recorded as 1,000 cells/ml) were recorded at weekly intervals. Kilograms of milk per day (KGMILK), kilograms of protein per day (KGPROT), and kilograms energy-corrected milk per day (KGECM) were used as production parameters. The latter was calculated according to *Sjaunja* (1984) as:

KGECM = (91.1*fat% + 58.6*protein% + 39.6*lactose%/750)*KGMILK

Clinical cases of mastitis, i.e. cases that were diagnosed by the herdsmen followed by veterinary treatment, were recorded.

All available data were considered to be the 'complete data-set'. For the process of estimating production loss, another data-set was derived from it consisting of "disease free" observations. This subset consisted of all observations (weeks) in which a) no clinical case of mastitis occurred, and b) the SCC was lower than or equal to 200 (*Dohoo & Morris* 1993). The latter threshold was chosen as to provide observations with low probability of missclassification. These data were considered to constitute the 'healthy data-set'.

The complete data-set had 18,131 records on 274 cows, of which 9,614 observations on 137 cows were from the SRB, 5,116 observations on 85 cows from SLB, and 3,401 observations on 52 cows from SJB. These observations were from a total of 603 lactations (lactations 1 to 9) of which more than a third (n = 220) were lactation 1. The healthy data-set consisted of 13,179 observations from 572 lactations in 267 cows. The distribution of number of cows, lactations and observations over the different breeds was very similar to that of the complete dataset.

*Statistical analysis*

Data from first lactation cows and from cows in lactations >1 were analysed separately, because heifers tend to have a flatter (more persistent) lactation curve than older cows. The recorded production was corrected for fixed effects prior to the analysis of relationship between SCC and production. Adjustment factors were based on the healthy data-set, so that the estimates of these effects were not directly influenced by mastitis occurrence. The resulting corrected production was used to estimate the direct effect of SCC on production.

The estimation procedure was thus carried out in 2 stages. First, using the healthy data-set, the year-season effect and the effects of production level and lactation stage were determined according to the least-squares analysis of variance in the GLM procedure of SAS (*SAS Institute Inc.* 1989). The breed effect and the animal within breed effect were also included in this first stage.

The first stage model (I):

$$Y_{ijkln} = \mu + b_i + a(b)_{ij} + pl_k + ys_l + e_{ijkln} \qquad (I)$$

Y = production

$\mu$ = intercept

$b_i$ = the effect of breed i (i = 1,..,3)

$a(b)_{ij}$ = the random effect of animal j, nested within breed i

$pl_k$ = the combined effect of production level and lactation stage k (k = 1,..,120)

$ys_l$ = the combined effect of year and season l (l = 1,..,34)

$e_{ijkln}$ = random error

There were 120 classes for the combined effect of production level and lactation stage. The production level for every animal was based on the average daily production of 'healthy' (no mastitis and SCC≤200) observations during the first 9 weeks of lactation. The animals were divided into 3 production levels, with thresholds 23 and 31 kg, respectively. Days in milk were divided into 40 lactation stages. The classes were defined as 1-week periods if lactation week fell between the 2nd and the 35th week. The first 2 lactation weeks were considered as one class because of the low number of observations in lactation week 1. Furthermore, 2-week periods were defined between weeks 34 and 43, and 4-week periods between weeks 42 and 51. Weeks in lactation exceeding 51 were considered as one class.

Every year included in the analysis was divided into 4 quarters, so that 34 year-season classes were obtained.

In the second stage, the production parameters were additively corrected for the year-season effect and for the effect of production level – lactation stage as calculated in stage 1. The effect of SCC was thereafter determined as the relationship between the corrected production and the $Log_{10}$(SCC). This analysis was done for the complete data-set and according to the same procedure as for stage 1. The model also contained the effects of breed, and animal within breed.

The second stage model (II):

$$Ycorr_{ijn} = \mu + b_i + a(b)_{ij} + m_m + e_{ijmn} \qquad (II)$$

*Y*corr = production corrected for the *pl* and the *ys* effects
$\mu$ = intercept
$b_i$ = the effect of breed i (i = 1,..,3)
$a(b)_{ij}$ = the random effect of animal j, nested within breed i
$m_m$ = the effect of $Log_{10}$(SCC)
$e_{ijmn}$ = random error

Quadratic and cubic effects of $Log_{10}$(SCC) were also tested.

