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Once-daily milking effects in high-yielding Alpine dairy goats

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ABSTRACT

Two experiments were conducted to determine the milk loss of high-yielding Alpine goats resulting from once-daily milking (ODM) and its relationship to udder cisternal size. We investigated the effects of application of this management strategy on milk yield, composition, and technological parameters: lipolysis, fat globule size, and cheese yield. In a second experiment, we investigated the effect of repeated periods of ODM management during lactation. Goats at the beginning of both experiments were at 25 d in milk on average and were previously milked twice daily (twice-daily milking; TDM). In experiment 1, which was conducted for 2 periods (P) of 9 wk (P1, P2), 48 goats were grouped (1, 2, 3, and 4) according to milk yield, parity, and somatic cell count (SCC). Over the 2 periods, goats from group 1 were managed with TDM and those from group 2 were managed with ODM. In group 3, goats were assigned to TDM during P1 and ODM during P2, conversely, those in group 4 were assigned to ODM in P1 and TDM in P2. During P1, the 12 goats from group 3 underwent 2 distinct morning machine milkings to measure milk repartition (cisternal and alveolar) in the udder based on the "atosiban method." On P1 plus the P2 period of 18 wk, milk loss caused by ODM (compared with TDM) was 16%. In our condition of 24-h milk accumulation, there was no correlation between milk loss and udder cisternal size. Milk fat content, fat globule size, or apparent laboratory cheese yield was not modified by ODM, but milk protein content (+2.7 g/kg), casein (+1.8 g/kg), milk soluble protein concentration (+1.0 g/kg), and SCC increased, whereas lipolysis decreased (−0.3 mEq/100 g of oleic acid). In experiment 2, which was conducted for 4 periods (P1, P2, P3, P4) of 5 wk each, 8 goats, blocked into 2 homogenous groups (5 and 6), were used to study the effects of a double inversion of milking frequency (TDM or ODM) for 20 wk of lactation. Milk loss was 17% and ODM did not modify milk fat or protein contents, SCC, casein, or milk soluble protein concentration, but lipolysis was decreased (−0.3 mEq/100 g of oleic acid). Neither experiment showed the effects of period of ODM management on milk yield, milk fat or protein content, SCC, fat globule size, lipolysis, casein, milk soluble protein concentration, or apparent laboratory cheese yield.

Key words: dairy goat, udder cisternal size, once-daily milking, milk quality

INTRODUCTION

In France, as in other countries around the world, dairy farmers want to reduce their labor requirements to devote time to other farm practices or to social and family activities. Unfortunately, in France, high labor costs make it difficult to afford to hire supplementary staff, so this cannot be a solution for small family farms. Once-daily milking (**ODM**) may offer a way to reduce the workload of dairy farmers because the time spent milking in twice-daily milking (**TDM**) has been identified as representing 50% of the daily labor time in French dairy cow herds (Chauvat et al., 2003). This percentage increases even more for cheese makers (i.e., more than 50% of dairy goat farmers in France), who must make and sell their cheese.

Once-daily milking has been studied in low-yielding dairy goat breeds, such as the Murciano Granadina (Salama et al., 2003), Canarian (Capote et al., 1999), and Damascus (Papachristoforou et al., 1982), and losses from 6 to 18% have been reported. A French study with Alpine goats (Mocquot et al., 1978) and more recent studies with Saanen goats (Wilde and Knight, 1990; Boutinaud et al., 2003) have demonstrated higher losses, ranging from 26 to 36%. These results have suggested that high-yielding goats or specific breeds cannot be adapted to ODM. Because these studies were done earlier or were conducted only for short periods (3 or 4 wk), no valid data exist on the ability of current high-yielding goats to adapt to ODM throughout a lactation or during specific and significant parts of a lactation. In addition, there are no data concerning the

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ability of goats to recover their milk production when ODM is applied during the first part of a lactation, before returning to TDM. In addition, no data exist on the way ruminant species respond to ODM when this management strategy is applied for more than 1 period per lactation.

A relationship between morphological udder measurements and milk production has been noted in goats (Linzell, 1966; Mavrogenis et al., 1989) as well as in cows (Knight and Dewhurst, 1994). However, if the response of dairy goats to ODM can be explained by their larger cisternal size, as suggested by Salama et al. (2003), this relationship remains to be verified in goats.

Reducing the milking frequency of goats from TDM to ODM results in increased milk fat and protein concentrations (Capote et al., 1999; Salama et al., 2003). Once-daily milking also increases the CN level and does not modify the SCC (Salama et al., 2003). However, the effects of ODM on technological parameters [lipolysis, fat globule size, and apparent laboratory cheese yield (**ALCY**)] have never been studied.

