Comparison of Feeding Management and Body Condition of Dairy Cows in Herds with Low and High Mastitis Rates

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ABSTRACT

Feeding practices, ration composition, and body condition scores (BCS) were assessed in an observational case-contrast study of Norwegian dairy herds with low ($n = 98$) and high ($n = 94$) mastitis infection rates. Differences between the 2 groups of herds were associated with feeding practices and amount of roughage. More herds in the low-infection group were fed a reduced amount of roughage at drying off, and reduced rations during the dry period resulted in lower BCS at calving. Cows in the low-infection herds had significantly lower BCS in the last month before calving and the first month of lactation than cows in the high-infection herds. The significant associations between mastitis infection rates and BCS, frequency of concentrate feeding, and amount of roughage at drying off and during the dry period indicated that feeding practices may have an important influence on the risk of mastitis in Norwegian dairy cows.

Key words: mastitis, feeding, body condition score, dairy cow

INTRODUCTION

High-yielding dairy cows usually exhibit a negative energy balance after calving, which may influence both the immune system and the metabolic system of the individual (Goff and Horst, 1997). Chronic deficiencies of energy, protein, minerals, or vitamins have repeatedly been associated with increased disease susceptibility as a result of depressed immune function. Because most udder infections occur in the peripartum period, optimal feeding, both in the dry period and during early lactation, may be important in preventing mastitis (Treacher et al., 1986; Gearhart et al., 1990). It seems difficult for the high-producing dairy cow to ingest enough feed shortly after calving to meet lactational demands for energy and protein. Cows with high BCS at calving lose

more condition and achieve positive energy balance later than do cows with lower BCS (Garnsworthy and Topps, 1982; Treacher et al., 1986; Ruegg and Milton, 1995). These findings suggest that there might be differences in the length and severity of the immunosuppressive period after calving, which may influence the risk for mastitis.

Several studies have demonstrated an increased incidence of postparturient diseases, particularly metritis, ketosis, and milk fever, in cows overconditioned during the dry period (Fronk et al., 1980; Treacher et al., 1986; Gearhart et al., 1990; Markusfeld et al., 1997), whereas other studies have reported no detrimental health effects of increased body condition at calving as a result of overfeeding in the dry period (Garnsworthy and Topps, 1982; Boisclair et al., 1984).

Most studies of the association between BCS and postparturient diseases have been based on experiments involving a limited number of individuals. Whether herd-level BCS and other herd factors related to feeding are associated with udder infections has not been fully investigated. The purpose of the present observational case-contrast study was to measure differences in ration composition, feeding routines, and mean BCS in herds with low vs. high mastitis infection rates and evaluate their associations with herd-level udder health.

MATERIALS AND METHODS

The present study was part of a survey on herd factors contributing to good or poor udder health in dairy cows. The study was conducted in the counties of Trøndelag, Møre and Romsdal, and Rogaland in the southern part of Norway.

Selection of Herds

Two groups of herds with stable low or stable high new infection rates of mastitis (**NEWINF**) were randomly selected based on data from the Norwegian Dairy Cow Recording System (**DCRS**). Selection of herds was based on data for three 1-yr periods from July 1, 1995, through

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Table 1. Distribution of the study population and 3-step selection according to herd size for Norwegian dairy herds with at least 10 cow-years and production level per cow-year of 6,000 kg or higher

Herd size (cow-years)	Quartile	Population size	Selected herds (n)					
			Step 1		Step 2		Step 3	
			Low ¹	High ²	Low	High	Low	High
10 to 12.5	1	1,021	59	54	28	26	26	26
12.6 to 14.8	2	1,072	56	51	33	24	28	24
14.9 to 18.5	3	1,065	52	62	25	23	20	22
18.6 to 101.1	4	1,061	58	58	27	26	24	22
Total		4,219	225	225	113	99	98	94

¹Low-infection group (mastitis).²High-infection group (mastitis).

June 30, 1998. To be eligible for inclusion in the study, the herd size had to be a minimum of 10 cow-years with an annual production level of at least 6,000 kg of milk per cow-year. To reduce the traveling costs, the study was limited to the counties of Trøndelag, Møre and Romsdal, and Rogaland. According to the DCRS, 48% of the Norwegian dairy herds that met the criteria for inclusion in the study were located in these areas.

