Performance and Feeding Behavior of Primiparous Cows Loose Housed Alone or Together with Multiparous Cows

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ABSTRACT

Lactating Holstein cows (52 multiparous and 90 primiparous) were monitored over a period of 10 mo to observe effects of grouping primiparous cows (PPC) separately from multiparous cows (MPC) on performance, feeding behavior, feed intake, feed efficiency, and milk production of PPC. Cows were kept in 2 symmetrical pens each equipped with a robotic milking unit, 2 waterers, and 28 feeding spaces. Typically, 100 lactating cows were present at a time, thereby ensuring 1.78 cows per feeding place in each pen. One pen (PP) was composed exclusively of PPC whereas the other pen (PM) included 30% PPC and 70% MPC. Primiparous cows were evenly distributed to each pen by days in milk and daily milk production. As they calved, additional primiparous cows were assigned sequentially to each of the 2 treatment groups; multiparous cows calving during the study were allocated to the PM group. Both PP and PM groups were managed equally and were fed the same basal ration twice daily plus 3 kg/d of concentrate during milking. Individual eating behavior and feed consumption at each visit were monitored electronically. Milk production was recorded daily, and milk composition monthly. Observed arithmetic means and standard errors are presented but application to other management situations is limited because animals within pen were not independent. Total dry matter intake (18.7 vs. 18.1 ± 0.9 kg/d) and milk production (25.9 vs. 25.6 ± 0.8 kg/d) of PPC were similar in both the PM and PP groups, respectively. Primiparous cows in the PP group had numerically more visits to the robotic milking unit (3.26 vs. 2.68 ± 0.15) and to the feed troughs (4.91 vs. 4.02 ± 0.43), but apparently spent less time eating (2.72 vs. 3.22 ± 0.1 h/d) than did PPC in the PM group. Differences in feed efficiency were low but PPC in the PP group had numerically higher feed efficiency at times through 200 d in milk. Alternative grouping strategies

illustrate potentially important differential responses among primiparous cows that warrant further study.

Key words: behavior, intake, parity, feed efficiency

INTRODUCTION

According to the NRC (2001) nutritional model, primiparous cows (**PPC**) consume less feed and in a different pattern (peaking later) than multiparous cows (**MPC**). It is believed that PPC are usually more timid and occupy a lower rank in the social herd hierarchy (Wierenga, 1990); thus, it is commonly recommended to group PPC separately from MPC (Grant and Albright, 1995). However, there are only 3 published studies that support this concept. Konggaard and Krohn (1978) reported that PPC ($n = 13$) isolated from older cows had 15% lower milk yield (16.16 vs. 19.18 kg/d, respectively) when housed in cubicles (freestalls), but had 21% higher milk production (20.4 vs. 17.06 kg/d, respectively) when housed on a bedded manure pack compared with PPC housed with MPC. Later, Phelps (1992) reported much higher milk production of PPC when they were separated from MPC in a single herd compared with 3 herds with mixed PPC and MPC. However, because of the lack of replication as well as insufficient information regarding ration, management, and housing conditions of the different herds, it is difficult to strictly attribute differences to the grouping regimen. More recently, Phillips and Rind (2001) reported a moderate 1% improvement in milk production (over a 42-d period) when housing PPC separately from MPC. To our knowledge, there are no studies addressing the effects of separating PPC from MPC on feed intake, feeding behavior, feed efficiency, and milk production of PPC when separated from MPC in loose-housed conditions and milked with a robotic milking system. Because of the difficulty in replicating robotic milking groups, this study attempted to mimic field conditions for use of robotic milking systems and to describe feed intake, feeding behavior, milk production, and feed efficiency when PPC were managed alone or together with MPC. Because the study is observational, means and standard errors are reported for measured variables for primiparous cows

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in the 2 groups but inferential statistics are not reported.