The aim of the first part of our study was to investigate the effects of ODM on high-yielding Alpine goat milk yield, composition, and technological parameters (lipolysis, fat globule size, and ALCY). In addition, we wanted to verify whether the response of dairy goats to ODM was related to udder cisternal size. We also investigated the ability of dairy goats to recover the previous milk production level after application of ODM. The second part of our study examined the effects of repeated periods of ODM application on milk yield and milk quality.

MATERIALS AND METHODS

Animals and Experimental Design

Two experiments were conducted on a total of 56 dairy Alpine goats (48 for experiment 1 and 8 for experiment 2) from the herd of the experimental farm of the French National Institute for Agricultural Research (INRA) of Le Rheu. Kids were separated from their dams immediately on parturition day. All goats were milked twice daily for 2 wk postpartum. Mean stage of lactation was 25 ± 10 d at the beginning of the experiments.

Experiment 1. Forty-eight goats were blocked into 4 groups (1, 2, 3, and 4) of 12 animals each according to milk yield, parity, and SCC of the preexperimental period. Their parities were first (n = 24, primiparous), second (n = 12), third (n = 8), and more than third (n = 4) lactation. Treatments were randomly applied to the groups. The trial was conducted over 2 periods (**P1** and **P2**) of 9 wk each. In group 1, goats were milked twice daily (TDM) over the 2 periods; in group 2, goats were milked once daily (ODM) over the 2 periods. In group 3, goats were assigned to TDM during P1 and ODM during P2, and in group 4 goats were assigned to ODM during P1 and TDM in P2, as summarized in Figure 1.

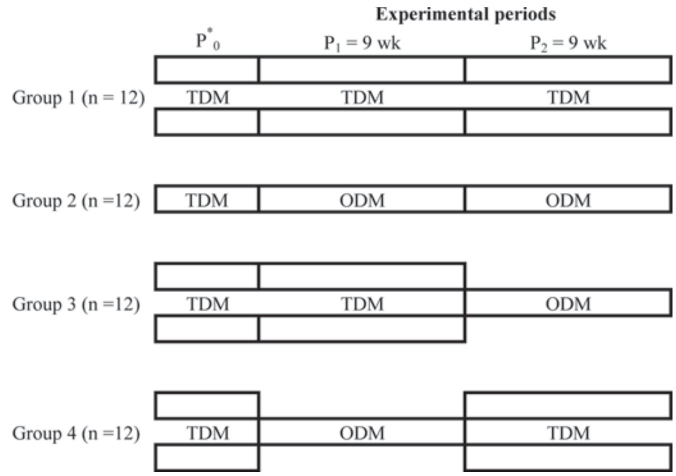

Figure 1. Milking frequency treatments from groups in experiment 1. An asterisk (*) indicates the period from parturition day to 25 DIM on average. P = period; TDM = twice-daily milking; ODM = once-daily milking.

Experiment 2. Eight goats were blocked into 2 homogenous groups (5 and 6) of 4 goats each with good udder health (SCC <400,000 cells/mL). Their parities were first (n = 3, primiparous), second (n = 3), and third (n = 2). Treatments were randomly applied to the groups. The trial was conducted in 4 periods (P1, P2, **P3**, and **P4**) of 5 wk each. In group 5, TDM was applied in P1, ODM in P2, TDM in P3, and ODM in P4. In group 6, ODM was applied in P1, TDM in P2, ODM in P3, and TDM in P4, as summarized in Figure 2.

In both experiments, goats assigned to ODM were separated physically from those assigned to TDM to limit the possible effects of machine milking (machine

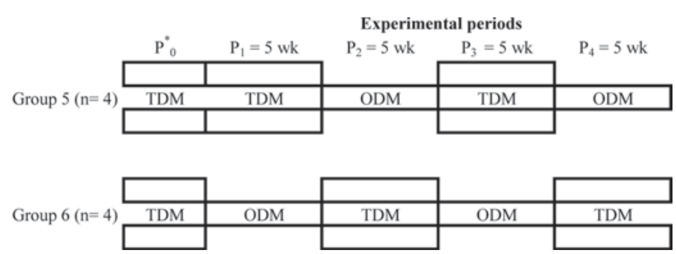

Figure 2. Milking frequency treatments from groups in experiment 2. An asterisk (*) indicates the period from parturition day to 25 DIM on average. P = period; TDM = twice-daily milking; ODM = once-daily milking.

Table 1. Chemical analysis and feed component values from experiments 1 and 2

Item	Feed component		
	Hay[1]	Alfalfa[1]	Concentrate[2]
DM (%)	85.0	90.6	86.1
Mineral matter (%)	9.0	11.7	5.8
Total N (N × 6.25; %)	12.7	18.4	17.4
Cellulose (Weende; %)	29.5	28.3	5.0
NDF (%)	59.1	46.1	17.7
ADF (%)	32.1	32.6	7.9
Acid detergent lignin (%)	—	8.3	3.1
Ca (g/kg)	4.6	22.3	8.7
P (g/kg)	3.2	2.7	5.2
Net energy (UFL[3]/kg)	0.80	0.70	0.94
PDIN[4] (g/kg)	85	120	115
PDIE[5] (g/kg)	91	104	97

[1]Data from INRA (Saint-Gilles, France).