Selection of Herds: Step 1. To ensure an even distribution of herd sizes, the population was divided into 4 equally sized groups, corresponding to the first, second, third, and fourth quartile cow-years (Table 1). From each group, we selected the upper 10% (high-infection group) and the lower 10% (low-infection group) according to the average annual NEWINF. The NEWINF was the number of new infections per 100 cows sampled, based on milk control samples during the study period. New infection rate was defined as a conversion of individual (composite) SCC from <200,000 to >200,000 cells/mL or an event of mastitis treatment if the previous SCC for the particular cow was <200,000 cells/mL (Valde et al., 2005). To be in the high-infection group, the herds also had to be above the median in average reported cases of clinical mastitis (CM) per 100 cow-years in the 3 yr preceding the study and among the upper fourth according to the previous year's NEWINF. To be in the low-infection group, the herds had to be below the median in average reported cases of CM and among the lower fourth according to the previous year's NEWINF. From each of these 2 groups, 225 herds were randomly selected for inclusion in the study.

Selection of Herds: Step 2. All the farmers were contacted first by mail and then by phone. Those who had made changes to their barn, milking equipment, or management procedures after July 1, 1995, were excluded from the study. Seventy-four (32.9%) and 57 (25.3%) herds from the high- and low-infection groups, respectively, were excluded for this reason. Excluded also were farmers who refused to participate or who

had stopped milk production and those who had been involved in a mastitis prevention program during the period [52 (23.1%) from the high-infection group and 55 (24.4%) from the low-infection group].

Selection of Herds: Step 3. The calculated NEWINF was influenced by the frequency of individual cow SCC measurements in each herd (Valde et al., 2005). To compare herds with different numbers of individual milk samplings (N-SAMPLING), NEWINF was corrected according to N-SAMPLING by calculating the adjusted new infection rate (ADJ-NEWINF). Adjusted-NEWINF was calculated by using the following formula (Valde et al., 2005):

$$\text{ADJ-NEWINF} = \text{NEWINF} - 7.28 \times \text{N-SAMPLING} + 0.17 \times \text{N-SAMPLING}^2 + 37.54.$$

Herds that did not meet the criteria for NEWINF after adjustments were excluded from the statistical analyses. A total of 192 herds, 98 from the low-infection group and 94 from the high-infection group, were included in the statistical analyses. Low-infection herds, regarded as cases, and high-infection herds, regarded as controls, were coded 1 and 0, respectively.

Collection of Data

All farms were visited once by 1 of 2 technicians during the study period from March 2, 1999, through February 24, 2000. These technicians did not have any information regarding which farms belonged to the high-infection group and which belonged to the low-infection group.

Data on ration composition and feeding routines were collected by means of a questionnaire that was sent to the farmers prior to the visit. The questionnaire was collected and checked on the day of the visit, and any missing information was added. A summary of the variables included in the analyses is shown in Table 2.

Table 2. Summary of feeding variables included in the analyses of differences in nutrition and feeding management between herds with low and high incidence rates of mastitis

Variable
Ration composition
Type of roughage: ensiled forage vs. bales
Whey as part of feeding: yes vs. no
Use of hay as part of the ration: yes vs. no
Use of straw as part of the ration: yes vs. no
Mineral supplementation during lactation: yes vs. no
Management related to feeding
Two-step harvesting: yes vs. no
Preserving agent in silo: formic acid vs. other
Roughage analyses: yes vs. no
Cleaning of silo: yes vs. no
Lactating cows on pasture during the summer: yes vs. no
Length of the pasture period in weeks
Type of pasture: enclosed pasture vs. forest
Feeding during summer: indoor by night vs. pasture both night and day
Frequency of concentrate feeding: twice a day vs. >twice a day
Amount of ration
Supplementation of feed other than roughage and grain: yes vs. no
No access to feed part of the day: yes vs. no
Rest of roughage still present in the morning: yes vs. no
Maximum amount of concentrate during lactation (kg): above 10 vs. 10 or below
Change of grain composition in the high-yielding period: yes vs. no
Amount of roughage at drying off: appetite feeding vs. reduced amount
Feeding of roughage in the dry period: appetite feeding vs. reduced to fat cows
Feeding of concentrate in the middle of the dry period: yes vs. no
Stealing of grain from adjacent cow during the dry period: may occur vs. does not occur
Amount of daily concentrate on calving day (kg): below 3 vs. 3 or greater
Water
Water source: private well vs. public water
Water quality: documented good, poor, or unknown
Feeding of calves
Amount of colostrum in first 24 h of life (kg): above 4 vs. 4 or below
Frequency of milk feeding to suckling calves: >twice a day vs. twice a day
Cases of diarrhea in suckling calves: sometimes or often vs. rare or never
Mean age when calves are weaned: <4 mo, 3–4 mo, ≥4 mo
Mineral supplementation to calves: yes vs. no
Age of calves when given free water supply: <22 d, 21–60 d, >60 d
Feeding calves with milk containing antibiotic residues: yes, only bull calves, no
Feeding heifer calves milk with high SCC: yes vs. no
Newborn calves suckling the mother: never vs. always or sometimes
Method of feeding newborn calves: bottle vs. bucket