MATERIALS AND METHODS

Animals and Grouping

One hundred forty-two lactating Holstein cows (52 multiparous and 90 primiparous) were used over a period of 10 mo (from March 4 to December 28, 2004). The animals were managed and handled under the approval of the Animal Care Committee of IRTA (Bellaterra, Spain). The study began 1 mo after the 2 groups of animals were arranged. All cows were kept on the same farm with loose housing conditions in 2 symmetrical pens, each containing 28 feeding places, 2 waterers (200 × 60 cm and 140 × 45 cm), and a robotic milking unit (VMS, DeLaval, Sweden). Cows had free access to respective robotic milking units and were milked at any time, provided that more than 4 h had elapsed since the previous milking. Milking intervals for each cow were monitored 4 times per day at approximately 0700, 1200, 1500, and 1900 h. In situations where cows were observed to have a milking interval > 12 h, they were fetched and brought to the robotic milking unit. To avoid excessively long wait times at the robotic milking unit, no more than 6 cows were fetched at any one time. Each pen had 250 m² of a bedded pack (bedded with about 400 kg of straw every other day) and 550 m² for exercise (on concrete floors). On average, the total number of cows at any particular time of the study was 100, evenly distributed in the 2 pens (50 cows/pen). The ratio between number of cows and number of feeding places was kept, on average, at 1.78 ± 0.02 in both pens. One pen (**PP**) was composed exclusively of PPC, whereas the other pen (**PM**) included 30% PPC and 70% MPC to simulate the most common relationship of PPC to MPC in commercial dairy herds with about 30% replacement rates. Therefore, parity grouping regimen and pen were confounded, despite individual observations on each animal, and thus this work is presented as an observational study.

At the beginning of the study, PPC were evenly distributed to each of the 2 pens according to their DIM and milk production level. During the 10-mo study, there were 67 PPC in treatment PP, and 23 PPC and 52 MPC in the PM treatment. As new heifers calved during the study, they were randomly assigned to each treatment alternately. All adult cows that calved during the study were allocated to the PM group. The PP and PM groups received the same basal ration (Table 1) ad libitum twice daily at 0830 and 1530 h. Cows were provided 1.5 kg of concentrate (Table 1) during milking to a maximum allowance of 3.0 kg/d; thus, animals that visited the robotic milker more than twice a day did

Table 1. Ingredient and nutrient composition of the TMR and the concentrate offered during milking

	TMR	Concentrate
Ingredient composition (% as fed)		
Ryegrass silage	60.0	—
Distillers dried grains	—	9.9
Alfalfa hay	9.1	—
Barley	—	3.3
Cottonseed whole	5.2	—
Citrus pulp	2.6	—
Corn	13.1	29.6
Soybean meal	3.7	29.6
Corn gluten feed	5.7	16.5
Soybean hulls	—	6.6
Molasses	—	2.0
Sodium bicarbonate	—	1.6
Calcium carbonate	0.23	—
Dicalcium phosphate	0.05	—
Magnesium oxide	—	0.33
Salt	0.21	0.66
Micromineral-vitamin premix	0.05	—
Nutrient composition (DM basis)		
Energy, ¹ Mcal of NE _I /kg	1.56	1.89
CP, %	15.6	25.8
Ether extract, %	4.9	2.9
NDF, %	35.4	21.7
ADF, %	20.7	11.2
Absorbable Ca, %	0.4	0.2
Absorbable P, %	0.3	0.4

¹Net energy of lactation was calculated at a level of intake equivalent to 23.5 kg/d of DM following the NRC (2001) model.

not receive concentrate during the latter visits. Cows in both groups were managed by the same people and under the same guidelines, criteria, and schedules.

Measurements

Individual eating behavior, including time, number, and duration of visits to the feed troughs, as well as individual feed consumption at each visit were continuously monitored throughout the study using a computerized system (Bach et al., 2004). Daily, a grab sample of fresh TMR and a grab sample of refusals from the previous day were obtained to determine the DM content of TMR and refusals. Assuming that the moisture loss rate of the TMR throughout the day was constant, then each meal consumption was adjusted to the predicted DM content corresponding to the time of the day at which consumption occurred. Individual BW was recorded biweekly at the exit of the robotic milking systems. Individual milk production was recorded at each milking by the robotic milking units and milk composition (fat and protein) was determined monthly at an official laboratory (ALLIC, Cabrilis, Spain).

Calculations

Only data referring to PPC were considered in this study. To group consecutive visits to the feed troughs

into a single meal, meal criteria (maximum amount of time between visits to the feed troughs to consider a visit as a part of the same meal) were calculated using a model composed of 3 or 2 normal distributions resulting from the natural logarithm of time (in seconds) between feed trough visits. The implementation of the package MIX 3.1.3 (MacDonald and Green, 1988) on R for MacOS X (R Development Core Team, 2004) was used to fit these 3 mixture distributions with the method of exact maximum likelihood and the following mixed distribution function:

$$g(\chi|\pi, \mu, \sigma) = \pi_1 f(\chi|\mu_1, \sigma_1) + \dots + \pi_k f(\chi|\mu_k, \sigma_k),$$

where g is a weighted sum of k component densities with mean = μ , and standard deviation = σ . In the present study, $k = 3$ represented the 3 distributions of intervals: those within meal, those within meal but with drinking activity, and those between meals (Yeates et al., 2001; Melin et al., 2005). When a 2-distribution function was used, only the intervals within meal and between meals were modeled. The reading intervals of the computerized system were performed at 3.7-s intervals (on average), and this periodicity seemed to alter the distribution pattern of intervals below 8 s. Therefore, when fitting the distribution, the population of intermeal intervals (most left-hand distribution) was truncated to remove intervals below 2.0 ln s. Meal criteria were calculated for each cow accounting for their stage of lactation (divided into 4 categories: 1 for DIM less than 60 d, 2 for DIM between 61 and 120 d, 3 for DIM between 121 and 200 d, and 4 for DIM greater than 200 d). Individual daily feed efficiencies were calculated by dividing daily fat-corrected (3.5%) milk production by total daily DMI assuming that milk fat content was maintained constant between milk fat determinations (monthly).