[2]Ingredients: 60% wheat, 19.71% colza, 2.75% soybean oil cakes, 1.73% palm oil cakes, 8.60% Amyplus (Tate & Lyle, Nestlé, France), 4% molasses, and 3.23% mineral and vitamin premix (data from Cooperl-Hunaudaye, Lamballe, France).

[3]Energy feed unit equivalent to 1,700 kcal of net energy for lactation.

[4]True protein digested in the small intestine according to N supply.

[5]True protein digested in the small intestine according to energy supply.

and milking noises; movements, and vocalizations of goats). They were housed indoors and fed by group. The goats of each group had access to hay ad libitum. The supplement per goat was 800 g/d of alfalfa and 1 kg/d of concentrate (INRA goat GR VRAC, Cooperl-Hunaudaye, Lamballe, France). The amount of supplement did not differ according to milking frequency. The chemical analysis and values of the feed components are shown in Table 1. The goats were milked in a double-12-stall parallel milking parlor. Milking was performed with a low line at a vacuum pressure of 38 kPa, a pulsation rate of 120 pulsations/min, and a pulsation ratio of 60:40. Goats in the TDM management group were milked at 0645 and 1645 h, whereas those in the ODM group were milked at 1645 h.

Animal Measurements and Milk Sampling

Milk yields of individual goats on the TDM and ODM treatments were measured with an Mk 5 Waikato milk meter (direct measurement device; Waikato, Hamilton, New Zealand) at the morning and evening milking 5 d/wk (from Monday to Friday). Individual samples to measure milk composition (fat, protein, SCC, and lipolysis) were taken twice per week (Tuesday and Thursday) from goats (8 goats, 4 multiparous and 4 primiparous per group for experiment 1 and all goats in experiment 2) in the TDM treatment at the morning and evening milking and in the ODM treatment at the one evening milking. Milk composition was analyzed by a dairy interprofessional laboratory (Lillab, Châteaugiron, France). In addition, milk samples (300 mL) were collected in each period (in the second and fourth weeks) for detailed compositional analysis: total N, NPN, and noncasein N (Kjeldahl method ISO 8968-1; IDF, 2001); fat globule size by a Coulter Multisizer II instrument (Coulter Electronics Limited, Luton, UK) as described by Couvreur (2006); and ALCY. To measure the ALCY, individual milk (100 mL) was standardized (pH 6.5) with lactic acid, heated to (35°C), and equilibrated for 1 h 30 min. Rennet (2.5 μL/mL) with 52 mg/L of chymosin (Pourprix Négoce Laiterie, Lyon, France) was then diluted 1:10 with deionized water and added for coagulation in 1 h at 35°C. A rennet curd sample (50 mL) was taken in a tube that had previously been weighed (WT). The ALCY was measured after centrifugation (10 min, 35°C, and 2,700 × g) of the rennet curd and after weighing of the tube with curd plus whey (WCW) and without whey (WC). The ALCY was determined by using the following equation: ALCY = [WC − WT]/[WCW − WT].

The individual live weight of goats was measured at wk 2 of lactation and at wk 5, 9, 14, and 18 of the experimental period in both experiments. The 12 goats in group 3 were used to measure milk repartition (cisternal and alveolar) in the udder at the Friday morning milking in wk 3 and 8 during TDM. Cisternal milk was measured by machine milking after intravenous injection of Atosiban (0.7 mg/mL), a reversible oxytocin (**OT**) receptor-blocking agent (Ferring Research Institute Inc., San Diego, CA). Because of this strong OT receptor blockade, milk ejection during machine milking could not occur, and only the cisternal milk was obtained. Because Atosiban (antagonist), injected before milking, fixed the site of receptor of OT (agonist), that prevented the OT released during milking to bind at the same site. Consequently, alveolar cells did not contract because OT is known to cause alveolar cell contractions involving complete ejection of the milk. Alveolar milk was then obtained by machine milking, after intravenous injection of an extra physiological dose of OT (Syntocinon, 5 IU/mL, Novartis Pharma, Rueil-Malmaison, France) able to displace the antagonist bonds to receptors.

