Dairy cow health and the effects of genetic merit for milk production, management and interactions between these: udder health parameters

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Abstract
Milk production per cow has increased significantly as a result of breeding, feeding and other management factors. High producing cows are often compared with athletes that require special care. Therefore concerns about consequences of high production for animal health are increasing. This study aims to address such concerns and deals with health risks for low and high producing dairy cows. In a 2x2x2 factorial design, HF Heifers (n=100) of high or low genetic merit for milk yield that were milked 2 or 3 times a day and fed a Mixed Ration with high or low energy content were compared during the first 14 weeks of lactation. Milk composition and cell counts were determined weekly, quarter milk bacteriology at 3 and teat condition at 4 time points during the experiment. The experimental factors, especially ration composition, resulted in substantial differences in milk production between treatment groups. The results of this study indicate that ration composition did not affect cell counts, teat condition or bacteriological status of the quarters despite the large effect on milk production. Teat condition was impaired but cell counts were lower whereas bacteriological status was not influenced by increased milking frequency. Cell counts were higher for cows with high genetic merit for production, these cows also had more quarters in which Staphylococcus and less quarters in which other bacteria were found. Teat condition was not related to genetic merit for milk production. The group of animals milked twice daily with a low energy diet and high breeding value had substantially higher cell counts than the other treatment groups.

Introduction
The dairy industry has been very successful in increasing milk production per cow per lactation. Due to the high heritability and well structured information collection in milk recording schemes genetic improvement has contributed very significantly to this development. However, also improvements in feeding (including roughage harvesting and conservation), housing and other management aspects have increased milk production. In the mean time farms are becoming bigger, which means that farmers can spend less time per cow. On the other hand todays dairy cows do not get significantly older than in 25 years ago (), despite the high economic value of stayability. Fertility problems (not becoming pregnant), udder health problems (mastitis, high cell counts) and feet and legs problems are major reasons for culling. A lot of health and fertility problems are at least partly subscribed to negative energy balances in early lactation, and especially high producing cows have the strongest negative energy balances. This has led to concerns in and outside the dairy industry with regard to consequences of high milk production for health and fertility.

Although literature does reveal negative effects of breeding for high milk production on fertility traits (), it is not clear whether this is partly due to inadequate management. It is often speculated that cows with high genetic merit for milk production need other feed, housing and/or health care than cows with relatively low genetic merit. In line with this is the call for specific breeding goals for different farm circumstances, such as organic farming or extensive farming.

To gain more insight in risks for health and fertility problems in relation to milk production level and interaction between genetics and management factors an experiment was set up. The experiment was financed by the Dutch ministry of Agriculture.

Material and methods
In a 2x2x2 factorial design, HF Heifers (n=100) of high (H) or low (L) genetic merit for milk yield that were milked 2 or 3 times a day and fed a Mixed Ration with high (E) or low (S) energy content were compared during the first 14 weeks of lactation. The experiment was carried out at the research farm Nij Bosma Zathe, Goutum, The Netherlands. The experimental setup is in Figure 1.

Figure 1 Experimental setup

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FEEDING LANE		FEEDING LANE
High Energy ration 2* daily milking	MILKING PARLOUR	High Energy ration 3* daily milking
Low Energy ration 3* daily milking		Low Energy ration 2* daily milking
FEEDING LANE		FEEDING LANE

In each of the four treatment groups cows of both low and high genetic merit were kept under the same management conditions, each compartment could house 16 cows. Both the high energy ration and three times a day milking were expected to further increase production. The milking parlour was separately accessible for each group, feed intake was registered individually with RIC. Cows entered and exited the experiment individually, the experiment started in may 2003 and was ended in December 2004. During the experiment the compartments housed both cows that participated in the experiment and fill cows. Cows milked 2*/day were milked at 6:00 and 17:00 hour, cows milked 3*/day were milked at 6:00, 14:00 and 22:00 hour. The available heifers were randomly assigned to one of the four treatments.

