Effect of Omitting One Milking Weekly on Lactational Performances and Morphological Udder Changes in Dairy Cows

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ABSTRACT

The response of dairy cows to omitting one milking weekly was investigated in two successive experiments conducted with Holstein cows milked twice daily. Experiment 1 compared the lactational performances and udder changes in eight cows (31.2 L/d, 201 d in milk) in the 5 wk before and the 5 wk after introducing the suppression of one milking weekly. Milk yield was recorded daily and milk composition twice weekly. Milk partitioning in the udder (alveolar and cisternal milk) and cisternal size (ultrasonography), 8 h after milking, were also measured at the start and the end of the experiment. Although daily milk yield decreased 32% during the experiment (10 wk), linear regression analysis revealed a loss of milk yield of 1.1 L/d (3.7%) as a consequence of the omission of one milking weekly. Milk composition, lactation persistency, and somatic cell count (SCC) were unaffected by milking omission. Milk partitioning in the udder decreased by 38% in alveolar milk volume and showed a tendency to decrease in cisternal milk volume (15%) and cisternal size (7%), as a result of milking omission and advancing lactation. Loss in total milk yield was negatively related with cisternal milk volume ($r = -0.77$) and cisternal size ($r = -0.70$) indicating smaller losses in the udders with large cisterns. In Experiment 2, five cows (21.0 L/d, 227 d in milk) previously adapted to the milking omission schedule were used to study the daily effects of milking omission on milk yield, milk composition and udder health during 10 wk. Milk yield and milk composition were approximately constant but SCC increased with lactation stage. The omission of one milking caused an important decrease in milk yield, fat content and SCC on the omission day and a compensatory increase over the following 2 d, but milk protein and lactose did not vary. All variables reached the average weekly value three days after the milking omission (six milkings). In conclusion, under the conditions used, omitting one

milking weekly slightly reduced milk yield and did not affect milk composition when healthy cows were used. Milk losses by milking omission depend on udder cistern characteristics; evaluating cistern size by ultrasonography may be a useful tool for choosing cows that are better adapted to a reduced milking frequency.

(Key words: milking frequency, cisternal size, udder health, ultrasonography)

Abbreviation key: 2x = twice-daily milking.

INTRODUCTION

The excess of milk production caused by a subsidized market and by continual technical progress is a permanent problem for dairy policy in the European Community (Langer, 1990). To control this situation, a policy of rents and improvement in the quality of life for farmers has been recently proposed. With this in mind, the reduction of daily milking frequency seems to be an interesting alternative for limiting milk yield, as well as an improvement in the work conditions. Moreover, the omission of one or more milkings per week (preferably on Sunday afternoon) would provide an important improvement in the quality of life of farmers, especially in small or family based dairy farms.

Throughout the world, twice-daily milking (2x) is the most frequent milking schedule of dairy cattle. Although, in the last 30 yr, 12-h intervals have been widely recommended, the 12-h milking frequency is not common in practice. Due to economical and social conditions, the unequal 8-16-h, 9-15-h or 10-14-h milking interval is more suitable than the equal 12-12-h milking interval (Sahr and Ormiston, 1966; Labussière and Coindet, 1968; Knight et al., 1994). The accumulation of milk in the udder during extended milking intervals reduces the activity of mammary cells, which indicates that milk secretion is under local intramammary control (Peaker and Wilde, 1996; Stelwagen and Knight, 1997; Stelwagen, 2001). Omitting one milking weekly, which can be done with a 24- or 18-h milking interval, may reduce milk yield to a lesser extent than once daily milking.

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There are few reported studies on the effect on milk yield in dairy animals of omitting one milking weekly, compared to twice a day milking. Yield losses ranged from 3 to 10% in cows (Labussière and Coindet, 1968; Radcliffe et al., 1973), 8 to 26% in ewes (Casu and Labussière, 1972; Labussière et al., 1974; Huidobro, 1988) and 3 to 5% in goats (Mocquot, 1978; Le Mens, 1978; Le Du, 1989). Yield losses seem to be related to the level of milk yield, breed, and udder morphology.