BCS

All heifers and cows in the period from 2 mo prior to parturition until the 12th month of lactation were given a BCS by 1 of the 2 trained technicians. The BCS method described by Edmonson and modified and tested on Norwegian Red cattle in a study in Norway was used (Edmonson et al., 1989; Gillund et al., 1999). The system is based on a diagram of 4 different body parts: A—spinous process; B—the depression between the spinous and transverse process; C—tuber coxae and tuber ischii bony prominences; and D—the spinous and transverse process of the coccygeal vertebrae and ischiorectal fossa (depression beneath the tail). Each body part is given a score on a 5-point scale, where 1 = severe undercondition and 5 = severe overcondition; 0.25 intervals were in-

cluded. The average score of all body parts was reported as the cow's BCS.

To ensure consistent evaluation of the cows' BCS, the technicians were trained and their scoring of the same cows was compared prior to the study, during the study period, and at the end of the study. No significant differences in body condition scoring between the 2 technicians were observed in any of the tests according to a *t*-test (PROC TTEST, SAS Institute, 1990).

Statistical Analysis

The statistical analyses of the feeding variables were performed in 2 steps. First, the distribution of categorical variables between the 2 groups of herds was determined by using the frequency procedure of SAS (PROC FREQ,

SAS Institute, 1990) and tested by chi-squared tests. Differences between the low-infection herds and the high-infection herds with respect to the continuous variables were tested by use of a *t*-test (PROC TTEST, SAS Institute, 1990). Variables that showed an association with a *P*-value of less than 0.10 were tested further by using logistic regression. The general model was a herd-level model using logistic regression analyses (PROC LOGISTIC) as follows:

$$\text{Logit (Low vs. High)} = \alpha + \beta_1 X_1 \\ + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon,$$

where α is the intercept, β_k is the regression coefficient of feeding variable X_k , and ε is residual random error. To be evaluated by the model, the independent variables should not be highly correlated and should not contain missing values.

Prior to modeling, the variables were tested by correlation analysis (PROC CORR; SAS/STAT, SAS Institute, 1990). If a correlation coefficient of >0.25 between 2 variables was found, the variable with the highest association found by the frequency procedure (categorical variable) or the *t*-test (continuous variables) was offered to the final model. The best fit was found by using a forward selection procedure for model reduction. Statistical significance was assumed at a *P*-value of ≤ 0.05 by a residual chi-squared test for covariates.

Influence of a herd effect on BCS was avoided by calculating the mean BCS for each herd, which was thus included in the model. Because BCS was dependent on the stage of lactation, mean DIM was calculated for each herd and included in the model during the model selection procedure.

The relationship between BCS and the 2 categories of herds was further tested in a cow-level model that included a lactation stage-specific (monthly) comparison, adjusted for the cluster effect (herd effect) and the effect of parity and DIM. The calculations were performed by SAS, with herd included as a random variable (PROC GENMOD, SAS Institute, 1990).

RESULTS

Feeding Variables

Variables found significant in the first step of the analyses are shown in Table 3. Eleven variables showed an association with the mastitis infection categories with a *P*-value of <0.10 . One variable ("method of feeding newborn calves") was tried in the model but not offered to the final model because of missing values (Table 3, footnote 4). This variable was not statistically associated with the outcome when included in the model. The vari-

able "feeding of roughage in the dry period" was dropped because it was correlated with "amount of roughage at drying off," which had a stronger univariable association with the outcome. Mean DIM was included in the model to test whether it could influence the effect from BCS. Mean DIM was 160 for the low-infection group and 157 for the high-infection group. Because DIM was not statistically different between the 2 groups of herds ($P = 0.74$), it did not act as a confounding factor and was therefore dropped from the model.