Genetic selection

The majority of the animals used in the experiment were bought from commercial dairy farms in the Netherlands between 1 week and 6 months before their first calving, two animals were born and raised on the experimental farm. Selection criteria were an expected breeding value for “inet” of <0 (low) or >140 (high), pure HF pedigree and an acceptable status of the herd of origin for infectious diseases such as BHV and BVD. The latter was in order to prevent the introduction of such diseases in the experimental herd. The availability of animals that fulfilled these criteria was a limiting factor for the experiment, especially for animals with low expected genetic values. Finally we were able to use 56 animals with high expected breeding values and 44 with low expected breeding values. The realised average difference between both groups was €195 inet, which represents about 9 years of selection.

Ration composition

As stated above one of the treatment factors was ration composition. Both rations were fed as a basic TMR with additional concentrates fed in the milking parlour (1.2 kg/cow/day) and concentrate feeders (1.8 kg/cow/day for the low and 6.8 kg/cow/day for the high energy diet). Some characteristics of the rations are presented in Table 1.

Table 1 Ration characteristics

	Low Energy TMR	High Energy TMR
Nutritional parameters		
Crude protein (g/kg DM)	148	166
Rumen protein balance (g/kg DM)	11	13
Net energy lactation (MJ/kg DM)	6.3	6.9
Feed components (% of DM)		
Grass silage	70%	19%
Corn silage		32%
Concentrates	30%	49%

These rations are comparable to rations on extensive Dutch farms with fibrous roughage and rations on intensive Dutch farms with high quality roughage respectively. For each ration different grass silages and concentrates were used to achieve the desired nutritional values, for instance in the low energy TMR more fibrous grass silage was used. Heifers on the Low Energy ration were expected to produce 19 kg of milk/day, the animals on the High Energy ration were expected to produce 31 kg of milk/day (Zom et al., 2002).

Data collection

The experiment was set up to investigate health risks of high milk production, of which udder health was one of the aspects. Milk composition and cell counts were determined weekly in samples from 2 consecutive days. Quarter milk samples for bacteriological culturing were taken at 3 time points during the experiment: weeks 2, 8 and 14. Teat condition was scored as described by Neijenhuis (2004) at 4 time points during the experiment: weeks 2, 6, 10 and 14. From the observations two traits were determined: teat end roughness (yes or no) and teat end callosity(scale 1-5). Furthermore diseases and treatments were recorded if they occurred.

Statistical methods

The data from the experiment were analysed with AS-REML (Gilmour et al., 2004). Fixed effects modelled were:

- μ = mean
- ewk = linear effect of experimental week (1-81)
- lwk = linear effect of lactation week (1-14)
- mf = effect of milking frequency (2/3)
- ra = effect of ration composition (low/high energy)
- gg = effect of genetic group (high/low)

For the treatment factors mf, ra and gg also interaction terms were included in the model. A spline function was added to the model to improve the fit of the effect of experimental week. Furthermore spline functions were added to the model for lactation week and lactation week within treatment. Cow was modelled as a random effect. For traits that were scored for individual teats (teat condition, bacteriology) cow.teat was modelled instead of cow.

Results

Treatments did have effects on milk production as expected, as is illustrated shortly in Table 2.