Statistical Analysis

Data from 1 goat (multiparous) in group 2 were excluded from the statistical analysis because this goat developed clinical mastitis that dramatically impaired milk production. All data (period mean) were analyzed by using the lactation stage of the goats at the beginning of the experimental period as a covariable in the general linear models procedure. The relationship be-

Table 2. Effects of milking frequency [twice-daily milking (TDM) or once-daily milking (ODM)], period, goat parity, and their interactions on milk yield and composition and on cheese yield in experiment 1

Item	n	Milking frequency		Period		Parity		Effect[1]				
		TDM	ODM	1	2	1	2	M	P	R	P × M	R × M
Milk yield (kg/d)	47	3.2	2.7	3.1	2.8	2.8	3.1	***	**	**	NS	NS
Milk fat content (g/kg)	31	31.8	32.9	34.9	29.8	31.8	33.0	NS	***	NS	*	NS
Milk protein content (g/kg)	31	27.7	30.4	29.7	28.5	28.8	29.4	***	*	NS	NS	NS
ln SCC	31	12.1	12.4	11.9	12.6	12.0	12.5	*	***	**	NS	**
Total fat yield (g/d)	31	106.1	90.4	111.2	85.2	94.7	101.7	**	***	NS	**	NS
Total protein yield (g/d)	31	91.8	83.3	93.9	81.1	85.4	89.6	*	***	NS	*	NS
Lipolysis (mEq/100 g of oleic acid)	31	0.8	0.5	0.5	0.8	0.5	0.8	*	†	NS	NS	NS
Fat globule size (μm^2)	31	1.3	1.3	1.2	1.3	1.3	1.3	NS	**	NS	NS	NS
CN (g/kg)	31	20.8	22.6	22.0	21.4	21.6	21.8	**	NS	NS	NS	NS
Soluble protein (g/kg)	31	4.2	5.2	4.8	4.6	4.5	4.9	***	NS	†	†	*
ALCY[2] (g/kg)	31	16.6	17.6	18.9	15.3	16.5	17.6	†	***	NS	NS	NS

[1]M = milking frequency; P = period; R = goat parity; P × M = interaction of period and milking frequency; R × M = interaction of goat parity and milking frequency.

[2]Apparent laboratory cheese yield, measured after centrifugation of the rennet curd.

NS = not significant ($P \geq 0.1$); †$0.05 < P < 0.1$ (tendency); *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

tween yield loss and cistern size was assessed by simple linear regression analysis. All statistical analyses were carried out with SAS software (SAS Institute, 1999). The statistical models used were as follows.

Experiment 1. The primary statistical analysis demonstrated no residual effect of milking frequency in P1 compared with P2. Thus, we used the following statistical models:

- Group effects:

$$Y_{ij} = \mu + P_i + G(P)_j + S + \lambda_{ij},$$

where μ is the parameter average, P is the period effect (i = 1, 2), G(P) is the group in period (j = 1, 2, 3, 4), S is the goat lactation stage effect, and λ is the random error.

Periods, parities, milking frequency, and their interaction effects:

$$Y_{ijk} = \mu + R_i + P_j + T_k + (R \times T)_{ik} + (P \times T)_{jk} + S + \lambda_{ijk},$$

where μ is the parameter average, R is the parity effect (i = 1, primiparous; 2, multiparous), P is the period effect (j = 1, 2), T is the milking frequency effect (k = ODM, TDM), R × T is the interaction between goat parity and milking frequency, P × T is the interaction between the period and milking frequency effect, S is the goat lactation stage effect, and λ is the random error.

Experiment 2. We used the following statistical model:

- Periods (P1, P2, P3, and P4), milking frequency, and their interaction effects:

$$Y_{ij} = \mu + P_i + T_j + (P \times T)_{ij} + \lambda_{ij},$$

where μ is the parameter average, P is the period effect (i = 1, 2, 3, 4), T is the milking frequency effect (j = ODM, TDM), P × T is the interaction between period and milking frequency effect, and λ is the random error.

RESULTS

Experiment 1

Milk Yield and Goat ODM Ability. Mean milk loss caused by ODM (compared with TDM) during the trial was 16% ($P = 0.0004$; Table 2). However, individual losses of goats revealed wide variability [from 8 to 35%; see Figure 3 for an example of the variability in milk loss between goats (n = 12) in group 3]. Nevertheless, milk loss caused by ODM (compared with TDM) was not related to cisternal size ($P = 0.7$; Figure 3).

There were no significant differences in milk production between goats managed with the same frequency of milking over both periods; that is, the milk yield of goats from group 3 was not different from those of group 1 during P1 and from group 2 during P2 ($P = 0.8$ and 0.5, respectively). In the same way, the milk yield of goats from group 4 was not different from those of group 2 during P1 and from group 1 during P2 ($P = 0.9$ and 0.8, respectively; Figure 4). In goats from group 4 during ODM, mean milk yield was different in P1 (2.8 vs. 3.4 kg/d) compared with the control (group 1) in TDM, but was not different (2.9 vs. 3.0 kg/d, respectively) when both groups were in TDM during P2 (96% of recovery). This recovery was immediate after the milking frequency was switched from ODM to TDM. Moreover, the interaction between period and