The final logistic regression model is shown in Table 4. Five variables remained in the final model after the selection procedure. Only one qualitative factor ("preserving agent in silo") remained in the final model. On the other hand, quantitative factors such as "amount of roughage at drying off," "frequency of concentrate feeding," "mean age when calves are weaned," and BCS were found to be jointly associated with the herd-level mastitis rate.

BCS

A total of 3,870 cows were given a BCS in the 192 herds included in the statistical analyses. Body condition score was treated as a continuous variable in the analyses and was approximately normally distributed, with a mean and median of 3.34. The overall mean score in the low-incidence group was 3.29, which was significantly lower than the overall mean score of 3.38 for the high-incidence group.

The highest BCS was measured during the last month before calving, with an average value of 3.71, and the lowest BCS was in the third month after calving, with an average value of 3.07. Our results showed that cows in the period from 30 d before calving until calving had significantly higher BCS than cows in any of the other lactation periods after calving.

The comparison of mean BCS for each 30-d period during lactation for the 2 herd categories is shown in Figure 1. Cows belonging to the low-infection group had significantly lower mean BCS in the last 2 mo before calving and during the first lactation month than cows in the high-infection group ($P < 0.05$). The calculations adjusted for herd effects showed that parity (1, 2, and above 2) influenced BCS during the 2 mo prior to parturition and during the second to fifth lactation month: an increasing lactation number was associated with a decreasing BCS. Days in milk had a significant effect on BCS during the first lactation month. Both parity and DIM were controlled in the analysis.

DISCUSSION

The strength of the present study was that the selection of herds was based on both mastitis treatment rates and new infection rates, which in turn were calculated

Table 3. Variables offered to the final model in the study of feeding and BCS in relation to low and high mastitis infection rate among Norwegian dairy herds

Variable	Code ²	Description	Frequency	Low-infection herds (%)	High-infection herds (%)	Odds ratio ¹	
						Value	90% confidence interval
Preserving agent in silo	1	Formic acid	89	33.7	59.6	0.345	0.210 to 0.564
	0	Other	103				
Feeding during summer	1	Indoors by night	130	62.2	73.4	0.597	0.357 to 0.999
	0	Pasture both night and day	62				
Frequency of concentrate feeding	1	>Twice a day	125	73.5	56.4	2.142	1.288 to 3.562
	0	Twice a day	67				
Feeding of roughage in the dry period ³	1	Appetite feeding	134	62.2	77.7	0.474	0.279 to 0.808
	0	Reduced to fat cows	58				
Water quality	1	Documented good	103	61.2	45.7	1.873	1.157 to 3.032
	0	Poor or unknown	89				
Mean age when calves are weaned	1	≥4 mo	62	24.5	40.4	0.487	0.285 to 0.803
	0	<4 mo	130				
Feeding heifer calves milk with high SCC	1	Yes	145	70.4	80.9	0.564	0.321 to 0.991
	0	No	47				
Newborn calves suckling the mother	1	Always or sometimes	24	17.4	7.5	2.608	1.194 to 5.697
	0	Never	168				
Method of feeding newborn calves ⁴	1	Bottle	58	36.1	24.5	1.743	1.030 to 2.949
	0	Bucket	133				
Amount of roughage at drying off	1	Appetite feeding	140	67.4	78.2	0.557	0.323 to 0.962
	0	Reduced amount	52				
			n	Mean for low-infection herds	Mean for high-infection herds	t-Test	
BCS (unit score 1–5)			192	3.29	3.38	P < 0.01	

¹Odds of being a low-infection herd compared with a high-infection herd.²Codes refer to the value that each category was given in the analysis.³Correlated to “amount of roughage at drying off.”⁴Tried in the model and found not significant. Not offered to the final model because of missing values.

from the results of the regular individual (composite) cow milk SCC measurements during the 3-yr period (Valde et al., 2005). The data were extracted from the DCRS for 3 subsequent years, and data on feeding and feeding

routines were collected by means of a questionnaire that was completed by the technicians on the day of the visit.

