Effect of Feeding Frequency of a Total Mixed Ration on the Performance of High-Yielding Dairy Cows

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ABSTRACT

Forty Finnish Ayrshire cows, 16 primiparous and 24 multiparous, were randomly assigned to 1 of 2 treatments (FF1 or FF5). Total mixed ration (TMR) was fed once a day on the FF1 treatment and 5 times a day on the FF5 treatment. The experiment began at calving and continued to wk 28 of lactation. The TMR consisted of a grass silage and concentrate mix. The amount of concentrate in the TMR was 51% on a DM basis. The feeding frequency had no effect on milk or energy-corrected milk yields or on milk composition. The average energy-corrected milk yield was 32.8 kg/d on the FF1 treatment and 32.5 kg/d on the FF5 treatment. The less frequent feeding increased the dry matter intake (DMI) of cows. The average DMI during the experiment was 20.9 kg/d on the FF1 treatment and 19.9 kg/d on the FF5 treatment. The difference in DMI was due to the differences in DMI of the mature cows. Energy and protein conversion tended to be lower with feeding once a day compared with feeding 5 times a day. The cows' feeding behavior was also observed. Cows fed 5 times a day tended to eat quite evenly after each delivery, whereas on the FF1 treatment there were 2 clear feeding peaks in the evening after the feed delivery. The time spent eating during the observation period was longer on FF5 than on FF1. The cows fed once a day spent more time lying than the cows fed 5 times a day. Based on the observations of feeding behavior, feeding a TMR 5 times a day seemed to be too frequent based on the increased restlessness and decreased lying time of the cows.

Key words: feeding frequency, dairy cow, total mixed ration, milk production

INTRODUCTION

In Finland it is common practice to feed dairy cows a TMR once or twice a day to keep the labor cost to a minimum. However, feeding robots are available,

allowing more frequent feeding with a limited labor requirement. These robots are quite an expensive investment, although the building cost of new cow barns can be reduced, because robots require less room than a tractor-pulled mixer wagon. The effect of feeding frequency on the performance of dairy cows has been examined in many studies. In a review of 35 experiments, Gibson (1984) concluded that increasing the feeding frequency of dairy cows to 4 or more times a day, compared with once or twice a day, increased the milk fat percentage by an average of 7.3% and increased milk production by 2.7%. In the studies reviewed, however, the feeding strategies varied from feeding concentrates separate from forages to feeding complete diets, so the results are not directly applicable to today's high-producing cows fed TMR.

More recent results with TMR feeding have been variable. In the studies by Shabi et al. (1999) and Le Liboux and Peyraud (1999), increasing the number of feedings from 1 to 2, to 4 to 6 increased the DMI of the TMR, but had no effect on milk production. Contrary to these results, in the study by Phillips and Rind (2001), the DMI and milk yield were higher with feeding once a day compared with 4 times a day. Phillips and Rind (2001) concluded that frequent feeding disturbed the cows and reduced milk production. In their study the cows were housed in a free-stall barn, whereas in the studies by Shabi et al. (1999) and Le Liboux and Peyraud (1999), the cows were stanchioned. The housing type can change the feeding behavior (Albright and Arave, 1997) and therefore alter the effect of feeding frequency on the cows' performance. The feeding behavior of high-yielding cows has also been shown to differ from the behavior of low producers (Grant and Albright, 1995). Thus, the milk-producing capacity of the cow can influence its response to different feeding frequencies. This experiment was conducted during the indoor period to examine how feeding frequency of a TMR might affect the feed intake, milk production, and feeding behavior of high-yielding cows housed in a free-stall barn.