Recent studies suggest that udder anatomy (size of mammary cisterns) in terms of milk storage characteristics may be an important factor in determining reduced yield associated with extended milking intervals (Knight and Dewhurst, 1994; Stelwagen et al., 1996; Davis et al., 1998). A new approach using direct udder scanning for the study of udder cisterns in dairy cow milk production has been reported by Ayadi et al. (2003).

The objective was to evaluate the short term effects of omitting one milking weekly (Sunday afternoon) on milk yield and milk composition and the medium-term effects of the reduced milking frequency on milk yield and udder cistern size measured by ultrasonography.

MATERIALS AND METHODS

Experiment 1

Animals and feeding. Eight Holstein cows (5 multiparous and 3 primiparous) from the S1GCE (Servei de Granges i Camps Experimentals) of the Universitat Autònoma of Barcelona were used during a 10 wk period to study the milk yield and morphological udder changes induced by the omission of one milking weekly. At the start of the experiment days in milk were 201 ± 15 d and milk yield was 31.2 ± 5.8 L/d (mean $\pm$ SEM). Cows were kept in tied stalls, with a 6 h/d period of exercise in a paddock provided with group feed-bunks and a water-point and fed ad libitum a total mixed ration (1.58 Mcal NE_L/kg; 16.6% CP, dry matter basis) according to their requirements (NRC, 2001).

Routine milking. During the experiment, milking was conducted in the stalls by using a high pipeline Westfalia Landtechnik (Granollers, Barcelona, Spain) milking system at 50 kPa (Vacurex, Westfalia Landtechnik). Pulsation ratio and rate were set at 60:40 and 60 pulses/min by using a Metatron 12 (Westfalia Landtechnik). The milking routine for the regular daily milking (0800 and 1800) included teat cleaning, machine stripping and teat dipping (P3-cide plus, Henkel Hygiene S.A., Madrid, Spain). All cows were free from clinical mastitis at the start of the experiments.

Experimental procedures, calculations, and milk analysis. For the first 5 wk period of the experiment, cows were milked twice a day at a 10-14-h milking

interval (0800 and 1800). For the second 5 wk period, cows were milked twice a day at the 10-14-h milking interval from Monday p.m. to Saturday p.m. and on Sunday only one milking was performed at 1300. The Monday a.m. milking was brought forward by one hour to 0700 to match the long milking intervals (18 h). So, the milking pattern at the weekend was as follows: Saturday a.m., 0800; Saturday p.m., 1800; Sunday p.m., 1300; Monday a.m., 0700; and, Monday p.m., 1800.

Yield of each milking was recorded individually by using a Metatron 12 automatic milk recording and proportional milk sampling unit (Westfalia Landtechnik). Milk yield loss produced by the omission of one milking weekly was calculated as the difference between the extrapolated values from milk yield regression of each experimental period on the week in which the milking schedule was changed (wk 5). Lactation persistency was calculated on a 4 wk basis from the slope of the milk yield regressions.

Representative milk samples for milk composition analysis of each cow were taken weekly at Friday (a.m. and p.m.) and Saturday (a.m. and p.m.) milkings to avoid residual effects of the milking omission according to the procedures recommended by Labussière and Coindet (1968). The a.m. and p.m. samples were composited in a daily sample according to milk yield at each milking. Milk fat, milk protein and milk lactose content were analyzed by using CombiFoss 5000 equipment (Foss España, Barcelona, Spain) and somatic cell count (SCC) by Fossomatic equipment (Fosselectric, Hillerød, Denmark).

