Feeding of Pellets Rich in Digestible Neutral Detergent Fiber to Lactating Cows in an Automatic Milking System

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ABSTRACT

If the milking frequency in an automatic milking system (AMS) is increased, the intake of concentrated pellets in the robot may be raised accordingly. Consumption of a large quantity of starchy grains within a short time can impair the appetite, decrease voluntary visits to the milking stall, and lower intakes of dry matter (DM) and neutral detergent fiber (NDF). Therefore, the hypothesis to be tested in this study was whether conventional starchy pellets fed in the AMS could be replaced with pellets rich in digestible NDF without impairing the cows' motivation to visit a milking stall voluntarily. Fifty-four cows were paired according to age, milk yield, and days in milk, and were fed a basic mixture along the feeding lane (19.9 kg of DM/cow per d), plus a pelleted additive (approximately 5.4 kg of DM/cow per d) that they obtained in the milking stall and in the concentrate self-feeder that they could enter only after passing through the milking stall. The 2 feeding regimens differed only in the composition of the pelleted additive, which, for the control group, contained 49% starchy grain, and for the experimental group contained 25% starchy grain plus soy hulls and gluten feed as replacement for part of the grain and other low-digestible, NDF-rich feeds. Both diets resulted in similar rates of voluntary milkings (3.31 vs. 3.39 visits/cow per d). Average yields of milk and percentages of milk protein were also similar in the 2 groups. The results suggest that an alternative pellet composition can be allocated in the AMS in conjunction with basic mixture in the feeding lane, without any negative effect on appetite, milk yield, milk composition, or milking frequency of the cows. It also opens the opportunity to increase yields of milk and milk solids by increasing the amount of pelleted concentrates that can be allocated to selected high-yielding cows via the AMS, because this can be done while maintaining a high frequency of voluntary milkings.

Key words: individual feeding management, milking robot, milking frequency, starchy pellet

INTRODUCTION

Several options were suggested in the literature for “inviting” a lactating cow to a milking robot and, accordingly, to feed her in the milking stall. One option is a forced (or semiforced) cow-traffic routine in which a cow is guided to the robot on her way to or from the forage lane (Ipema 1997; Hermans et al., 2003; Melin et al., 2005), pasture yard, or water troughs (Ketelaar-De Lauwere et al., 2000; Woolford et al., 2004). However, studies in the late 1990s (Halachmi, 1999; Ketelaar-De Lauwere et al., 1999) showed that forced cow traffic, semiforced traffic, or the usage of selection units might interfere with cows' visits to the forage lane and consequently, might reduce the forage feed intake of specific high-yielding cows in the herd. Consequently, all AMS farms in Israel were designed around the free cow-traffic concept (Halachmi, 2004).

Another option is called the “candy concept,” based on a sweetened feed or an additive in the robot that should attract the cow. However, several unpublished field tests have shown that the cows become accustomed to the sweet taste, so that its influence declines within a few weeks (Aart van't Land, Lely Industries nv, Maasland, the Netherlands; personal communication). The third option is to maintain free cow traffic and to attract the cows into the robot by providing a minimal amount of concentrate pellets; that is, reduce the amount fed by the robot to the minimum needed quantity that will not reduce cows' visits to the robot (Halachmi et al., 2005b). However, in practice, the exact minimum amount to be fed in the robot without adversely affecting the cows' voluntary visits is as yet unknown for most enterprises (Rodenburg et al., 2004; Halachmi et al., 2005a). Moreover, there is a wide variation in concentrate intake between cows that visit at a high frequency compared with cows that visit at a low frequency; therefore, determination of the minimum needed quantity simply requires a compromise between the feed intakes of the low- and high-frequency visitors to the robot.

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Most Israeli AMS practice the third option, and cows are usually attracted to enter the robot by no more than 3 to 4 kg/d of starchy pellets allocated in the robot in conjunction with a basic mixture (BM) containing reduced level of starch supplied along the feeding lane. Unfortunately, this feeding regimen is not very effective in developing high-yielding cows (50 to 60 L/d) or in encouraging high frequency visits to the robot (Halachmi et al., 2005b). Increasing the amount of pellets fed in the robot or in a concentrate self-feeder (CSF) located after the robot is, therefore, desirable to improve energy balance and possibly to increase visiting frequency and milk yield (Halachmi et al., 1998, 2005b; Halachmi, 2004). However, previous studies showed that with a higher intake of starchy pellets within a short time, the starch had inhibitory effects on the digestibility and the rate of digestion of dietary NDF by ruminal bacteria (Miron et al., 2004a,b). This, in turn, negatively affected the appetite and voluntary intake of the cows and resulted in reduced milk and FCM production (Miron et al., 2004b). Therefore, the supplementation of concentrates in the AMS is a question of quality as well as quantity. The current practice is to use starchy pellets as the attractant to the milking stall; therefore, high levels of supplementation for high-yielding cows might impair nutritional efficiency.