## Results

*Descriptive statistics*

Milk production and SCC. Table 1 gives means and standard deviations (s.d.) of production parameters and $Log_{10}$(SCC) over the different lactations for the complete data-set. As expected, kg milk yield was lower in lactation 1 than in the other lactations, as was also the average $Log_{10}$(SCC). Cows in lactations >1 had an average $Log_{10}$(SCC) of 2.03 (geometric mean = 107.2), compared with an average of 1.80 (geometric mean = 63) for heifers.

Means and standard deviations for the healthy data-set are given in Table 2. The average milk yield was higher than in the complete data-set, but the level of $Log_{10}$(SCC) was, as expected, much lower. Older cows had an average $Log_{10}$(SCC) of 1.70 (geometric mean = 50.4) compared with 2.03 (geometric mean = 107.2) in the complete data-set.

Mastitis. In the complete data-set, 175 cases of clinical mastitis were recorded and 3,251 observations with high SCC (>300; *Holmberg & Isaksson* 1970). Table 3 sets the incidence of clinical mastitis and high SCC in relation to number of cow-weeks-at-risk and to number of lactations-at-risk. The average incidence of clinical mastitis was 1% of the weeks-at-risk and 19.8% of the lactations-at-risk. High SCC occurred in 17.9% of the weeks and in 72.3% of the lactations. The weekly incidence of high SCC increased with lactation number. Only 11.4% of the weeks in lactation 1 had a high SCC, while 51.5% of the weeks in lactation ≥6 had a high SCC.

Figs. 1 and 2 show the incidence of clinical mastitis and high SCC, respectively, over lactation month for lactation 1 and lactations >1. Many clinical cases were found in the first month of lactation. For example, 55% (lactation 1) and more than 45% (lactations >1) of the cases were found in the first 3 months of lacta-

Table 1. Distribution (mean and standard deviation) of kilogram milk per day, fat%, protein%, lactose%, and SCC over lactation number (lact. no.) for the complete data-set.

| Lact. no. | n[a] | Kg milk | | Fat % | | Protein % | | Lactose % | | $Log_{10}$(SCC) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean(geo[b]) | s.d.[c] |
| 1 | 6,991 | 19.7 | 6.0 | 5.02 | 1.09 | 3.65 | 0.50 | 4.73 | 0.24 | 1.80 (63.1) | 0.53 |
| 2 | 5,204 | 21.5 | 8.3 | 5.04 | 1.20 | 3.64 | 0.54 | 4.60 | 0.27 | 1.89 (77.6) | 0.57 |
| 3 | 3,456 | 22.5 | 9.0 | 5.06 | 1.28 | 3.64 | 0.53 | 4.54 | 0.32 | 2.13 (134.9) | 0.61 |
| 4 | 1,646 | 22.4 | 8.8 | 5.20 | 1.41 | 3.66 | 0.59 | 4.52 | 0.32 | 2.10 (125.9) | 0.55 |
| 5 | 568 | 21.1 | 8.7 | 5.38 | 1.36 | 3.79 | 0.55 | 4.44 | 0.34 | 2.24 (173.8) | 0.60 |
| ≥6 | 266 | 22.9 | 9.0 | 4.77 | 1.11 | 3.53 | 0.37 | 4.45 | 0.30 | 2.42 (263.0) | 0.59 |

[a] Number of cow-weeks-at-risk in the complete data-set.
[b] Geometric mean of the SCC.
[c] s.d. of the $log_{10}$(SCC).