MATERIALS AND METHODS

Animals and Experimental Design

Forty Finnish Ayrshire cows, 16 primiparous and 24 multiparous, were blocked by projected date of parturi-

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Table 1. The chemical composition and estimated feed values of the ingredients and TMR (mean $\pm$ SD)

Item	Grass silage	Concentrate mix ¹	TMR
Chemical composition			
DM, %	25.2 $\pm$ 2.6	88.3 $\pm$ 0.6	39.6 $\pm$ 3.4
In DM, %			
Ash	7.5 $\pm$ 0.6	6.8 $\pm$ 0.4	7.1 $\pm$ 0.3
CP	14.8 $\pm$ 0.6	19.1 $\pm$ 0.7	17.0 $\pm$ 0.4
Ether extract	ND ²	5.3 $\pm$ 0.4	4.7 $\pm$ 0.1
NDF	51.2 $\pm$ 4.4	22.7 $\pm$ 1.6	36.9 $\pm$ 2.1
Starch	ND	35.2 $\pm$ 3.3	18.3 $\pm$ 1.7
Digestible OM	70.6 $\pm$ 1.7	ND	ND
Water-soluble carbohydrates	5.7 $\pm$ 1.9		
Lactic acid	7.3 $\pm$ 1.3		
Acetic acid	2.2 $\pm$ 0.5		
Butyric acid	0.02 $\pm$ 0.02		
pH	3.97 $\pm$ 0.15		
Ammonia-N, g/kg of N	73 $\pm$ 6.7		
Soluble N, g/kg of N	571 $\pm$ 70.6		
Feed values in DM			
ME, ³ MJ/kg	11.3 $\pm$ 0.3	12.5 $\pm$ 0.06	11.9 $\pm$ 0.09
AAT, ⁴ g/kg	86 $\pm$ 1.6	116 $\pm$ 1.1	101 $\pm$ 0.9
PBV, ⁵ g/kg	1 $\pm$ 6.3	6 $\pm$ 5.6	4 $\pm$ 3.3

¹A mix (% in DM) of barley (60.6), rapeseed meal (27.0), molassed sugar beet pulp (10.0), and mineral and vitamin mix (2.4).

²Not determined.

³Metabolizable energy (MAFF, 1975, 1984).

⁴Amino acids absorbed from the small intestine (MTT, 2004).

⁵Protein balance in the rumen (MTT, 2004).

tion and parity (primiparous or multiparous) and randomly assigned to 1 of 2 treatments (**FF1** or **FF5**) differing in feeding frequency. In the FF1 treatment the TMR was fed once a day, and in the FF5 treatment it was fed 5 times a day. The experiment began at calving and continued to wk 28 of lactation. The average age and weight after calving were 24.5 mo and 586 kg for the primiparous cows, and 47.9 mo and 636 kg for the multiparous cows.

Feeds, Feeding, and Housing

All cows were fed the same TMR, which consisted of a grass silage and concentrate mix (Table 1). The amount of concentrate in the TMR was 51% on a DM basis. The grass silage used was prepared from primary-cut timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) sward wilted for 1 to 2 h. A formic acid-based additive (5 L/t) was used at ensiling. The concentrate mix contained, in DM (%), barley (60.6), rapeseed meal (27.0), molassed sugar beet pulp (10.0), and mineral and vitamin mix (2.4). The mineral and vitamin mix (Suomen Rehu Ltd., Helsinki, Finland) contained (g/kg) calcium (210), phosphorus (2), magnesium (100), sodium (100), selenium (0.02), vitamin A (13,000 IU/kg), vitamin D (81,000 IU/kg), and vitamin E (470 mg/kg).

The cows were housed in a 2-compartment free-stall barn. Cows on different treatments were placed in dif-

ferent compartments, which were separated by a milking parlor. Cows in different compartments were not able to see each other; therefore, the more frequent feeding of the FF5 group did not disturb the cows in the FF1 group. The cows were fitted with transponder collars that allowed identification in the milking parlor and feeding place. Each cow had an individual feeding place with free access to the TMR through computerized gates (RIC Access Doors; Insentec, Marknesse, The Netherlands). The TMR was mixed in a mixer wagon (Junkkari Ltd., Ylihärmä, Finland), and the feeding was carried out by a feeding robot (TR Feeding Robot; Pellonpaja Ltd., Ylihärmä, Finland). In the FF1 treatment, feeding took place at 1600 h and in the FF5 treatment at 0800, 1320, 1430, 1800, and 1940 h. The gaps between feedings on the FF5 treatment were not uniform because of the feeding schedule of the other animals. To ensure ad libitum feeding, at least 5% daily refusals were required.