To evaluate the effect of milking omission on the morphological changes produced in the cow udders, cisternal scans were performed 8 h after the a.m. milking and in duplicate for each udder quarter according to the methodology proposed by Ayadi et al. (2003). Cows were randomly selected for scanning between Tuesday and Friday at the start and at the end of the experiment by using a real time B-mode ultrasonograph (Ultra Scan 900, Ami Medical Alliance Inc., Montreal, Canada) with a 5 MHz sectoral probe (2 dB power, 80° scanning angle, 0.5 mm axial and 1.5 mm lateral resolution). Prior to udder scanning, 10 μ g/kg BW of an oxytocin receptor blocking agent (Atosiban, Ferring Lab., Malmö, Sweden) was injected into the epigastric vein to prevent the milk ejection reflex and to make possible the recording of cisternal and alveolar milk fractions separately (Knight et al., 1994; Bruckmaier et al., 1997; Wellnitz et al., 1999). Afterwards, duplicated udder scans in perpendicular planes were taken and the images were transmitted in groups of four to a portable computer and stored for processing. Image treatment software (MIP4 Advanced System, Microm España, Barcelona, Spain) was used to estimate by triplicate

the cisternal area in the scans, and pixels converted to cm^2 ($1 \text{ cm}^2 = 1,024 \text{ pixels}$) for calculations as indicated by Ayadi et al. (2003).

After the scans, cisternal milk was milked from each udder quarter using a quartered claw and the values recorded. Alveolar milk was machine milked by using the quartered claw after a $20.0 \times 10^{-3} \text{ IU/kg BW i.m.}$ injection of oxytocin (Veterin Lobulor, Lab. Andreu, Barcelona, Spain). Milk fractions per quarter were weighed separately following collection to an accuracy of 10 g, and the weights recorded.

Experiment 2

Animals, feeding, and routine milking. Five Holstein cows (3 multiparous and 2 primiparous) from the S1GCE of the Universitat Autònoma of Barcelona, different from the cows used in Experiment 1 and previously adapted to the omission of one milking weekly schedule from the start of the first lactation, were used during a 10-wk period to study the daily effects of the omission of one milking weekly. At the start of the experiment days in milk were $227 \pm 67 \text{ d}$ and milk yield was $21.0 \pm 3.4 \text{ L/d}$ (mean $\pm$ SEM). Cows were kept in tied stalls with a 6 h/d period of exercise in a paddock, as in Experiment 1, and fed ad libitum a total mixed ration (1.2 Mcal NE_l/kg ; 16.1% CP, dry matter basis) according to their requirements (Jarrige, 1989). The same milking routine and milking equipment as described in Experiment 1 were used.

Experimental Procedures and Milk Analysis. For the 10 wks of the experiment, cows were milked twice a day at 0800 and 1800 but on Sunday one milking only was performed at 1200. Monday morning milking was done at the regular time (0800) due to labor organization reasons, resulting in unequal long milking intervals (Saturday p.m. to Sunday, 18-h; and, Sunday to Monday a.m., 20-h). Throughout the experiment, milk yield at each milking was recorded individually using a Metatron 12 (Westfalia Landtechnik). Milk samples of each cow at each milking were taken every day to analyze daily milk composition changes. Milk fat, protein and lactose content were analyzed by using NIRS equipment (Infra Alyser 450 D, Bran + Luebbe, Nordstedt, Germany), according to the methodology described by Albanell et al. (1999). Milk SCC were analyzed by using Fossomatic equipment (Fosselectric, Hillerød, Denmark). Average milk yield and composition for Friday and Saturday were used as reference values to evaluate the effect of changing the milking frequency on Sunday.

Statistical Analysis

Data were processed by the PROC MIXED procedure for repeated measurements of SAS (version 8.1). The

Figure 1. Change in milk yield (●), in percentages of milk fat (○), protein (△), lactose (□) and log₁₀ SCC (■) during the 10 wk of the experiment. Values are the total dairy milk yield measured for 8 cows. Vertical bars represent SEM.

model included general means and the effects of the treatment, animal, experimental week, and the respective interactions and residual error. Logarithmic transformation ($\log_{10}$) of SCC was previously carried out for statistical analysis. When the probability of the interaction term was non significant ($P > 0.20$), it was deleted from the model. Differences between Least Square Means were localized with the PDIF test and significance was declared at $P < 0.05$. Linear regression analysis of milk yield for each experimental period was done by using the REPEATED statement in PROC MIXED using time as a regression variable. Pearson's correlation coefficients between cisternal areas and cisternal milk were also calculated.