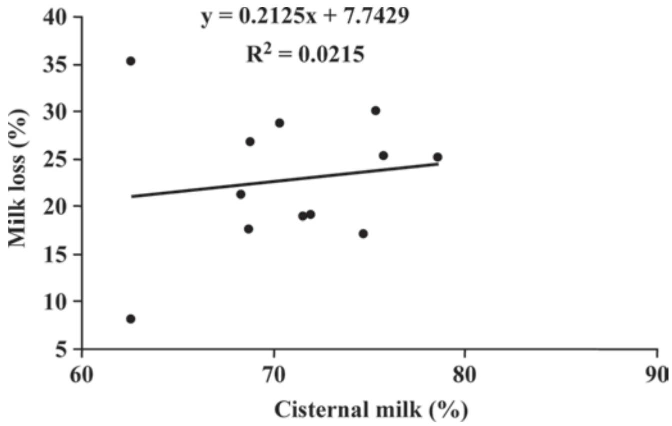

Figure 3. Linear relationship between milk loss and udder cistern size after 24 h of milk accumulation in the mammary gland in goats from group 3: TDM during period 1 and ODM during period 2, in experiment 1. TDM = twice-daily milking; ODM = once-daily milking.

milking frequency was not significant with regard to milk yield ($P = 0.4$; Table1).

Mean milk yield (3.1 kg/d) of multiparous goats was higher than that of primiparous goats (2.8 kg/d). Nevertheless, the interaction between parity and milking frequency effects on milk yield was not significant (Table 2).

ODM Effect on Milk Composition. The milking frequency effect was not significant with regard to milk fat content ($P = 0.3$) or fat globule size ($P = 0.1$). There was a tendency for ODM to increase ALCY ($P = 0.08$). Milk protein content, SCC, CN, and milk soluble protein concentration were significantly increased by ODM, but fat content was not modified. Conversely, ODM (compared with TDM) decreased total fat, total protein yield, and lipolysis of milk (Table 2).

Interactions between period and milk frequency were not significant for milk protein content ($P = 0.1$), SCC ($P = 0.7$), lipolysis ($P = 0.2$), fat globule size ($P = 0.1$), CN concentration ($P = 0.9$), or ALCY ($P = 0.6$). Milk fat content tended to be higher in P1 than P2 under ODM management (34.3 vs. 31.5 g/kg, respectively; $P = 0.07$). In addition, ODM tended ($P = 0.06$) to increase milk soluble protein concentration in P2 compared with TDM.

The SCC of primiparous goats was lower than that of multiparous goats (162,700 vs. 268,300 cells/mL)

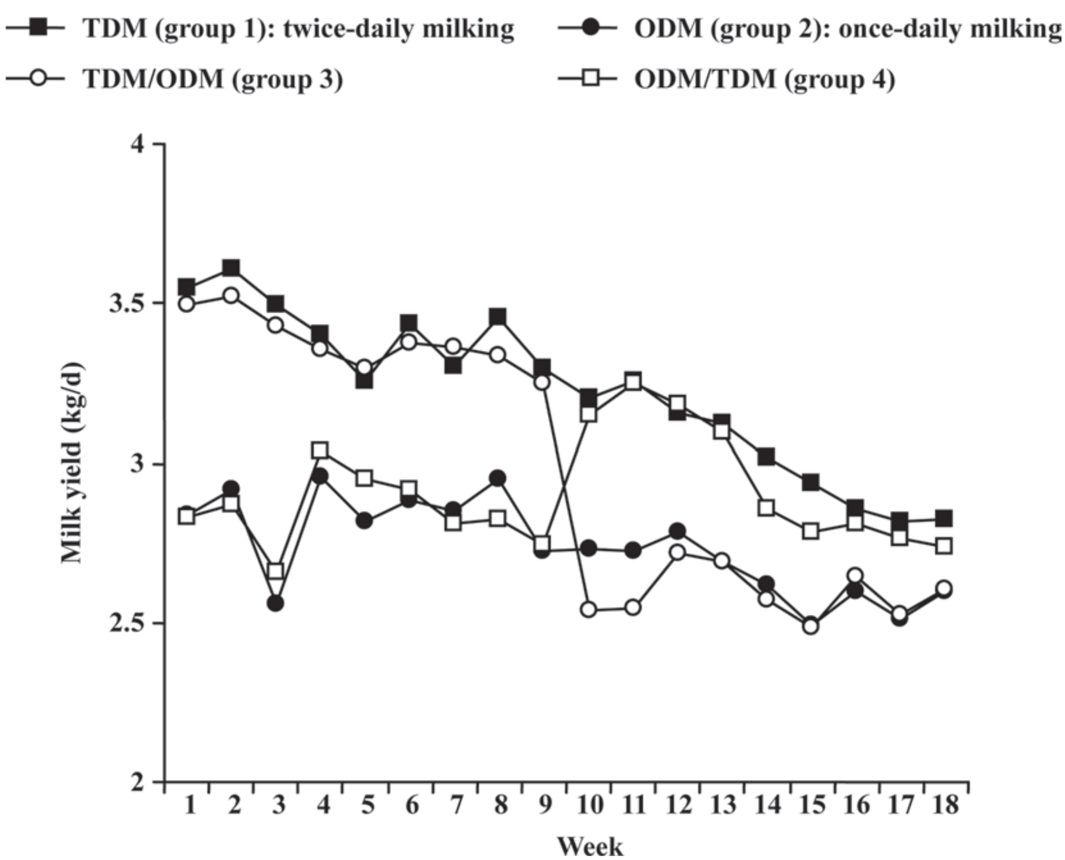

Figure 4. Milk yield of dairy goats according to TDM, ODM, and milking frequency by simple inversion (TDM to ODM or ODM to TDM) in experiment 1. TDM = twice-daily milking; ODM = once-daily milking.