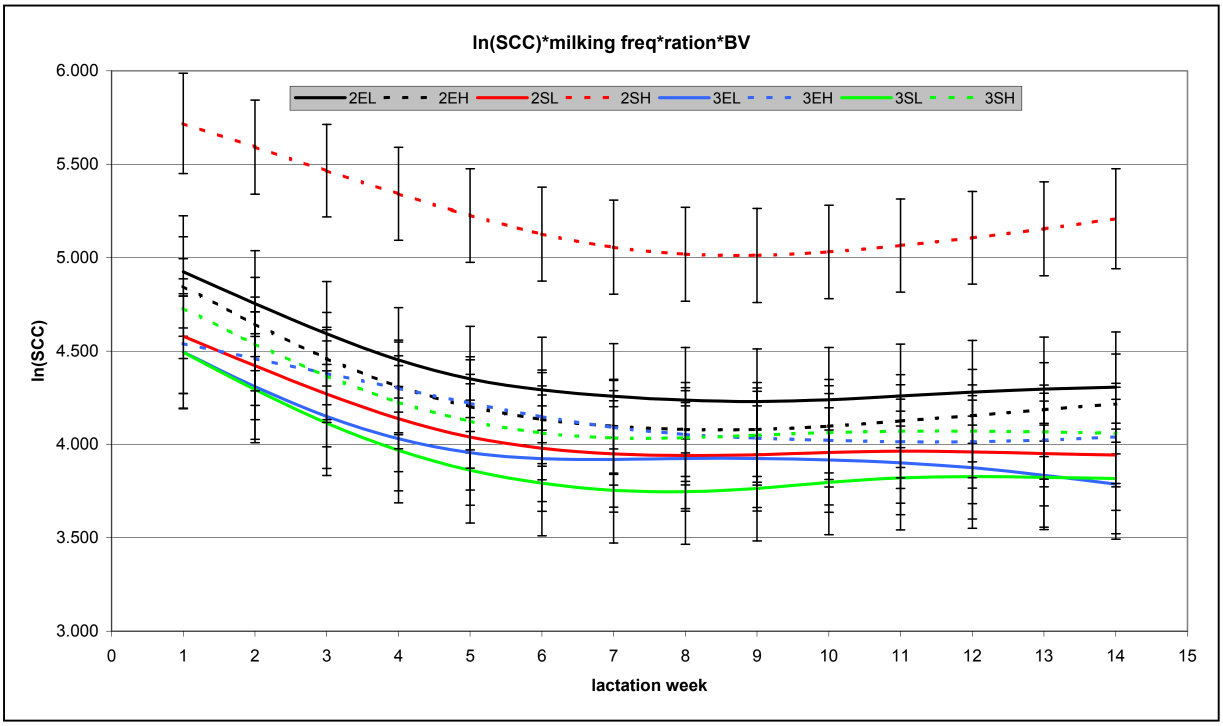
Table 2 Production average per treatment

Factor	Class	kg milk/day	%vet	%eiwit
Genetic group	Low BV milk	24.1	4.27	3.13
	High BV milk	25.6	4.32	3.19
Milking frequency	2*/day	23.3	4.40	3.25
	3*/day	26.5	4.21	3.09
Ration	Low energy content	20.9	4.38	3.05
	High energy content	29.0	4.24	3.24

The cows milked three times /day had more negative Energy Balance (EB) than the animals milked twice. Rations with low energy content resulted in more negative EB than rations with high energy content. Genetic merit did not significantly influence EB, but animals with high BV had nearly significantly more negative EB. More details will be presented by Beerda et al. (2005). All animals that entered the experiment did complete the observation period. During the treatment period three cases of mastitis occurred, all for animals with high breeding values. No differences in mastitis incidence between treatment factors were significant however.

The predictions for ln(cell count) according to the model for all treatments is in Figure 2.