Because the observations from each individual animal within each group were not totally independent due to some dependence, for example, arising from social facilitation, social hierarchy, or unknown effects of pen, individual cows could not be considered as true replicates. Pseudoreplication occurs when replicates are not statistically independent (Hurlbert, 1984). The simple pseudoreplication of this study could have been avoided by using a crossover design; however, such designs with robotic milking systems are very cumbersome as cows need to be adapted to the new milking unit and the milking unit needs to “learn” about the new cow’s udder conformation. Such an approach could have been used with a small number of cows, but this would have defeated the objective of using a large number of animals within each group. Therefore, we decided to conduct the experiment as an observational study simulating

Table 2. Feeding behavior and feed consumption of primiparous cows housed alone (PP) or together with multiparous cows (PM)

	Group		SE
	PM	PP	
Meal criterion, ¹ min	58.59	46.70	3.04
Meal duration, ¹ min	50.90	35.74	2.44
Total eating time, ¹ min/d	192.9	163.5	6.29
Meal size, ¹ kg of DM/meal	4.20	3.45	0.387
Eating rate, ¹ g of DM/min	88.8	91.2	3.72
Number of daily meals, ¹ /d	4.02	4.91	0.428
Total DMI, kg/d	18.7	18.1	0.925

¹Excluding concentrate consumption during milking.

normal field conditions as much as possible and using a large number of animals. To avoid potentially misleading conclusions, data are presented as arithmetic means with respective standard errors, without further inferential statistical analyses. Therefore, extrapolation of the results presented herein to other situations should be avoided.

RESULTS AND DISCUSSION

Feed Intake and Feeding Behavior

The determination of the meal criteria was achieved, in most cases, by fitting a 2 normal mixture model, and a 3 normal mixture model was needed for only 26 cows. The values obtained (Table 2) are in line with those recently reported for dairy cattle milked with robotic milking systems (Melin et al., 2005) and with conventional milking systems (DeVries et al., 2003).

The hypothesis of this study was that PPC in the PP group would have greater access to limited resources (e.g., feed and water) and thus, achieve greater DMI than PPC in the PM group. In contrast, we observed a numerical increase in DMI of the PPC housed in the PM group compared with the PPC in the PP group (Table 2). Furthermore, total eating time, excluding the time devoted to eat concentrate during milking, was about 30 min longer (numerically) in the PPC cows in the PM than in the PP group (Table 2). These results are in contrast with those reported earlier by Konggaard and Krohn (1978) who showed 10 to 15% longer eating times of PPC separated from MPC than when kept together with MPC in free stalls. In contrast, the results observed in the current study agree with those obtained by Konggaard and Krohn (1978) when cows were housed on deep straw bedding (as in the current study), in which a 15% lower eating time was observed for PPC separated from MPC compared with PPC housed with MPC. The time that PPC spent eating appeared to be lowest during the first 60 d of lactation (162 min/d) and then remained constant at approxi-

mately 179 min/d during the rest of lactation (data not shown). Eating rate (g of DM/min) was within the range previously reported in dairy cattle (Olofsson, 1999; Shabi et al., 2005) and similar for PPC in the PP and PM groups (Table 2). In addition, each meal was, on average, about 25 min longer in PPC in the PM group than in the PP group, but cows in the PP group had almost 1 more meal per day than the PPC in the PM group (Table 2). Because eating rate was very similar between groups, and meal duration was numerically shorter for the PPC in the PP than in the PM group, PPC in the PM group showed a meal size of about 0.8 kg more than cows in the PP group (Table 2). Olofsson (1999) reported that in a situation of competition for feed, cows consumed feed more rapidly (more g/min) than when there was ample access to feed. In this study, we expected some degree of competition for accessing the feed troughs, as the ratio between cows and available feeders was 1.78. However, there was no evidence that PPC yielded access to MPC in the feed troughs when comparing the average time at which cows first accessed the feed troughs between 0800 and 0930 h (0916 vs. 0912 h for PPC and MPC, respectively) and between 1500 and 1630 h (1550 vs. 1549 h for PPC and MPC, respectively) coinciding with the times when fresh feed was delivered. In fact, 35.2 and 39.6% of the feed troughs of the PM group were occupied by PPC immediately after fresh feed was offered in the morning and in the afternoon, respectively. These numbers indicate that more than 50% of the PPC in the PM group accessed the feed troughs when fresh feed was provided, suggesting that MPC did not represent a deterrent to having access to the feed trough for PPC in this particular study.