Table 3. Effects of milking frequency [twice-daily milking (TDM) or once-daily milking (ODM)], period, and their interactions on goat milk yield and composition and on cheese yield in experiment 2[1]

Item	Milking frequency		Period				Effect		
	TDM	ODM	P1	P2	P3	P4	M	P	P × M
Milk yield (kg/d)	3.0	2.5	3.0	2.9	2.7	2.5	***	*	†
Milk fat content (g/kg)	35.1	33.9	37.2	34.6	35.1	31.0	NS	*	NS
Milk protein content (g/kg)	30.3	30.8	30.9	30.2	30.5	31.0	NS	NS	NS
ln SCC	12.3	12.2	12.0	12.1	12.3	12.5	NS	NS	NS
Total fat yield (g/d)	109.6	89.0	114.9	104.0	98.5	79.5	***	***	NS
Total protein yield (g/d)	92.5	78.6	92.7	88.8	83.5	77.3	**	†	*
Lipolysis (mEq/100 g of oleic acid)	0.7	0.4	0.4	0.6	0.6	0.7	**	†	NS
CN (g/kg)	22.8	22.2	22.2	22.3	22.9	22.8	NS	NS	NS
Soluble protein (g/kg)	5.4	5.5	5.3	5.4	5.7	5.4	NS	NS	NS

[1]n = 8. M = milking frequency; P = period; P × M = interaction of period and milking frequency.
NS = not significant ($P \geq 0.1$); †$0.05 < P < 0.1$ (tendency); *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

and their milk soluble protein concentration tended ($P = 0.08$) to be lower compared with multiparous goats (4.5 vs. 4.9 g/kg). Interactions between parity and goat milking frequency were significant for these parameters. The SCC of primiparous goats in ODM did not differ from the SCC of primiparous goats in TDM (162,700 vs. 179,800 cells/mL, respectively, $P = 0.6$). The SCC of multiparous goats in ODM was higher ($P = 0.0007$) than the SCC of multiparous goats in TDM (400,300 vs. 179,800 cells/mL, respectively). Soluble milk protein concentration of primiparous goats managed by ODM was higher ($P = 0.007$) than that in TDM (4.8 vs. 4.1 g/kg). In addition, soluble milk protein concentration was increased ($P = 0.0001$) in multiparous goats in ODM compared with multiparous goats in TDM (5.6 vs. 4.2 g/kg, respectively).

The parity effect and the interaction effect between parity and milking frequency were not significant for milk fat content ($P = 0.4$; 0.6, respectively), protein content ($P = 0.4$; 0.9, respectively), total fat yield ($P = 0.3$; 0.9, respectively), total protein yield ($P = 0.4$; 0.7, respectively), lipolysis ($P = 0.1$; 0.5, respectively), fat globule size ($P = 0.2$; 0.6, respectively), CN ($P = 0.8$; 0.4, respectively), or ALCY ($P = 0.2$; 0.5, respectively).

Animal BW and Global Effects on Goats (Measurement or Observation by the Breed Manager). Mean live weight of the goats was not affected by milking frequency ($P = 0.2$), period ($P = 0.4$), or their interaction ($P = 0.6$). Multiparous mean live weight (59.0 kg) was higher than primiparous mean live weight (51.1 kg). However, the interaction between parity and milking frequency was not significant with regard to mean live weight ($P = 0.5$).

Concerning udder status, only 1 goat on ODM from group 2 developed clinical mastitis. No milk leakage in the parlor or on straw litter and no abnormal udder hardening before or after milking was observed, although some goats' udders were somewhat touch sensitive at the beginning of the ODM application. No abnormally hard or warm udders were observed at the beginning of the ODM application.

Experiment 2

Milk Yield and Composition. Mean milk loss caused by ODM (compared with TDM) during the trial was 17% ($P = 0.0001$; Table 3). Management of ODM in P2 and P4 tended to decrease milk yield more than management of ODM during P1 or P3 ($P = 0.05$).