Table 2. Distribution (mean and standard deviation) of kilogram milk per day, fat%, protein%, lactose%, and SCC over lactation number (lact. no.) for the healthy data-set.

| Lact. no. | n[a] | Kilogram | | Fat % | | Protein % | | Lactose % | | $Log_{10}$(SCC) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | (geo[b]) | s.d.[c] |
| 1 | 5,699 | 20.2 | 5.9 | 4.99 | 1.08 | 3.63 | 0.49 | 4.75 | 0.21 | 1.61 | (40.7) | 0.35 |
| 2 | 3,956 | 22.5 | 8.0 | 5.04 | 1.20 | 3.61 | 0.53 | 4.64 | 0.22 | 1.65 | (44.7) | 0.37 |
| 3 | 2,120 | 24.5 | 8.6 | 5.03 | 1.27 | 3.59 | 0.52 | 4.63 | 0.22 | 1.75 | (56.2) | 0.34 |
| 4 | 1,026 | 24.4 | 8.2 | 5.16 | 1.36 | 3.62 | 0.59 | 4.61 | 0.24 | 1.78 | (60.3) | 0.37 |
| 5 | 281 | 23.8 | 7.7 | 5.52 | 1.39 | 3.78 | 0.53 | 4.61 | 0.18 | 1.77 | (58.9) | 0.40 |
| ≥6 | 97 | 26.7 | 7.6 | 4.40 | 1.04 | 3.35 | 0.30 | 4.68 | 0.13 | 1.78 | (60.3) | 0.34 |

[a] Number of cow-weeks-at-risk in the healthy data-set.
[b] Geometric mean of the SCC.
[c] s.d. of the $log_{10}$(SCC).

Table 3. Incidence of clinical mastitis and high SCC (i.e. SCC >300) over lactation number (lact. no.) in the complete data-set.

| Lact. no. | Weeks[a] | Lact.[b] | Clinical cases | | | | High SCC (> 300) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | n[c] | %[d] | nlac[e] | %lac[f] | n | % | nlac | %lac |
| 1 | 6,991 | 220 | 49 | 0.7 | 32 | 14.5 | 799 | 11.4 | 140 | 63.6 |
| 2 | 5,204 | 171 | 39 | 0.7 | 29 | 17.0 | 758 | 14.6 | 115 | 67.3 |
| 3 | 3,456 | 121 | 64 | 1.9 | 39 | 32.2 | 967 | 28.0 | 101 | 83.5 |
| 4 | 1,646 | 61 | 13 | 0.8 | 11 | 18.0 | 388 | 23.6 | 54 | 88.5 |
| 5 | 568 | 17 | 8 | 1.4 | 6 | 35.3 | 202 | 35.6 | 16 | 94.1 |
| ≥6 | 266 | 13 | 2 | 0.8 | 2 | 15.4 | 137 | 51.5 | 10 | 76.9 |
| Total | 18,131 | 603 | 175 | 1.0 | 119 | 19.8 | 3,251 | 17.9 | 436 | 72.3 |

[a] Number of cow-weeks-at-risk.
[b] Number of lactations-at-risk.
[c] Number of cases.
[d] Incidence of cases per 100 cow-weeks-at-risk.
[e] Number of lactations with a case of mastitis.
[f] Incidence of cases per 100 lactations-at-risk.

tion. The high SCC cases were more evenly distributed over the different months in lactation, but with an increased incidence in the first month and toward the end of the lactation.

*Effects on production parameters*

The first stage (model I) determined the combined effect of production level – lactation stage and the effect of year-season on observations which were regarded as healthy. These estimates were obtained for further use in the analyses, and only one example of the results is presented here. Fig. 3 shows the parameter estimates, expressed as deviations from the last class, per production level and lactation stage for lactations >1. The parameter estimates can be seen as additive adjustment factors for KG-MILK at that lactation stage and at that specific production level. A similar trend in parameter values was found for lactation 1.