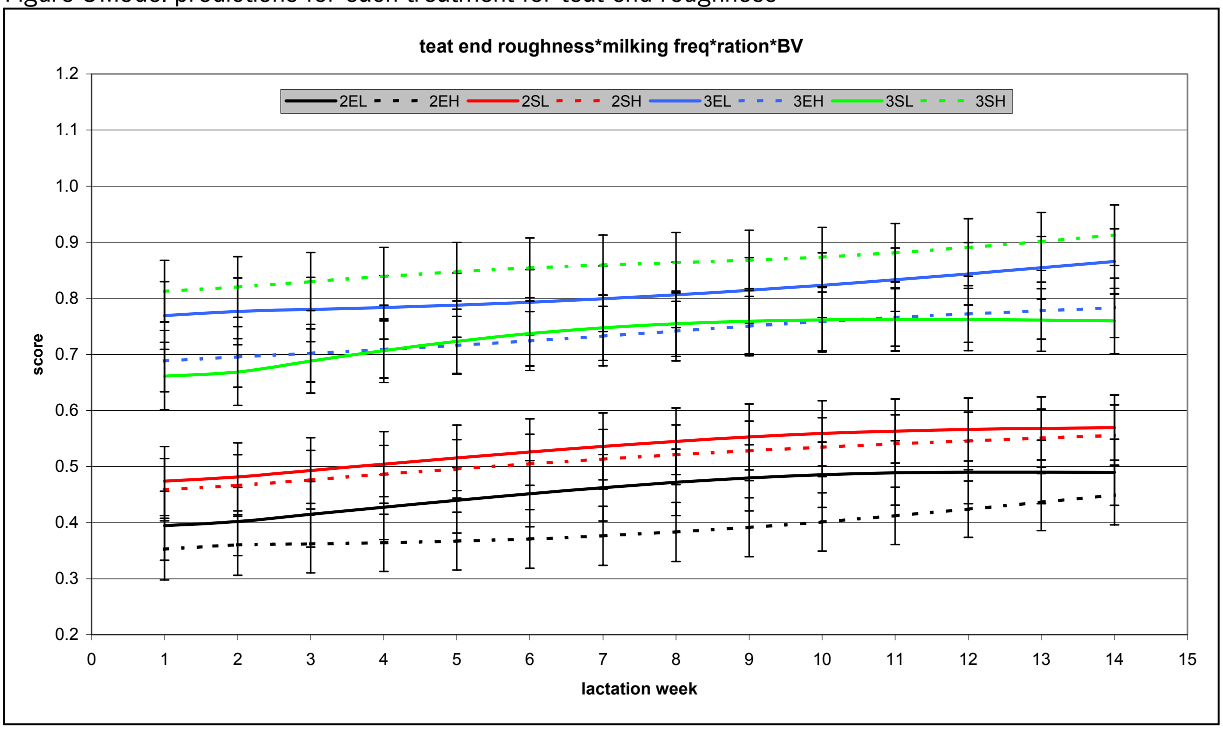
Figure 2 Model predictions for each treatment for cell counts



The analysis of cell counts revealed that ration did not significantly influence cell counts, although the animals on the low energy diet on average had slightly higher cell counts throughout the experimental period. Remarkable was that the cell count difference between rations only appeared for twice daily milking. Twice daily milking resulted in significantly higher cell counts throughout the first 14 lactation weeks than tree times a day milking. Animals with a high breeding value for milk production did have significantly higher cell counts in the first 14 lactation weeks, and this difference was particularly present for animals milked twice daily and for animals on the low energy diet. The group of animals milked twice daily with a low energy diet and high breeding value did differ substantially from the other treatment groups, but none of the interaction terms was significant.

Results for teat condition are judged through teat end roughness and teat end callosity. Model predictions for roughness are in Figure 3.