The effect of milking frequency was not significant for milk fat content ($P = 0.3$), protein content ($P = 0.5$), SCC ($P = 0.8$), CN ($P = 0.2$), or soluble protein concentration ($P = 0.7$). However, total milk fat yield, total protein yield, and lipolysis were reduced by ODM (Table 3). Interactions between period and milking frequency were not significant for milk fat content ($P = 0.8$), protein content ($P = 0.9$), SCC ($P = 0.8$), CN ($P = 0.9$), soluble protein concentration ($P = 0.5$), total fat yield ($P = 0.7$), total protein yield ($P = 0.3$), or lipolysis ($P = 0.1$).

Animal BW and Global Effects on Goats (Measurement or Observation by the Breed Manager). Mean live weight of the goats was not affected by milking frequency ($P = 0.8$), period ($P = 0.5$), or their interaction ($P = 0.4$). No clinical mastitis was recorded during this experiment. No milk leakage in the parlor or on straw litter and no abnormal udder hardening before or after milking was observed. Similar to experiment 1, ODM application did not cause abnormally hard or warm udders.

DISCUSSION

Milk Losses and Goat ODM Ability

The 16 or 17% reduction in milk yield with ODM compared with TDM in both experiments agrees with a previous trial (long period of lactation) in high-yielding Alpine goats (Lefrileux et al., 2008). This milk loss is consistent with the previous value (18%, entire lactation) reported by Salama et al. (2003) in low-yielding Murciano Granadina goats. It was less than the results (26 and 36%, respectively) from studies conducted for a short period (3 and 4 wk) in high-producing Saanen goats (Wilde and Knight, 1990; Boutinaud et al., 2003) and an earlier study for an entire lactation in high-yielding Alpine goats (Mocquot et al., 1978). Nevertheless, in experiment 1, individual milk losses demonstrated wide variability (from 8 to 35%). This suggests the possibility of genetic selection for a better response to ODM.

Experiment 1 showed that milk losses were not correlated with the cisternal size of goats. This result is surprising because it has been commonly accepted that cisternal storage is one of the main contributors in the response of cows (Knight and Dewhurst, 1994) and ewes (McKusick et al., 2002) to ODM. In addition, it is well known that goats have a larger gland cistern (80 to 90% of udder milk; Peaker and Blatchford, 1988) than cows (20 to 30% of udder milk; Knight et al., 1994) and sheep (50 to 75% of udder milk; McKusick et al., 2002). One explanation could be that the number of goats (n = 12) used in our study may have been too limited. Consequently, our correlation may not be representative enough for differences in udder storage capabilities to have been evidenced. Another explanation could be that physiological mechanisms regulating milk synthesis and secretion in goats, such as negative local feedback regulations, could have been triggered before the udder cistern was full of milk.

In experiment 1, goats from group 4 recovered up to 96% of the milk production of goats from group 1 (control) without delay when they were switched from ODM to TDM. This suggests there is no residual effect of ODM in high-yielding Alpine goats. In accordance, milk yield in this experiment was not affected by the period of ODM application because no interaction was observed between period and milking frequency. These results suggest that milk losses caused by ODM do not depend on stage of lactation in goats. Nevertheless, the interaction between period and milking frequency tended to affect milk yields in experiment 2, with few goats (n = 8) and a double-inversion milking frequency over 4 periods. Our results in experiment 1 are in contrast to those of Salama et al. (2003), who reported that the reduction in milk yield caused by ODM was more marked during the first 3 mo of lactation (19%) than in late lactation (14%). This difference could be due to the higher genetic potential of our dairy goats compared with Murciano Granadina goats.

Under our conditions in experiment 1, primiparous and multiparous milk losses attributable to ODM were not different because no interaction between parity and milking frequency was observed. These results are in contrast to those of Salama et al. (2003) and Lefrileux et al. (2008), who reported higher milk losses caused by ODM in primiparous goats than in multiparous goats managed under ODM. Our results could be explained by the fact that our goats were milked twice daily for 2 wk postpartum before ODM was initiated, whereas Lefrileux et al. (2008) began ODM immediately on parturition day. Casu and Boyazoglu (1974) also verified in ewes that the percentage of milk loss was lower when ODM management was practiced after 2 wk in TDM. Such a duration of TDM could be sufficient to develop parenchyma and reach peak milk yield, especially in primiparous goats. Nevertheless, Salama et al. (2003) also began ODM after TDM for 2 wk postpartum. The difference with this study might be explained by the capabilities of the different breeds, but further studies are needed to verify this hypothesis.