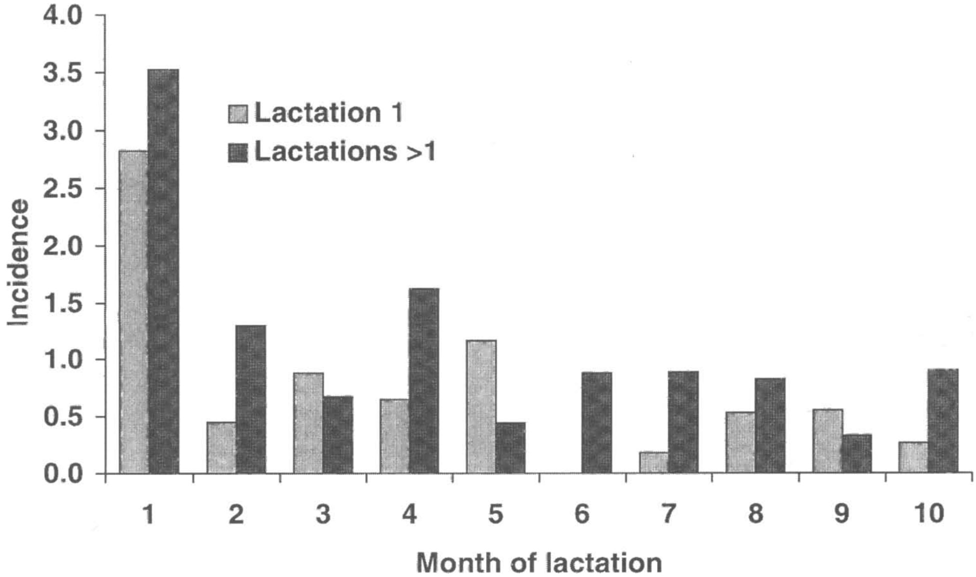


Figure 1. Incidence of clinical mastitis (cases per 100 cow-weeks-at-risk) over lactation months.

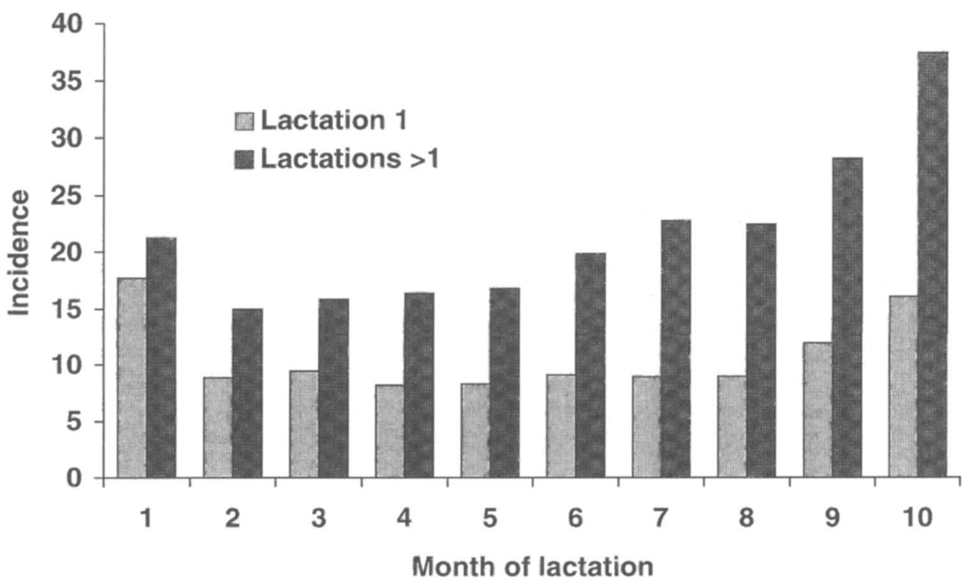


Figure 2. Incidence of high (>300) somatic cell counts (cases per 100 cow-weeks-at-risk) over lactation months.