Several studies have been conducted that have used the elevation of bulk milk SCC (**BMSCC**) as a criterion

Table 4. Regression coefficients and significance level for each feeding variable and mean BCS in the final logistic regression model comparing low-infection herds with high-infection herds (incidence of mastitis)

Variable ¹	Status	Coefficient (β)	95% confidence interval (β)	P-value (Wald test)	Odds ratio ¹
Intercept		8.401	2.99 to 13.82	0.002	
Amount of roughage at drying off	Appetite feeding	−0.767	−1.49 to −0.05	0.037	0.465
	Reduced amount	0			
Preserving agent in silo	Formic acid	−0.997	−1.64 to −0.36	0.002	0.369
	Others	0			
Mean age when calves are weaned	≥4 mo	−0.929	−1.60 to −0.26	0.007	0.395
	<4 mo	0			
Freq of concentrate feeding	>Twice a day	0.801	0.13 to 1.47	0.019	2.228
	Twice a day	0			
BCS (unit score 1 to 5)		−2.333	−3.99 to −0.67	0.006	0.097

¹Odds of being a low-infection herd compared with a high-infection herd.

Figure 1. Mean BCS for cows in different stages of lactation in high (□) and low (■) mastitis infection herds. S = significant differences between the herd categories ($P < 0.05$).

for mastitis or poor udder health. Even though studies have demonstrated an association between mastitis rates and BMSCC (Salonemi, 1980), the association may be weak. Data from the Norwegian DCRS showed only a weak correlation between BMSCC and CM rates (Valde et al., 2005), indicating that studies using CM as the selection criterion are not necessarily comparable with studies based on BMSCC.

The present study was part of a project called Health Plus. We wanted to focus on herds with steady low levels of mastitis (coded 1 as cases) to identify variables associated with a low mastitis infection rate. Many variables on housing, management, and milking procedures, which are well known to be risk factors, could be considered, but in this paper we wanted to focus on feeding and BCS. Moreover, too many variables in the model would reduce the degrees of freedom and might lead to an overdispersion of the data. Therefore, despite the possibility of losing explanatory or confounding variables, we decided to limit the analyses to variables related to feeding.

The differences between the herds with respect to feeding management practices were found to be small, which could be because all the farmers belong to the same dairy cattle health service and receive similar advice from the technicians. Factors that may have an impact on udder health may not have been detected simply because the variation among the farmers was too small. Such factors

could be some of the qualitative variables measured in this study (e.g., “yes” or “no” factors such as the use of hay, whey, mineral supplementation, or 2-step harvesting; Table 2). In addition, few herds used whey, hay, or straw as part of the ration, and further analyses of the amount were not appropriate. No herds fed TMR, which is more common in other dairy regions in the world. Data on calf management and feeding were collected, even though these factors were regarded as markers for herd management rather than risk factors for mastitis.

Feeding Management

The present study found that restricted roughage feeding at drying off might reduce the risk of CM during the subsequent lactation. Milk production of a cow on the day prior to drying off has been shown to influence the time until quarter closure by formation of the teat canal keratin plug (Dingwell et al., 2004). The amount of high-quality roughage at drying off may be important for the rate of decrease in milk production when the cows enter the dry period and thus influence the time until quarter closure. However, automatic feeding equipment does not always allow the herdsmen to reduce the amount of roughage to individual cows.

Nutrition affects udder health through its effect on the immune response in the periparturient period (Hogan et al., 1993). Several studies regarding the relationship

between nutrition and mastitis have focused on minerals and vitamins, especially selenium, vitamin E, vitamin A, and β -carotene. In a clinical trial, Smith et al. (1984) found that supplementation of vitamin E during the dry period led to a lower incidence risk of CM in the period around calving. In our study, mineral supplementation to lactating cows was used more frequently in low-infection herds than in high-infection herds, but the association was not significant. Relatively few herds (25%) were fed extra minerals, probably because the standard commercial concentrates are enriched with minerals and vitamins and are thus regarded as sufficient even for high-yielding cows.

The observed difference between the herd categories with respect to the preserving agent used in grass silage was unexpected and is difficult to explain. The conservation process could possibly reduce the content of vitamin E and other vitamins in the silage, thus having an effect on immune function, but no studies supporting this theory have been reported.