Measurements, Sampling, and Analysis

The amount of TMR offered was recorded automatically each day and TMR intakes were measured by recording the orts with an accuracy of 0.5 kg (fresh weight). A sample of the grass silage was taken twice a week. The subsamples were combined to give a 2-wk sample for analysis. Samples were stored at -20°C . Thawed samples were analyzed for DM, ash, CP, NDF,

quality of silage fermentation, and in vitro OM digestibility. The silage DM was corrected for the loss of volatiles according to Huida et al. (1986). The OM of the feeds was determined by ashing at 600°C for 18 h. Neutral detergent fiber was analyzed according to Van Soest et al. (1991) using sodium sulfite in a NDF-detergent solution. Crude protein content was analyzed using a Dumas-type N analyzer (Leco FP-428 nitrogen analyzer; Leco Corporation, St. Joseph, MI). The in vitro OM digestibility of the silages was determined using a cellulose-based (Onazuka R-10; Yakult Honsha Ltd, Tokyo, Japan) method (Friedel, 1990). The silage was also analyzed for VFA (Huhtanen et al., 1998), lactic acid (Haacker et al., 1983), water-soluble carbohydrates (Somogyi, 1945), and ammonia N (McCullough, 1967). Concentrate samples were collected once a week and were combined to give a 4-wk sample for analysis. The concentrate samples were analyzed for DM, ash, CP, ether extract, NDF, and starch. Dry matter was determined by drying at 105°C for 20 h. Starch was analyzed according to McCleary et al. (1994). Ether extract in the concentrates was determined after acid (HCl) hydrolysis according to the method of AOAC (1990).

Cows on the FF1 treatment were milked at 0630 and 1600 h, and cows on the FF5 treatment were milked at 0730 and 1645 h in a 2 × 6 auto-tandem milking parlor. The milk yield was weighed and recorded automatically during each milking. Milk samples for milk protein, fat, and lactose analyses were collected every 2 wk from 2 consecutive milkings. The analyses were done using a MilkoScan 605 analyzer (Foss Electric, Hillerød, Denmark). Constituent concentrations were calculated as a weighted mean according to milk yield. Milk samples for milk urea analysis were collected every fourth week from 2 consecutive milkings of 7 cows per treatment and were pooled according to milk yield. The milk urea concentration was measured as ammonia following urease hydrolysis (McCullough, 1967).

The live weight of each cow was recorded automatically after each milking. The BCS were measured on a scale of 1 to 5 (1 = skinny to 5 = very fat) with intervals of 0.25 as described by Lowman et al. (1976). The BCS were recorded at calving and every second week thereafter.

The behavior of the cows was observed for 15 h a day (0600 to 2100 h) with 3 replicates. This made a total of 45 h of observation time per treatment. A day's observation was done in three 5-h periods (0600 to 1100 h, 1100 to 1600 h, and 1600 to 2100 h). The observation time covered the time when the TMR was delivered to the cows. During observation, the cows were identified by large numbers painted on their sides. A cow's behavior was classified and recorded on a handheld computer

(Psion Workabout; Psion PLC, London, UK) every 5 min using the following categories: eating, lying, standing, lying and ruminating, standing and ruminating. The time spent at milking was also recorded.

Calculation and Statistical Analysis

The ME content of the silage was based on the content of digestible OM in the DM (16 MJ/kg). The ME content of the concentrates was calculated according to the Ministry of Agriculture, Fisheries and Food (MAFF, 1975, 1984). The digestibility coefficients of the nutrients in the concentrates were taken from the Finnish feed tables (MTT, 2004). The AA absorbed from the small intestine were calculated according to the Finnish feed tables (MTT, 2004). The energy and nutrient contents of the TMR were calculated from the values for grass silage and concentrate based on the proportion of each component in the TMR.