Therefore, a fourth option is suggested in the present study: increase the amount of pellets fed in the AMS up to 7 kg/cow per d, and change the pellet composition to replace a starch-rich feed with a feed higher in digestible NDF. Our hypothesis is that a nonroughage by-product that is rich in readily digestible NDF fraction, such as soy hulls and corn gluten feed, could successfully replace starchy grain in pellets supplied to lactating cows in an AMS, to increase NDF use for milk fat production without adversely affecting the cows' motivation to voluntarily visit a milking stall. The nutritional aspect of this hypothesis was previously tested under the conditions of low-forage diets: Miron et al. (2004b) studied pellets made of soy hulls and corn gluten feed as a replacement for starchy grain; they were fed individually to lactating cows in addition to a basic TMR. Also, Miron et al. (2004a) examined a similar nutritional regimen in cows fed via concentrate self-feeders. In both studies, use of pellets rich in digestible NDF by-products as starch replacement increased the yield of FCM and milk fat while maintaining the level of milk production. The effects on cow behavior were also tested in previous studies (Miron et al., 2004a,b): the palatability of the starchy pellets was better, but the visiting behavior in the computer-controlled self-feeders indicated a need to examine this concept under AMS conditions (Miron et al., 2004b). The increasing use of AMS justifies a study of pellets rich in digestible

Table 1. Composition of the 2 types of pellets fed in the robot and in the subsequent concentrate self-feeders (CSF) and of the basic mixture served along the feeding lane

Ingredients	Dietary treatment ¹	
	Experimental pellets	Control pellets
Basic mixture, ² kg/ton of dietary DM	790	790
Pellet additive, kg/ton of dietary DM	210	210
Pellet composition, % of pellets DM		
Ground barley grain	12.4	24.7
Ground corn grain	13.0	21.6
Ground sorghum grain	0	2.5
Soy hulls	30.8	2.61
Corn gluten feed	15.5	7.98
Wheat bran	0	7.53
Soybean meal	10.8	6.53
Sunflower meal	0	9.02
Corn gluten meal	1.78	1.78
Cottonseeds	10.4	10.4
Protected fat	2.02	2.02
Vitamin and mineral mix ³	3.33	3.33

¹Experimental pellets = pellets containing soy hulls and gluten feed as starchy grain and medium digestible NDF replacer, served in the automatic milking system (AMS) and CSF at a level of 7 kg/cow per d. Control pellets = pellets containing 49% starchy grain served in the AMS and CSF at a level of 7 kg/cow per d.

²Basic mixture, served for ad libitum intake along the feeding lane to both groups, contained (kg/ton of DM): wheat silage, 317; wheat hay, 34.1; clover hay, 153; rolled barley grains, 60.3; ground corn grains, 54.1; control pellets, 381.5.

³Vitamin and mineral mix. (g/kg of DM pellets): sodium chloride, 5.75; calcium chloride, 5.75; calcium carbonate, 6.12; dicalcium phosphate, 3.75; sodium bicarbonate, 9.57; trace minerals + vitamins mix, 2.36 (Miron et al., 2004a).

NDF as a substitute for starchy grain. However, there is a lack of information about this feeding regimen for lactating cows in an AMS (Ipharraguerre and Clark, 2003). Moreover, there is also a lack of information about the effectiveness of such pellets rich in digestible NDF in motivating high-yielding cows to visit a milking stall.

The objective of the present study was to quantify the effects of pellets rich in digestible NDF used as a substitute for starchy grain pellets on the AMS visiting-behavior pattern of high-yielding cows and on their milking performance.