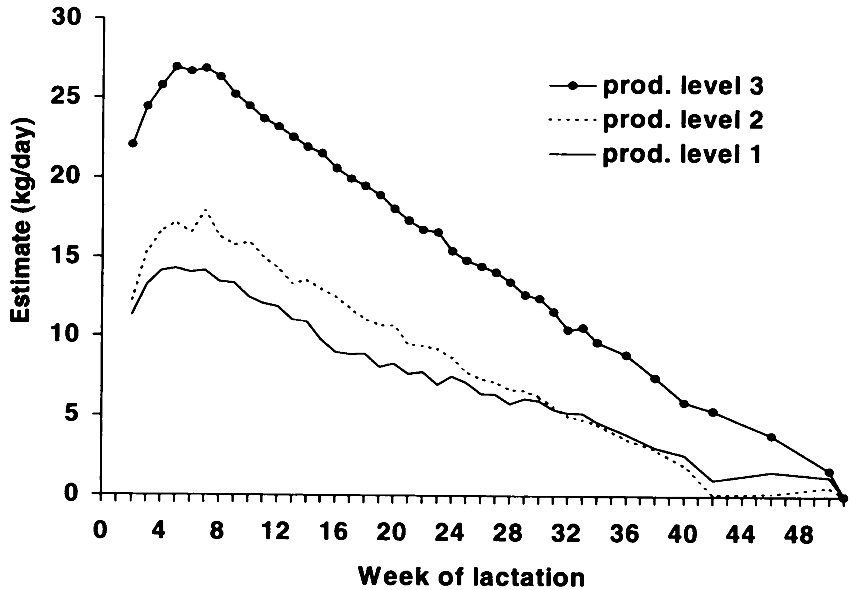


Figure 3. Parameter estimates for test-day milk yield for lactations >1 (Model I).

In the second stage in the analysis (model II) the $Log_{10}$(SCC) was included as a continuous effect. Linear relationships were found between the corrected production parameter and the $Log_{10}$(SCC) for both lactation 1 and lactations >1. KGMILK decreased by 1.29 kg for each unit increase in $Log_{10}$(SCC) in lactation 1, and by 2.04 kg in lactations >1 (Table 4). Quadratic and cubic effects of Log10(SCC) were also tested. They were found to be statistically significant, but even small differences had a significant effect due to the large number of observations. Therefore, the decrease in mean square error (MSE) for the model with the extra effects was tested. The decrease when adding the quadratic and cubic effects was only about 1%. Thus, these effects contributed little to the decrease in MSE and were not included in the final model.

Results for KGPROT and KGECM are also presented in Table 4. The loss in lactation 1 was always less than for cows in lactations >1. Furthermore, the increase in loss from lactation 1 to higher lactations was greater for KGECM than for KGMILK.

## Discussion

Many studies have been performed on the relationship between production loss and mastitis. In our study the production loss was correlated to SCC, as it has been suggested that mastitis

Table 4. Decrease in production in kg/day for the production parameters (KGMILK, KGPROT and KGECM) per unit increase in $Log_{10}$(SCC) for lactation 1 and lactations >1.

| Parameter | Production loss per unit $Log_{10}$(SCC)[a] | |
|---|---|---|
| | Lactation 1 | Lactations >1 |
| KGMILK | −1.29 (± 0.081) | −2.04 (± 0.063) |
| KGPROT | −0.042 (± 0.003) | −0.067 (± 0.002) |
| KGECM | −1.15 (± 0.095) | −2.36 (± 0.074) |

[a] Regression coefficients (± s.e.) as estimated with Model II.

should be described as having quantitative effects (*Dabdoub & Shook* 1984) and SCC might better reflect this. Others have also used SCC and, albeit estimation procedures have varied substantially, our results compare reasonably well. Thus, test-day production loss per unit increase in $Log_{10}$(SCC) has been estimated to between 1.24 and 3.5 kg (*Dohoo et al.* 1983, *Miller et al.* 1983, *Salsberg et al.* 1984, *Bartlett et al.* 1990, *Nielen et al.* 1993). The results of *Tyler el al.* (1989) were one major exception; they found reductions of 7.4 and 4.1 kg for cows in lactations 1 and >1, respectively. It can also be shown that our results are consistent with the 309 to 659 kg loss of 305-d milk yield per unit increase in 305-d mean $log_{10}$(SCC) reported by others (*Raubertas & Shook* 1982, *Dentine & McDaniel* 1983, *Salsberg et al.* 1984), as well as the 6% loss reported by *Deluyker et al.* (1993) over the first 119-d of lactation.