The odds of feeding concentrate only twice a day were more than twice as high for the high-infection herds as for the low-infection herds, which experienced more frequent feeding of concentrate. Even though not recommended, 35% of the farmers fed concentrate only twice a day, even to high-yielding cows. An association between frequency of concentrate feeding and ketosis was demonstrated in an earlier study (Riemann et al., 1985). Large amounts of concentrate fed to high-yielding cows in one ration may increase the risk of subacute rumen acidosis. Two hypotheses to explain an association between concentrate feeding and mastitis include harmful effects on immune function and the possibility of greater environmental contamination from animals with diarrhea.

The fact that the mean weaning age of calves was higher among high-infection herds was probably due to larger amounts of discarded milk in herds with high levels of mastitis. Excess milk containing high SCC or antibiotic residues may lead to a higher weaning age simply because more milk not suitable for human consumption was available to the calves.

BCS

The BCS method used in this study was tested among Norwegian dairy herds in a study by Gillund et al. (1999), who found that the method adequately reflected the quantity of energy stores in the cows. Our results showed that cows in the period from 30 d before calving until calving had significantly higher BCS than cows in any of the other lactation periods.

It is important to note that our results reflected only a cross-section of BCS. None of the cows were followed over time, and we do not know each cow's BCS through-

out lactation. However, the significant difference in mean BCS between high- and low-infection herds around calving showed that cows in the high-infection herds had higher BCS and thus may have experienced a larger drop in BCS during the first 2 mo of lactation (Figure 1). This is in agreement with an experimental study by Treacher et al. (1986), who found that cows in a fatter condition at calving lost more BW and body condition over a longer period of time than cows in a thinner condition at calving. The same study also found more cases of postparturient diseases, including mastitis, among fat cows than among thin cows. However, in another experimental study (Boisclair et al., 1984), no difference was observed in disease incidence between control and overly fat high-yielding cows in which over-fatness was achieved by overfeeding in late lactation and the dry period. A weakness of experimental studies is that they have relatively few individuals included in the experiments and thus generate less power in the statistical analyses. Our study had more power in this respect but suffered from the lack of individual followup over time. Nevertheless, the study demonstrated that slightly higher mean BCS around calving was associated with high rates of udder infections at the herd level. This finding was also confirmed by the individual-level model, which is more robust for ecological fallacy because risk factors on the group level do not necessarily reflect risk factors on the individual level. The problem of ecological fallacy results from making a causal interference about individual phenomena based on the observations of groups. Aggregation bias due to grouping of individuals, and specification bias due to the confounding effect of the group itself can make the ecological association appear to be stronger or weaker than it is at the individual level (Morgenstern, 1982).

A study by Goodger et al. (1993) indicated that the condition of cows appeared to be an important explanatory variable for BMSCC and was related to the quality and quantity of feeding during the dry period. Feeding management must maintain the body condition of the cow during the dry period to ensure a healthy postpartum period when susceptibility to mastitis is high (Faye et al., 1998). Further investigations are necessary to determine what level of BCS at calving is optimal for health, reproductive performance, and production during the subsequent lactation.

The finding of lower BCS around calving among low-infection herds was supported by the result that the odds of being a low-infection herd were 2.1 times higher if the amount of roughage to fat cows was reduced during the dry period instead of appetite feeding to all. When using individual BCS in the analysis, we had to take into consideration that clusters (herds) were sampled and individual characteristics were measured. Herd-

mates are exposed to the same ration composition and feeding procedure, making it reasonable to believe that the BCS of herd mates are correlated. Statistical tests based on an assumption of individual independence will thus be incorrect and the estimated variance will be too low (McDermott and Schukken, 1994). In our study the herd effect was taken into account in the analyses, and both herd effect and the effect of lactation number and number of DIM were adjusted for in the analyses (PROC GENMOD, SAS Institute, 1990). The results should therefore not be biased because of potential differences between the 2 herd categories with respect to these variables.

The most interesting findings in the present study were the significant associations between mastitis infection rate and mean BCS, frequency of concentrate feeding, and amount of roughage at drying off and during the dry period. The results indicate that more attention must be paid to feeding during the dry period, which is metabolically and endocrinologically an active time in the productive cycle of the cow and must not be considered as a rest period during which the cow is not productive. Further research on the individual level is necessary to measure whether and at which magnitude BCS and feeding during the dry period influence the udder health of the individual cow.