RESULTS

Experiment 1

Milk Yield and Milk Composition. Milk yield decreased 32% ($P < 0.05$) during the experimental period (10 wk) according to progression in lactation (Figure 1). Persistency coefficient of milk yield was 95.9% on average during the experiment. Linear regression analysis of weekly milk yields for each experimental period,

Table 1. Effect of omitting one milking weekly on milk yield, milk composition, SCC and change of milk partitioning (cisternal and alveolar milk) in the udder 8 h after milking.

Item	14 milkings/wk (wk 1 to 5)		13 milkings/wk (wk 6 to 10)		Effect ($P =$)
	Mean	SEM	Mean	SEM	
Cows, n	8	...	8	...	...
Milk yield, L/d	28.81	2.11	24.60	2.70	0.042
Milk yield regression ¹					
a	32.06	2.18	29.76	3.19	...
b	-1.162	0.315	-0.912	0.315	...
R ²	0.97	...	0.94	...	...
Persistency coefficient ² , %	95.35	...	96.34	...	...
Milk composition					
Fat, %	3.11	0.21	2.91	0.21	0.771
Protein, %	3.06	0.09	3.10	0.08	0.936
Lactose, %	4.21	0.21	4.08	0.21	0.347
Log SCC $\times$ 1000	2.28	0.17	2.36	0.17	0.841
Milk partitioning ³					
Alveolar, L	8.89	0.82	5.53	0.28	0.001
Cisternal, L	3.16	0.26	2.67	0.31	0.069
Cisternal area ⁴ , cm ²	21.70	2.91	19.94	1.92	0.112

¹Milk yield (L/d) = $a + b \times (\text{week})$.

²Four wk milk yield persistency (%) = $100 - 4 \times b$.

³Measured 8 h after milking.

⁴Measured by ultrasonography 8 h after milking according to Ayadi et al. (2003).

before and after the omission of one milking weekly, revealed non significant ($P > 0.05$) differences in the slope of lactation curves from wk 1 to 5 and 6 to 10 (Table 1). Interaction between the suppression of one milking on Sunday afternoon and the experimental week was not significant ($P = 0.58$) and milk yield persistency before and after the omission of one milking weekly (Table 1) was unaffected by the treatment.

Although milk yield decrease before and after the milking omission schedule, including the effect of advancing lactation, averaged 4.21 L/d (Table 1), the specific loss produced by the weekly omission was lower than calculated by mean of the milk yield regressions before and after the omission of one milking. Milk yield loss due to the weekly milking omission estimated by regression was 1.08 L/d, or 3.7%. Individual analysis per cow did not show significant differences in the milk yield slope between the before and after experimental periods.

Milk composition did not change significantly ($P > 0.05$) during the experimental period (Table 1). Moreover, the omission of one milking applied from wk 5 did not induce any important change in any milk component (Figure 2).

Udder health change evaluated by monitoring the SCC during the experiment is also shown in Figure 2. Omitting one milking weekly did not affect ($P > 0.05$) the mean value of $\log_{10}$ SCC $\times$ 1000 which was steadily constant (2.32) during the experiment. The SCC response was very variable among cows and was depen-

dent on SCC at the start of the experiment. To investigate this possibility, cows were divided into two equal groups of animals according to the level of SCC: low (average 134.000 ± 40.000 cells/ml) and high (average 383.000 ± 59.000 cells/ml). Milking omission did not affect ($P > 0.05$) the SCC change in cows of the SCC low group but showed a tendency to increase in the cows of the SCC high group (+24%; $P = 0.20$).