The relationship between milk production and untransformed SCC is not linear (*Raubertas & Shook* 1982, *Jones et al.* 1984). In our study we found that the Log transformation of SCC gave a linear relationship with production, as was also shown for example by *Raubertas & Shook* (1982). It is biologically conceivable, however, that the decrease in production per unit Log(SCC) could be more severe at higher SCC levels. Therefore, quadratic and cubic effects of $Log_{10}$(SCC) were tested in our study, but were not included in the final model because of the small overall contribution of these extra effects. This was true for the full range of SCC values in our study, but further studies with particular emphasis on very low SCC values might be warranted. Instead of including quadratic or cubic effects, a di-phasic grafted regression technique, as applied by *Dentine & McDaniel* (1983), could perhaps give a better fit to the data. They showed that the di-phasic model gave a significantly better fit than did the linear model. The slope was steeper after the grafting point (SCC = 837), indicating a greater loss per Log-unit. The presence of a 'knee' has also been indicated by *Tyler et al.* (1989) and *Deluyker et al.* (1993), although at a much lower SCC value than that of *Dentine & McDaniel* (1983).

In order to obtain a reliable estimate of production loss, the $Log_{10}$(SCC) was correlated to an adjusted production, i.e. the expected production for a given production level – lactation stage and year-season, and not to that actually observed. If the correction factors had been based on the complete data or estimated simultaneously with the loss, as in many other studies, the estimate of production loss would have been biased by the 'non-healthy' animals, and the loss would probably have been underestimated. However, although most 'non-healthy' observations were excluded from the healthy data-set, the risk of underestimating production loss still exists. This is because 'healthy' observations may still be affected by a preceding or following case of clinical or subclinical mastitis, without displaying the 'non-healthy' properties on the sampling day.

One aspect, closely related to this, is selection of the threshold for a healthy data-set. In this study, observations with SCC≤200 and without clinical signs of mastitis, were included in the healthy set. If the threshold is set at a lower level, the observations in the healthy set are less likely to be affected by mastitis and better estimates for the production loss could probably be obtained. A disadvantage of lowering the threshold is of course that more observations will be excluded, but it might be justified as long as the loss of observations is reasonable.

Another possible source of bias has been introduced in some previous studies (e.g. *Miller et al.* 1983; *Emanuelson & Funke* 1991). This is the diluting effect of increasing milk yield on SCC. *Emanuelson & Funke* (1991) found, for instance, that high-producing herds can have a higher prevalence of mastitis compared with low producing herds, with a similar average bulk milk SCC. Since all factors that reduce milk production could have an indirect increasing effect on the SCC, when the total number of cells in the milk remains relatively constant, the production loss related to SCC *per se*, can be overestimated. On the other hand, a loss in milk production, for any reason, indicates a suboptimal production and is therefore always of great importance for an efficient dairy production.

In conclusion, there was a significant reduction in milk production with increasing SCC. The estimated decrease of 1.29 kg/day for young cows and 2.04 kg/day for older cows per unit increase in $Log_{10}$(SCC) is consistent with estimates in the literature. A curvilinear relationship was found to be statistically significant, but was deemed to be of little biological importance.

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**Sammanfattning**
*Samband mellan cellhalt och mjölkförlust.*

Sambandet mellan avkastning och cellhalt studerades på ett material omfattande 18.131 veckovisa observationer från 274 kor på en försöksstation. Avkastningsförluster skattades med minsta-kvadrat metodik för kg mjölk, kg protein och kg energikorrigerad mjölk. I syfte att undvika skattningsfel korrigerades avkastningsuppgifterna, före analys, till en nivå som kunde förväntas för uppgifter som inte påverkats av mastit.
I första laktationen var den genomsnittliga avkastningen 19,7 kg/dag, det geometriska medelvärdet för cellhalt 63,1 1000-tal celler/ml och incidensen klinisk mastit 14,5 fall per 100 risk-laktationer. Motsvarande siffror för äldre kor var 22,0 kg/dag, 107,2 1000-tal celler/ml respektive 22,7 fall per 100 risk-laktationer.
Resultaten visade på ett linjärt samband mellan avkastning och $\log_{10}$(cellhalt). Kvadratiska och kubiska termer undersöktes, men de bidrog mycket lite till modellens förklaringsgrad. Den uppskattade förlusten per enhets ökning i $\log_{10}$(cellhalt) var 1,29 kg mjölk/dag i första laktation och 2,04 kg/dag i senare laktationer. Motsvarande siffror för protein-avkastningen var 0,042 kg/dag respektive 0,067 kg/dag.

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