Animal Performance

The evolution of BW throughout lactation is depicted in Figure 1. Average DIM of PPC in PM and PP groups was 148 and 150 d, respectively. The percentage of milkings that were involuntary (cows had to be fetched) was 27.24 ± 1.13 and $16.67 \pm 0.91\%$ for the PPC in the PM and the PP groups, respectively. Grouping PPC alone seemed to result in a greater average number of daily milkings compared with PPC in the PM group (Table 3). The number of daily milkings decreased with increasing DIM in both groups and the numerical difference in the number of daily milkings between PPC in the PP and PM groups diminished as DIM increased (Figure 2).

Despite the numerically greater number of daily milkings observed in PPC in the PP group compared with the PM group, milk production was not greater in the PP than in the PM group (Table 3). Weekly coefficients of variation of milking intervals of PPC in the

Figure 1. Evolution of BW of primiparous cows housed alone (PP, dashed line) or together with multiparous cows (PM, solid line).

PP and PM groups were 62.2 and $50.3 \pm 2.33\%$, respectively. Bach and Busto (2005) showed that high coefficients of variation of milking intervals with robotic milking systems negatively affected milk production.

Milk protein content was similar in both groups of cows. However, milk fat content was 3.57 and 3.26% for PP and PM cows, respectively (Table 3), and consequently, milk fat yield of PP cows was 892 g/d whereas milk fat yield of PM was 817 g/d. There is little information regarding the effects of meal frequency and milk fat content, but the available studies (Sutton et al., 1985, 1986, 1988) suggest that increasing the number of daily meals increases milk fat content. Froetschel and Amos (1991) demonstrated that increased frequency of feeding resulted in greater production of VFA throughout the day, but with lower ruminal concentrations at any given time. Similarly, Bragg et al. (1986) demonstrated that increasing feeding frequency increased ac-

Table 3. Number of daily milkings, total milk yield, and milk composition of primiparous cows housed alone (PP) or together with multiparous cows (PM)

	Group		SE
	PM	PP	
Number of milkings/d	2.68	3.26	0.147
Milk yield, kg/d	25.93	25.57	0.79
Milk protein, %	3.33	3.34	0.031
Milk fat, %	3.26	3.57	0.088
Milk fat yield, kg/d	0.817	0.892	0.083

Figure 2. Number of daily milkings of primiparous cows as affected by stage of lactation and grouping strategy. Solid line represents number of daily milkings of primiparous cows housed with multiparous cows (PM); dashed line represents number of daily milkings of primiparous cows housed alone (PP).

etate and decreased lactate rumen molar proportions in steers.

Feed Efficiency

Due to the high relative importance of feed costs on total milk production costs, feed efficiency plays a major role in determining the profitability of dairy enterprises. Individual feed efficiencies of loose-housed cows have not been reported previously in the literature. Feed efficiency decreased with DIM as previously reported (Britt et al., 2003; Linn et al., 2004). Due to the similar milk yield and DMI, overall feed efficiency (kg of milk/kg of DMI) was also similar for PPC in the PM and in the PP cows (1.37 ± 0.085 and 1.42 ± 0.048 , respectively). Changes in feed efficiency across lactations are depicted in Figure 3. At the beginning of lactation (<200 DIM) feed efficiency was numerically greater in the PPC in the PP than in the PM group.

CONCLUSIONS

With robotic milking systems, grouping primiparous cows alone did not seem to improve milk production, although the number of daily milkings numerically increased. Total eating time was numerically longer when the primiparous cows were housed with multiparous cows. However, primiparous cows housed alone had al-

Figure 3. Feed efficiency of primiparous cows as affected by stage of lactation and grouping strategy. Solid line represents feed efficiency of primiparous cows housed with multiparous cows (PM); dashed line represents feed efficiency of primiparous cows housed alone (PP).

most 1 more meal per day than did those housed with multiparous cows. More than 50% of the feed troughs of the pen with primiparous and multiparous cows housed together were occupied by primiparous cows following the offer of fresh feed, suggesting that those cows were not intimidated by multiparous cows. More research involving group replicates is needed to further investigate potentially important behavioral differences among primiparous cows under differing grouping strategies.

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