Relationship between udder cisternal size and yield loss. Average values of measured cisternal areas and evacuated cisternal milk volumes per quarter ranged from 4.1 to 55.0 cm² and from 0.21 to 1.95 L, respectively. Cisternal size did not significantly change ($P > 0.05$) after the alteration in milking frequency; the scanning area values were 21.7 ± 2.91 cm² for the complete milking schedule and 19.94 ± 1.92 cm² for the Sunday afternoon milking omission schedule (Table 1). Milk partitioning in the udder 8 h after milking showed a decrease in alveolar milk volume (38%, $P < 0.001$) and a tendency to decrease in cisternal milk volume (15%, $P < 0.07$) and cisternal size (7%, $P < 0.11$) as a result of the joint effect of milking omission and advancing lactation (Table 1). Correlation between the scanning area and the volume of cisternal milk for each quarter 8 h after milking were significant and positive before ($r = 0.82$; $P < 0.01$) and after omitting one milking weekly ($r = 0.80$; $P < 0.01$), as well as when pooled data were used ($r = 0.83$; $P < 0.01$). No significant ($P > 0.05$) correlation was found between milk yield and the loss produced by omitting one milking weekly. Moreover,

Figure 2. Change in milk yield (●) and percentage of milk fat (○), protein (△), lactose (□), and $\log_{10}$ SCC (■) for different days of the week.

loss of milk yield was not significantly correlated with alveolar milk volume at 8-h. However, there was a significant negative relationship between the cisternal area measured at 8-h and the loss of total milk yield on omitting one milking weekly which can be described by the equation,

$$\text{Total milk yield loss (L/d)} = 1.651 - 0.0261 \times \text{cisternal area (pixels} \times 10^{-3})$$

$$r = 0.701 \ (P < 0.04; \text{residual SD} = 0.44).$$

Experiment 2

Milk yield, milk composition, and udder health. Average milk yield and milk composition did not significantly vary ($P > 0.05$) during the experimental

weeks, but SCC increased with lactation stage. The evolution of milk yield, milk composition and SCC for the different days of the week is shown in Figure 2. On Sundays, milk yield (15.6 L/d), fat content (3.38%) and $\log \text{SCC} \times 1000$ (2.59) decreased by 29, 21, and 27% ($P < 0.05$), respectively, as a result of the change in milking frequency. On Mondays, milk yield (23.9 L/d), fat content (4.84%) and $\log \text{SCC} \times 1000$ (3.02) increased by 9, 14, and 100% ($P < 0.05$) respectively. The increase in SCC was dependent on the previous measurement but decreased again after four milkings. All values reached the average level by Wednesday. Milk protein (3.47%) increased by 2% and lactose (4.37%) decreased by 2% ($P < 0.05$) on average during the week. Compared with estimated for 14 milkings/week, omitting one milking weekly decreased the weekly yields of milk (3%), fat (4%), protein (5%), and lactose (5%), but milk SCC increased by 25%. Loss of milk yield varied according to the cow's yield but not to experimental week. Clinical mastitis was not observed in any cows at any time during the experiment.

DISCUSSION

In our experiment we obtained an overall reduction in milk yield lower than 4% when omitting one milking weekly in cows yielding around 30 L/d. Previous studies, however, demonstrated a reduction in milk yield varying from as little as 3% to as much as 10% as a result of omitting one milking weekly in comparison with twice daily milking (Radcliffe et al., 1973; Labussière and Coindet, 1968). Recent studies on the short term effects of omitting one milking weekly to reduce labor requirements on dairy farms, suggest that milk yield was not affected in late lactation (Sheehy, 2001; O'Brien et al., 2002).

Moreover a reduction of 8 to 26% in milk yield in dairy ewes (Casu and Labussière, 1972; Labussière et al., 1974; Huidobro, 1988) and a reduction of 3 to 5% in milk yield in dairy goats (Mocquot, 1978; Le Mens, 1978; Le Du, 1989) by omitting one milking weekly has also been reported. This can be related to their respective cistern size. Pattern of milk yield change during the days of the week shown in our work agrees with the results obtained by Labussière and Coindet (1968) and Charron (1986) in which milk yield decreased during the day of the suppression and increased dramatically 24-h after. Nevertheless, milk yield values reached the average level 72-h after omitting the milking. In our experiments we observed that the loss of milk yield produced by omitting one milking weekly was not affected by milk yield (Experiment 1) or by the lactation wk of the cows (Experiment 2) although in both cases the cows were in late lactation (201 to 236

DIM in Experiment 1; and, 227 to 297 DIM in Experiment 2).