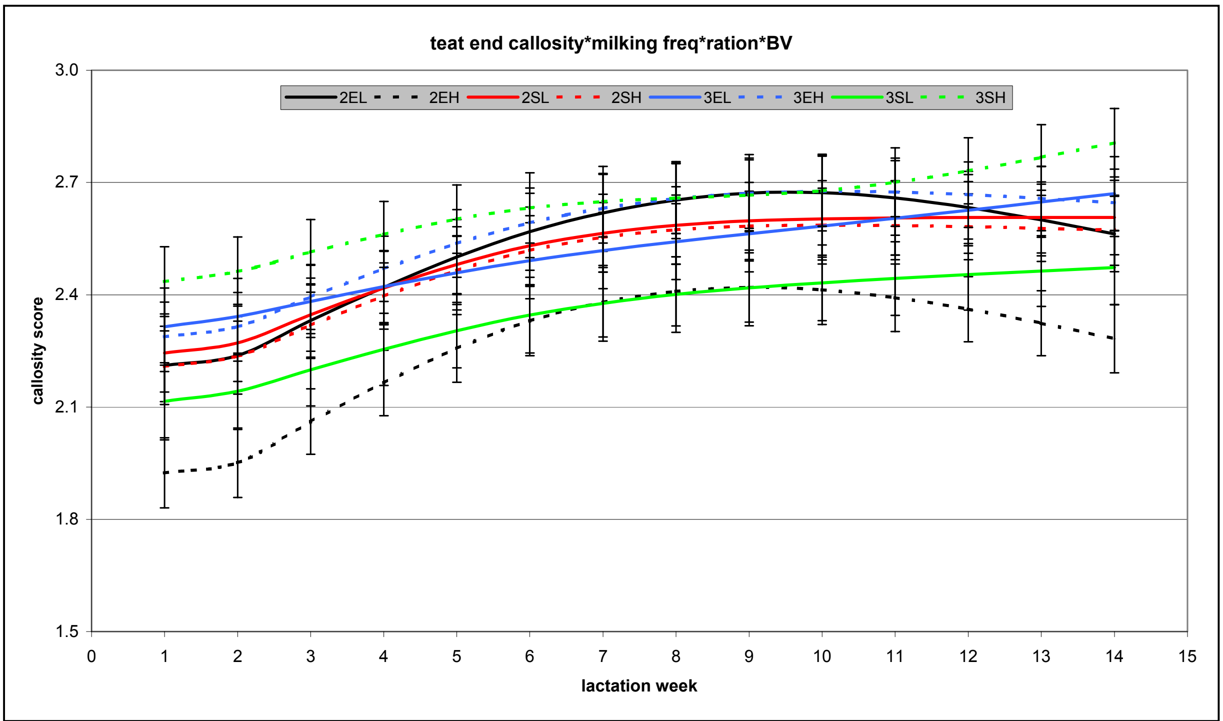
Figure 3 Model predictions for each treatment for teat end roughness



This figure shows a steady increase of roughness in all treatments in the first 14 weeks of lactation. As clearly indicated by this figure the major treatment factor is milking frequency, with more roughness for higher milking frequency. Differences between 2 and 3 times a day milking are already present in the first lactation week and remain more or less constant during the rest of the experimental period. Differences between rations and genetic groups were not significant, but animals on the high energy diet on average had lower roughness scores than the animals on the low energy diet and this difference was nearly significant for the animals milked two times a day and much smaller for the animals milked three times a day. The animals with high breeding values showed nearly significantly higher roughness scores when fed the low energy ration, whereas no difference between genetic groups was found for the high energy ration.

Model estimates for teat end callosity are in Figure 4.

Figure 4 Model predictions for each treatment for teat end callosity



Again a clear influence of lactation stage is shown for this trait, but after 8 to 10 weeks a maximum score is reached for most treatments. Milking frequency was the only significant experimental variable, with more callosity for more frequent milking, particularly in the first and last lactation weeks in the experiment. Despite this, differences between milking frequencies were limited. Ration effects seems to interact with milking frequency: for twice daily milking low energy ration has higher callosity but the opposite is seen with three times daily milking. Likely milking frequency and genetic group and ration and genetic group seem to interact: the animals with high breeding values have lower callosity with twice daily milking but higher callosity with three times daily milking; animals with high breeding values have lower callosity when fed the energy rich ration but higher callosity when fed the low energy ration.

At three points in time during the experiment (weeks 2, 8 and 14) quarter milk samples were taken for bacteriological culturing and determination of cell counts. A remarkable result was that quarter milk cell counts were significantly different for both rations (higher cell counts for low energy ration) and genetic group (higher cell counts for high breeding values), but not significantly different for 2 or 3 times daily milking. The bacteriological culturing resulted in 42% of the samples with no growth, 30% Staphylococcus, 19% Bacillus and a range of other bacteria with low incidence. In the samples of the animals with mastitis actinomyces pyogenes was found. In the samples of the animals with high breeding values more staphylococcus and less other bacteria were found. Differences in results of bacteriology were more pronounced with 2 times/day milking. No relations were found between ration and results of bacteriological culturing.