Milk Composition

Milk fat content was not affected by ODM, but milk protein content increased in experiment 1 (+2.7 g/kg). These parameters were not modified by ODM in experiment 2, which could be due to the reduced number of animals (n = 8 vs. 47) and to the time required to modulate the activity or number of epithelial cells significantly. The increases in milk protein content agree with the current study and with other studies in goats (Mocquot and Auran, 1974; Capote et al., 1999; Salama et al., 2003) and cows (Holmès et al., 1992; Cooper, 2000; Pomiès and Rémond, 2002). However, those authors showed that ODM increased milk fat content in cows and ewes (Holmès et al., 1992; Nudda et al., 2002; Pomiès and Rémond, 2002) as well as in goats (Capote et al., 1999; Salama et al., 2003). This difference in effect with our goats could be explained by the differences between species and breeds (Spanish and French). Nevertheless, the lack of increase in milk fat content in our study, first, requires verifying, by analyzing oxytocin release at milking, whether ODM in high-yielding goats is a potent stressor that is able to disturb alveolar milk ejection because alveolar milk was shown to contain up to 75% of milk fat when milk ejection was inhibited (Labussière, 1988). Second, it requires verifying whether ODM management in our feeding condition could induce an increase in the production of *trans*-10, *cis*-12 conjugated linoleic acid, a potent inhibitor of milk fat synthesis in lactating goats (Lock et al., 2008).

The SCC did not differ according to milking frequency in experiment 2, as demonstrated by Salama et al. (2003) in Murciano Granadina goats. This suggests that multiple switching of the milking frequency regimen throughout a lactation did not impair the SCC. However, the SCC was higher under ODM than TDM management (242,800 vs. 179,800 cells/mL, respectively) in experiment 1, in accordance with previous studies in cows and ewes (Holmès et al., 1992; Nudda et al., 2002; Rémond et al., 2004). The difference in both experiments could be due to the number of goats used (n = 8 vs. 47) and to individual variability. The difference between our results in experiment 1 and those of Salama et al. (2003) could be explained by the use of different breeds (Alpine vs. Murciano Granadina) and the milk yield level. Our experiment 1 demonstrated lower SCC in multiparous goats under TDM management than under ODM management (from 179,800 to 400,300 cells/mL). Nevertheless, both these increases in SCC (242,800 and 400,300 cells/mL, respectively, in all goats and multiparous goats) in experiment 1 remain under the penalty threshold (<1,000,000 cells/mL) when SCC is used as a quality parameter for milk payment, as is done in France.

To our knowledge, there are no data in the literature on the effects of ODM on the technological properties of milk (lipolysis, fat globule size, and ALCY) from dairy goats. Lipolysis was decreased, which is logical because lipolysis is known to be positively correlated with milking frequency, as demonstrated by Wiktorsson et al. (2000) in robotic milking. No significant difference was found for fat globule size (no risk of increased fat retention in the alveolus) and ALCY according to milking frequency (ODM and TDM). Thus, cheese-making properties did not seem to be modified by ODM.

The increase in CN concentration (+1.8 g/kg) attributable to ODM in experiment 1 agrees with the findings of Salama et al. (2003), indicating higher percentages of CN for ODM compared with TDM (2.57 vs. 2.5%). This result suggests the cheese-making ability of milk is maintained during ODM. Milk soluble protein concentration was also increased (+1 g/kg) by ODM in experiment 1, in accordance with the results of Lefrileux et al. (2008). This increase in milk soluble proteins attributable to ODM in experiment 1 did not seem to be a result of the tight junction opening (soluble protein leakages from blood to milk) in mammary glands because the integrity of the tight junction was restored by the 22nd day after beginning ODM in goats (Marnet et al., 2005). The origins of such soluble proteins (de novo synthesis, proteolysis) remain to be determined in goats under ODM management.

In both experiments, interactions between the effects of period and milking frequency were not significant for the milk global composition, suggesting that ODM could be applied at any period of lactation in goats without deleterious effects on the detailed composition of milk.

A parity effect and interactions between parity and milking frequency (except for a modification of the soluble protein concentration) were not significant for the milk global composition, suggesting that primiparous and multiparous goats managed under ODM presented the same evolution in detailed composition. Indeed, soluble protein concentration was lower in primiparous than multiparous goats (+0.7 and +1.4 g/kg, respectively).

Global Effects of ODM on Goats (Measurement or Observation by the Breed Manager)

Once-daily milking did not cause behavioral modifications, milk leakage in the parlor, or internal udder hardening in these goats. These observations confirm those reported by Lefrileux et al. (2008). They also agree with those of Tucker et al. (2007), who found no change in behavior or physiology, indicating that the welfare of cows was not impaired by ODM. Nevertheless, behavioral studies will need to be conducted to confirm our observations in goats.

CONCLUSIONS

This study demonstrated a moderate modification in milk yield and quality without impairment of the processability of milk for cheese in high-yielding Alpine goats under ODM. This management strategy could be practiced in these ruminants once or twice throughout the lactation without a residual effect on milk yield or deleterious effects on the detailed composition of milk. Although in this study the udder cisternal size did not seem to be predictive of the response of goats to ODM, the wide variability in their responses suggests the possibility of genetic selection for a better response to ODM in the future. However, other studies are required to understand why milk fat did not increase in high-yielding Alpine goats under ODM management and to evaluate the effects of this milking management strategy on their behavior, welfare, or both before it can be recommended without restriction.

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