The size of the cistern plays a major role in the ability of the udder to accumulate 24-h worth of milk secretion, it is responsible for approximately half of the functional udder capacity in cows (Davis et al., 1998). However, the question arises as to whether a larger cistern is associated with increased tolerance of the extended milking interval in animals.

In relation to understanding the yield loss incurred when extended milking intervals are applied, Davis et al. (1998) and Stelwagen (2001) reported that, together with cisternal size, the freedom of alveoli to drain (actively or passively) to the cistern is an important factor to explain the loss of milk yield observed when the milking interval is extended to 24-h. Knight et al. (1994) and Ayadi et al. (2003) showed that correlation between cisternal milk and cisternal size was higher at 8-h after milking than longer intervals. Based on those data, cisternal measurements in the present study (Experiment 1) were made 8-h after the morning milking.

The average size of the cisterns observed in our work by scanning for 8-h milking intervals was similar before and after omitting one milking weekly. Moreover, the methodology of Ayadi et al. (2003) was adequate to obtain a repeatable image of the udder cistern, as indicated by the high correlation between cisternal milk and cisternal size in the two periods of the experiment. Correlation between the scanning area and the cisternal milk for each quarter at the 8-h milking interval were significant and positive. This result agrees with those previously reported by Bruckmaier et al. (1994) and Ayadi et al. (2003) in cows. Moreover, Knight and Dewhurst (1994) reported a significant relationship between udder volume and milk yield. In our result (Experiment 1) we showed a strong negative correlation between the reduction in milk yield attributable to omitting one milking weekly and cisternal size measured by ultrasonography. The same conclusion was obtained in previous studies comparing once versus twice daily milkings (Knight and Dewhurst, 1994; Stelwagen and Knight, 1997; Davis et al., 1998) with the large cisternal cows showing the smallest decrease in yield. The interpretation of these data was that the putative effect of the Feedback Inhibitor of Lactation (FIL), which is a milk protein and an autocrine inhibitor of milk secretion (Peaker and Wilde, 1996), would be concentration-dependent and inactive in the cisternal milk as reported by Knight and Dewhurst (1994) and Wilde et al. (1995). Therefore, udders with large cisterns produce more milk and are more tolerant of longer milking intervals in dairy cows (Knight and Dewhurst, 1994), dairy goats (Peaker and Blatchford, 1988; Salama et al., 2003) and dairy ewes (Labussière, 1988;

Rovai et al., 2000). On the other hand, small cisternal cows, by virtue of being more affected by FIL, respond better to increased milking frequency (Knight and Dewhurst, 1994).

Omitting one milking weekly did not significantly affect the milk yield composition in Experiment 1. This result agrees with the recent short-term effects observed by Sheehy (2001) and O'Brien et al. (2002) but is not in accordance with data from all lactation. Labussière and Coindet (1968) obtained an overall reduction in milk composition of 6 to 7% when one milking was omitted. The results obtained in Experiment 2 about milk composition and SCC changes for the different days of the week were in accordance with Labussière and Coindet (1968) and all values reached the average level 72-h after omitting one milking weekly. All cows were free from clinical mastitis in both trials. Although SCC in milk after the omission of one milking weekly vary, previous studies confirmed our results in short and long term experiments in dairy cows (Labussière and Coindet, 1968; Sheehy, 2001; O'Brien et al., 2002), dairy ewes (Casu and Labussière, 1972; Labussière, 1974) and dairy goats (Mocquot, 1978; LeMens, 1978).

CONCLUSIONS

We conclude that, with our conditions, omitting one milking weekly slightly reduced milk yield and did not affect milk composition nor lactation persistency when healthy cows were used. Milk losses by milking omission depend on udder cistern characteristics; evaluating cistern size by ultrasonography may be a useful tool for choosing cows that are better adapted to a reduced milking frequency. Milk yield is reduced less in cows that store a greater proportion of their total milk production within the cistern. Also, milk recording should be conducted in the middle of the week to avoid alterations caused by the milking omission. New research on the effects of omitting one milking weekly on high yielding cows in early lactation is required before recommending this milking schedule for general practice.

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