Discussion

High milk productions per cow can be achieved through more frequent milking and genetic selection, but ration formulation is of particular importance. This experiment showed that these factors did not affect cell counts and teat condition in the same way. More frequent milking was beneficial for cell count, but did impair teat condition and thus as teats can be regarded as first line of defence did increase infection risk (Neijenhuis, 2004). Because of the limited duration of the experiment the impaired teat condition may not have resulted in more infections. It is remarkable that teat end roughness did not seem to stabilise within 14 weeks of lactation, whereas callosity was at is maximum 8 to 10 weeks after calving. The impact of higher milking frequency illustrates that with more frequent milking the technical functioning of the milking equipment is of great importance. It can be assumed that the milking equipment of Nij Bosma Zathe was well maintained. The positive effect of more frequent milking found in this study agrees with results of (Dahl et al. (2004), who even found a beneficial effect of milking 6 times a day in the first 21 days of lactation compared to 3 times. On the other hand Waterman et al. (1983) concluded from an infection trial that milking frequency did not affect udder health, this conclusion was based on the absence of significant differences in new infections for cows milked two or three times a day. The averge cell counts in their trial were also lower for the cows milked three times a day. As is clear from Figure 2 the effect of milking frequency is already present in the first week of treatment and does not chance much thereafter.

In general ration did not influence the udder health parameters studied, this is in line with the results of Sehested et al. (2003), who found no associations between concentrate supplementation level and health. It must be mentioned here that the purpose was that the rations only differed in energy content, and did not introduce any other imbalances. If a lower energy content is accompanied by poor mineral supply or protein deficiency for instance, other results can be expected. It is remarkable that despite the lower protein content of their diet the animals on the low energy ration had higher urea levels in their milk.

None of the animals in this experiment suffered from health problems that could be related to the experimental factors. This indicates that also the animals with high genetic merit do have the capacity to adapt to poor energy supply by limiting their production. Of course a limitation of this experiment is that it is carried out with heifers, who generally are less sensitive to metabolic diseases. The advantage of heifers however is that these animals usually have no history of various diseases and are a relatively uniform group compared to older cows. Despite that the experiment did not indicate clearly negative effects of production stimulating factors, a high milk yield seems to increase metabolic load as indicated by higher levels of pCo2, GLDH and Heart rate (Beerda et al., 2005). The duration of the experiment may have been too short to see negative effects of the increased metabolic load, and it is not unlikely that this phenomenon is responsible for the increase in cell count peaks of high producing cows on high productive herds (Windig et al., 2005).

This study indicated that cows with high genetic merit for milk production had higher cell counts. This is in line with negative genetic correlations between these traits (Sondergaard et al., 2002; Carlen et al., 2004). These higher cell counts generally are regarded as an indication of impaired udder health. Because breeding values for udder health are available nowadays in several countries, the unfavourable genetic trend can be changed through proper selection. On the other hand, herds with low somatic cell counts may have specific risks for clinical mastitis (Beaudeau et al., 2002). The group of high BV animals milked two times a day on the low energy diet according to Figure 2 had substantially higher cell counts than all of the other treatments, although interaction effects were not significant. In this group considerably more animals had very high cell counts than in any of the other groups. We consider this to be an artefact, because the increase is already present from the first lactation week onwards, when treatment is not likely to have had substantial effects. This may have influenced the difference found between high and low BV animals, but only for the animals milked two times a day on the high energy ration the low BV cows had higher ln(SCC) than the high BV cows.

Conclusions

The different factors that influence milk production (milking frequency, ration composition, genetics) have different effects on udder health parameters. Therefore relationships between milk production level and udder health are complex. Ration composition had a large effect on milk production, but did not affect cell counts, teat condition or bacteriological status of the quarters. Teat condition was impaired but cell counts were lower whereas bacteriological status was not influenced by increased milking frequency. Cell counts were higher for cows with high genetic merit for production, these cows also had more quarters in which Staphylococcus and less quarters in which other bacteria were found. Teat condition was not related to genetic merit for milk production. Interactions between management factors and breeding value for milk production were of limited practical importance. This indicates that good udder health is possible with cows with high breeding values for milk production given low energy rations. In general it can be stated that high milk production does not affect udder health of heifers in the first 14 weeks of lactation.

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