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REFERENCES

- Boisclair, Y., D. G. Grieve, J. B. Stone, O. B. Allen, and R. A. Curtis. 1984. Effect of prepartum energy intake and body condition on performance and health in early lactation. *J. Dairy Sci.* 67(Suppl. 1):100. (Abstr.)
- Dingwell, R. T., K. E. Leslie, Y. H. Schukken, J. M. Sargeant, L. L. Timms, T. F. Duffield, G. P. Keefe, D. F. Kelton, K. D. Lissemore, and J. Conklin. 2004. Association of cow quarter-level factors at drying-off with new intramammary infections during the dry period. *Prev. Vet. Med.* 63:75–89.
- Edmonson, A. J., I. J. Lean, L. D. Weaver, T. Farver, and G. Webster. 1989. A body condition scoring chart for Holstein dairy cows. *J. Dairy Sci.* 72:68–78.
- Faye, B., L. Perochon, N. Dorr, and P. Gasqui. 1998. Relationship between individual-cow udder health status in early lactation and dairy cow characteristics in Brittany, France. *Vet. Res.* 29:31–46.
- Fronk, T. J., L. H. Schultz, and A. R. Hardie. 1980. Effect of dry period overconditioning on subsequent metabolic disorders and performance of dairy cows. *J. Dairy Sci.* 63:1080–1090.
- Garnsworthy, P. C., and J. H. Topps. 1982. The effect of body condition of dairy cows at calving on their food intake and performance when given complete diets. *Anim. Prod.* 35:113–119.
- Gearhart, M. A., C. R. Curtis, H. N. Erb, R. D. Smith, C. J. Sniffen, L. E. Chase, and M. D. Cooper. 1990. Relationship of changes in condition score to cow health in Holsteins. *J. Dairy Sci.* 73:3132–3140.
- Gillund, P., O. Reksen, K. Karlberg, Å. T. Randby, I. Engeland, and B. Lutnæs. 1999. Testing of a body condition score method in Norwegian cattle. *Norsk veterinær tidsskrift.* 10(111):623–632.
- Goff, J. P., and R. L. Horst. 1997. Physiological changes at parturition and their relationship to metabolic disorders. *J. Dairy Sci.* 80:1260–1268.
- Goodger, W. J., T. Farver, J. Pelletier, P. Johnson, G. DeSnayer, and J. Galland. 1993. The association of milking management practices with bulk tank somatic cell counts. *Prev. Vet. Med.* 15:235–251.
- Hogan, J. S., W. P. Weiss, and K. L. Smith. 1993. Role of vitamin E and selenium in host defense against mastitis. *J. Dairy Sci.* 76:2795–2803.
- Markusfeld, O., N. Galon, and E. Ezra. 1997. Body condition score, health, yield and fertility in dairy cows. *Vet. Rec.* 141:67–72.
- McDermott, J. J., and Y. H. Schukken. 1994. A review of methods used to adjust for cluster effects in explanatory epidemiological studies of animal populations. *Prev. Vet. Med.* 18:155–173.
- Morgenstern, H. 1982. Uses of ecological analyses in epidemiological research. *Am. J. Public Health* 72:1336–1344.
- Riemann, H. P., R. Bjerke Larssen, and E. Simensen. 1985. Ketosis in Norwegian dairy herds—Some epidemiological associations. *Acta Vet. Scand.* 26:482–492.
- Ruegg, P. L., and R. L. Milton. 1995. Body condition scores of Holstein cows on Prince Edward Island, Canada: Relationships with yield, reproductive performance, and disease. *J. Dairy Sci.* 78:552–564.
- Saloniemi, H. 1980. Udder disease in dairy cows—Field observations on incidence, somatic cell and environmental factors and control. *J. Sci. Agric. Soc. Finl.* 52:85–184.
- SAS Institute. 1990. SAS/STAT User's Guide. Version 6. SAS Inst., Inc., Cary, NC.
- Smith, K. L., J. H. Harrison, D. D. Hancock, D. A. Todhunter, and H. R. Conrad. 1984. Effect of vitamin E and selenium supplementation on incidence of clinical mastitis and duration of clinical symptoms. *J. Dairy Sci.* 67:1293–1300.
- Treacher, R. J., I. M. Reid, and C. J. Roberts. 1986. Effect of body condition at calving on the health and performance of dairy cows. *Anim. Prod.* 43:1–6.
- Valde, J. P., O. Østerås, and E. Simensen. 2005. Description of herd level criteria for good and poor udder health in Norwegian dairy cows. *J. Dairy Sci.* 88:86–92.