Two cows on the FF1 treatment were removed from the experiment because of mastitis and premature calving. Their data were excluded. Individual weekly averages were calculated from the daily intake, production, and BW measurements. The weekly average intake and production data were analyzed using the MIXED procedure of SAS (Littell et al., 1996). The REML method was used to estimate the variance component, and the type of within-subject covariance matrix used was first-order autoregressive [AR(1)]. The model used was

$$y_{ijklmn} = \mu + FF_i + b_l I_j + P_k + S_{ijkl} + W_m + (W \times FF)_{mi} + e_{ijklm} \quad [1]$$

where FF_i represents the feeding strategy (feeding frequency 1 or 5 times a day); b_l is the linear effect of the pedigree index (I_j) of the cow appropriate for milk yield, fat, or protein content or yield; P_k is parity; S_{ijkl} is the random effect for the experimental cow; and W_m is the week of lactation. Weekly average BW data and bi-weekly BCS were also analyzed using the model (Equation 1) without the effect of $b_l I_j$ and, in the case of BCS, with the exception that W_m represented a 2-wk period. The results were calculated and tested from the whole data set but also from separate data sets for the primiparous and multiparous cows. The behavioral data were also analyzed with the MIXED procedure of SAS (Littell et al., 1996). The REML method was used to estimate the variance component, and the type of within-subject covariance matrix used was unstructured [UN]. The model used included the treatment and observation period. In statistical analysis, significance was declared when $P < 0.05$ (* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$). A tendency was declared when $P < 0.10$.

Table 2. Feed and nutrient intake (least-squares means) of the cows fed once or 5 times a day¹

Dependent intake variable	Treatment FF1	Treatment FF5	SEM	Significance
DM, kg/d	20.9	19.9	0.28	*
CP, kg/d	3.54	3.37	0.047	*
Ether extract, kg/d	0.97	0.92	0.012	*
Starch, kg/d	3.85	3.71	0.054	†
NDF, kg/d	7.75	7.45	0.107	†
ME, ² MJ/d	249	237	3.4	*
AAT, ³ kg/d	2.11	2.01	0.029	*

¹On the FF1 treatment, the TMR was fed once a day, and on the FF5 treatment, it was fed 5 times a day.

²Metabolizable energy (MAFF, 1975, 1984).

³Amino acids absorbed from the small intestine (MTT, 2004).

† $P < 0.10$; * $P < 0.05$.

RESULTS

Feeds and Feed Intake

The chemical composition and calculated feed values of the ingredients and TMR are presented in Table 1. The concentrate mix had 190 g of CP in DM and its ME energy content was 12.5 MJ/kg. The grass silage used had 706 g of in vitro digestible OM per kilogram of DM and the CP content was 148 g/kg of DM. The fermentation characteristics of the grass silage were good (Table 1). The DM content of the TMR ranged from 35.4 to 46.3% (Table 1). The average energy (ME) and CP contents of the TMR were 11.9 MJ/kg of DM and 170 g/kg of DM, respectively. The study was conducted in the winter so that secondary fermentation of the TMR in the feed bunk was not a concern.

The feed intake data for the cows are presented in Table 2. The average DMI of all the cows on the FF1 treatment was 20.9 kg/d and on the FF5 treatment was 19.9 kg/d ($P < 0.05$). When parities were analyzed separately, no effect of feeding frequency on the DMI of the primiparous cows (18.7 vs. 18.1 kg DM/d; $P > 0.05$) was found, whereas the multiparous cows fed once a day ate 1.5 kg/d more DM (23.1 vs. 21.6 kg DM/d; $P < 0.05$) than the multiparous cows fed 5 times a day. Changes in DMI over time for primiparous and multiparous cows are shown in Figure 1. During the first weeks of lactation, the primiparous cows on the FF1 treatment ate more than the cows on the FF5 treatment, whereas with older cows no difference in the feed intake during the first weeks was observed. Instead, after the seventh week of lactation, the multiparous cows on the FF1 treatment ate more than the cows on the FF5 treatment. However, the interaction between lactation week and treatment on the feed intake was not significant.

The energy and nutrient intakes of the cows on the different treatments are shown in Table 2. Because the cows on both treatments were fed the same TMR, the

differences in energy and nutrient intakes followed the differences in DMI.

Milk Production and Composition

The production data for the cows are presented in Table 3. The frequency of feeding had no effect on milk and ECM yields. The average ECM yield was 32.8 and

Figure 1. Dry matter intake of primiparous (A) and multiparous (B) cows fed a TMR once (FF1) or 5 (FF5) times a day.

Table 3. Milk production and composition as well as energy and protein conversion of cows fed once or 5 times a day¹

Dependent production variable	Treatment FF1	Treatment FF5	SEM	Significance
Milk, kg/d	31.8	31.8	0.92	NS
ECM, ² kg/d	32.8	32.5	0.84	NS
Milk fat, %	4.14	4.12	0.072	NS
Milk protein, %	3.42	3.42	0.043	NS
Milk lactose, %	4.91	4.94	0.028	NS
Milk urea N, mg/dL	10.2	10.0	0.61	NS
Milk fat, kg/d	1.31	1.30	0.034	NS
Milk protein, kg/d	1.07	1.08	0.029	NS
Milk lactose, kg/d	1.56	1.58	0.042	NS
ECM:ME, kg/MJ	0.131	0.139	0.003	†
ECM/kg of DM, kg/kg	1.56	1.65	0.003	†
Milk protein/feed protein, g/g	0.305	0.322	0.007	†

¹On the FF1 treatment, the TMR was fed once a day, and on the FF5 treatment, it was fed 5 times a day. NS = not significant.

²Calculated according to Sjaunja et al. (1990).

† $P < 0.10$.

32.5 kg/d on the FF1 and FF5 treatments, respectively. When parities were analyzed separately, no significant difference in ECM yield between treatments was found for primiparous or multiparous cows. However, the increased feed intake of the multiparous cows on the FF1 treatment after the seventh week of lactation also caused a nonsignificant increase in the ECM yield (Figure 2). The average ECM yields of the multiparous cows were 37.1 and 36.1 kg/d on the FF1 and FF5 treatments, respectively. The ECM yield of the primiparous cows was 27.1 kg/d on the FF1 treatment and 27.4 kg/d on the FF5 treatment. Feeding frequency had no effect on milk fat, protein, lactose, or urea content. In the multiparous cows, a significant interaction was found between feeding frequency and week of lactation for milk fat content. This was caused by the higher milk fat content on the FF1 treatment during the first 3 wk of lactation. The feeding frequency had no effect on milk fat or protein yields.

Energy and Protein Conversion and Development of BW and Body Condition

Because of the lower DMI of the FF5 cows, the energy (ECM:ME) and protein (milk protein:feed protein) conversion tended ($P < 0.10$) to be better on the FF5 treatment compared with the FF1 treatment (Table 3). The BW change of the primiparous and mature cows during the experiment is shown in Figure 3. No difference was observed in the BW of the primiparous cows fed once or 5 times a day. Also, for the multiparous cows, no difference was observed in BW during the first 19 wk of lactation. Instead, during the last experimental weeks, the mature cows on the FF1 treatment gained more weight than the mature cows on the FF5 treat-

ment; however, the interaction between lactation week and treatment was not significant. The feeding frequency had no effect on the development of the BCS of the cows during the experiment. At calving the BCS

Figure 2. Energy-corrected milk yield of primiparous (A) and multiparous (B) cows fed a TMR once (FF1) or 5 (FF5) times a day.

Figure 3. Body weight change of primiparous (A) and multiparous (B) cows fed a TMR once (FF1) or 5 (FF5) times a day.

was 3.1 and 3.0, and at the end of the experiment it was 2.8 and 2.9 on the FF1 and FF5 treatments, respectively. The BCS did not differ among parities.

Feeding Behavior

During the 15-h observation period, the cows fed 5 times a day spent more time eating than the cows fed once a day (Table 4), although the cows fed once a day consumed more feed. The difference in eating time between the treatments was not statistically significant. The distribution of eating times within the 15-h observation period was in accordance with the feed delivery times (Figure 4). The cows fed 5 times a day tended to eat quite evenly after each delivery. On the FF1 treatment, there were 2 clear peaks in feed consumption in the evening after the feed delivery. The first peak was immediately after allocation of fresh feed at 1630 h, with another one later at 2000 h. There was no difference in standing or ruminating times between the treatments, but the cows fed 5 times a day spent more time ruminating when standing and the cows fed once a day spent more time ruminating when lying (Table 4). Lying not ruminating and total lying times

(lying + lying and ruminating) were longer ($P < 0.01$) during the 15-h observation period on the FF1 treatment than on the FF5 treatment (Table 4).

DISCUSSION

Studies have shown that delivery of feed stimulates the eating activity of cows (DeVries and von Keyserlingk, 2005). Also in our study, an active eating period was noticed following delivery of the feed, and the total eating time was longer ($P > 0.05$) when feed was delivered 5 times compared with once a day. Therefore, one might expect the feed intake to be higher with more frequent feeding. However, in the present study the DMI was greater on the FF1 treatment than on the FF5 treatment. The reasons for the higher intake are not clear. It can be speculated that the larger meal size on the FF1 treatment, compared with the FF5 treatment, might have led feed to be wasted if it were pulled into the stall. However, the fact that the effect of treatment on DMI differed between parities does not confirm this conclusion, nor does the fact that measurable amounts of feed were not seen in the stall. It is likely that the difference in feed intake was associated with the differences in feeding behavior of the cows because of the different feeding frequencies. Phillips and Rind (2001) noticed in their study that cows with a reduced feeding frequency tended to have a higher DMI. This was associated with more relaxed and less aggressive behavior in the feeding passage and increased time spent lying and ruminating. They concluded that the undisturbed feeding situation with reduced feeding frequency gave the cows greater opportunities to select large mouthfuls of TMR. In the present study, we also noticed that the cows on the FF1 treatment spent more time lying than the cows on the FF5 treatment. It is possible that the cows on the FF1 treatment were more peaceful because they were not disturbed so often by feed delivery as the cows on the FF5 treatment. The effect of feeding frequency on feed intake was clearer with multiparous than with primiparous cows. This difference between parities can arise from the differences in milk production and feed intake capacity. High-producing multiparous cows eat large meals more quickly than low-producing primiparous cows (Dado and Allen, 1994).

Contrary to our results, in the studies by Shabi et al. (1999), Le Liboux and Peyraud (1999), and Kudrna et al. (2001), increasing feeding frequency increased the TMR intake. The higher intake was associated with increased feeding time in the study by Shabi et al. (1999), and in the study by Kudrna et al. (2001), the decreased feed intake with less frequent feeding was explained by the high temperature during the summer

Table 4. Behavior of the cows fed once or 5 times a day¹

Behavior, percentage of a 15-h period ²	Treatment FF1	Treatment FF5	SEM	Significance
Eating	20.0	21.4	0.98	NS
Ruminating lying	23.2	21.8	1.14	NS
Lying, not ruminating	24.9	20.5	1.12	**
Ruminating standing	4.0	4.8	0.63	NS
Standing, not ruminating	16.5	16.8	0.84	NS
Total standing	20.5	21.7	1.19	NS
Total lying	48.1	42.2	1.49	**

¹On the FF1 treatment, the TMR was fed once a day, and on the FF5 treatment, it was fed 5 times a day. NS = not significant.

²The observation period was 15 h/d between 0600 and 2100 h.

** $P < 0.01$.

season and a different level of secondary fermentation of the bunk feeds (Kudrna, 2003). Our study was conducted during the winter season, and we noticed no secondary fermentation of the TMR offered once a day. In agreement with our results, Phillips and Rind (2001), Nocek and Braund (1985), and Dhiman et al. (2002) also reported a tendency to have a higher DMI with lower feeding frequency, whereas no effect of feeding frequency on the DMI of the TMR was observed by Robinson and Sniffen (1985), Shabi et al. (1999), and Kudrna (2003).

In the study by Phillips and Rind (2001), the increased feed intake with lower feeding frequency was associated with increased milk production. In the present study, the increased feed intake of the cows on the FF1 treatment did not cause any increase in milk or ECM production. It is possible that with once-a-day feeding, the larger meal size and changes in the ruminal fermentation affected the digestibility of the diet. Dhiman et al. (2002) and Shabi et al. (1999) showed that the digestibility of DM and NDF decreased with less frequent feeding. Dhiman et al. (2002) found a 19%

Figure 4. Feeding behavior of cows fed a TMR once (FF1) or 5 (FF5) times a day. On the FF1 treatment, milking took place at 0630 and 1600 h, and on the FF5 treatment milking took place at 0730 and 1645 h.

decrease in NDF digestibility when TMR was fed once a day compared with 4 times a day. In their study, the average ruminal pH was not affected by the feeding frequency. However, the reduced fiber digestibility with less frequent feeding can be a result of increased diurnal variation in ruminal pH, as measured in the studies by Le Liboux and Peyraud (1999) and Shabi et al. (1999). In the present study, the cows on the FF1 treatment spent more time eating during the evening hours, whereas the distribution of eating time was more even over the course of the day on the FF5 treatment. This could have increased the diurnal variation in ruminal pH on the FF1 treatment when a highly digestible TMR was fed. Contrary to the results of Dhiman et al. (2002), Robinson and Sniffen (1985) measured no difference in the digestion of NDF components when a TMR was fed once or 4 times a day.

Neither milk fat nor protein content was affected by the feeding frequency. Phillips and Rind (2001) observed an increased milk fat content with lower feeding frequency. This was postulated to be due to more extensive fiber digestion as a result of increased rumination. In the present study, the time spent ruminating did not differ between treatments.

Feed sorting was observed in the study by DeVries et al. (2005) when a TMR was fed once a day. They compared the forage-to-concentrate ratio of the delivered feed and the orts and noticed that sorting of the TMR reduced the quality of the feed during the day, which could decrease the performance of subordinate cows who are afraid to visit the feed bunk at the time of feed delivery. In the present study, every cow had her own feeding place (transponder collars); therefore, the quality of the feed offered was the same for all cows. In theory it is possible that feed sorting of the FF1 treatment could have increased the diurnal variation in ruminal pH.

Because of the differences in feed intake, the energy and protein efficiency in milk production tended to be lower on the FF1 treatment compared with the FF5 treatment in the present study. In agreement with our findings, Nocek and Braund (1985) observed a slightly higher feed efficiency for primiparous cows fed 4 times a day compared with once a day. No difference in BW development between treatments was noticed in the present study. However, the multiparous cows, whose DMI was clearly higher on the FF1 treatment than on the FF5 treatment, also gained slightly more weight after the 19th week of lactation.

CONCLUSIONS

Feeding a TMR once or 5 times a day had no effect on milk production or milk composition, but cows fed

once a day consumed more TMR than cows fed 5 times a day. The higher intake with once-a-day feeding tended to decrease energy and protein conversion. The study was conducted in the winter; therefore, secondary fermentation in the feed bunk with less frequent feeding was not a concern. Based on the observations of feeding behavior, it seems that feeding TMR 5 times a day might be too frequent because of the increased restlessness and decreased lying time of the cows.

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