MATERIALS AND METHODS

Animals

The experimental period lasted 3 mo (August to October 2004) after a basal period of 4 wk on the control dietary regimen (Table 1). Fifty-four Israeli Holstein cows were selected in pairs and divided randomly into 2 dietary treatment groups of 27 cows each. The 2 groups of cows were characterized by similar lactations (2.42 ± 0.33), DIM (142.2 ± 0.47), daily milk yields (34.6

± 0.30 kg), BW (555 ± 8.2 kg), and visiting frequencies (3.13 ± 0.05 milkings/d). All the cows were >8 d in lactation when paired, and in at least their second lactation in the AMS; they were, therefore, thoroughly familiar with the AMS.

Treatments and Diets

All cows were fed a diet containing 19.9 kg of DM of the BM that was distributed along the feeding lane, plus a supplement of pelleted additive supplied by dual-channel feeders in the robot and in the CSF that was located behind it. The 2 feeding regimens differed only in the composition of the pellets fed in the robot and the CSF: those for the control group contained 49% starchy grain, whereas those for the experimental group contained 25% starchy grain plus soy hulls and gluten feed as grain replacer (Table 1).

Detailed compositions of the 2 types of pellets and of the basal mixture fed along the feeding lane are shown in Table 1. The high-starch pellets (control) were composed of 49% starchy grains, and contained a variety of protein-rich feeds used in Israel, including soybean meal, sunflower meal, corn gluten meal, corn gluten feed, and wheat bran. The experimental pellets contained soy hulls and corn gluten feed in place of half of the starchy grain, and these feeds plus soybean meal were also used to replace sunflower meal and wheat bran, which are rich in medium-digestible NDF (Miron et al., 2001; National Research Council, 2001). Additional small adjustments in the balance between protein and energy sources were made in the composition of the experimental pellets to achieve similar contents of CP (19.5%) and NE_L (1.96 MCal/kg of DM) in both types of pellets. The BM that was supplied along the feeding lane for ad libitum intake contained less grain and more roughage than a typical TMR fed to lactating cows in conventional (non-AMS) Israeli herds (Table 1): it contained 15.7% CP and 1.63 MCal of NE_L /kg of DM. Values of NE_L of the individual feeds used in this study were provided by the pellet manufacturer (Zemach Industries, Jordan Valley, Israel) and used to summarize NE_L content of the BM and the 2 types of pellets (Table 2).

All the cows were allocated a maximum of 4 kg of pellets/cow per d in the robot and 3 kg of pellets/cow per d in the CSF. The pellets were fed according to the usual practice of linear accumulation of the feed allowance. For example, a cow that was allowed 7 kg of pellets/d and had not visited the robot for 10 h would receive $(7/24) \times 10 = 2.9$ kg. In setting the robot parameters, the number of feed cycles was set to 24 and the number of feed periods to 1. The amount per meal ranged from a minimum of 1 kg up to a maximum of 3

kg. The CSF dispenser was calibrated to provide 300 g/min, and the robot feed rate was 250 g/min. Unconsumed feed was transferred to the following day's allocation; up to 4 kg could be transferred to the successive day (designated as "add balance = 4 kg" in the robot user interface).

Management

All the cows were kept together in a single group. Individual cows could be distinguished only by their associated feeding parameters in the management software of the robot. Thus, both control and experimental groups were exposed to identical conditions—the same housing, microclimate in the barn, management practices, and workers' cow handling, and both groups shared the same robot. The farm design and its effect on cow performance were described previously (farm E; Halachmi 2004). The study was conducted in the first open cowshed (not a free-stall or cubicle system) reported in the scientific literature to be originally designed for AMS (Halachmi, 1999, 2000, 2004; Halachmi et al., 2000a, 2001, 2002), and operated in a hot climate with high-yielding cows. The farm was designed to enable cows to move freely between the BM feeding lane and resting areas. However, they are motivated to visit the robot as the only way of accessing the pellets, either in the robot or in the CSF, because CSF was accessible only after cows passed through the robot, which provided an additional incentive to pass the milking stall. Halachmi et al. (1998, 2000a,b) coined this situation as "semi-free cow-traffic". The cowshed was designed to hold 65 to 75 cows in milking with about 20 m²/cow, and was equipped with a cow cooling system near the robot and the CSF. The cooling system along the feeding bank was synchronized with times of feed allocation and scattered feed recovery (i.e., moving mechanically scattered food to within reach of the cows).

The BM was distributed by a mixer wagon every day at 0600 h. At 0530 h and again between 1200 and 1300 h, the farm workers led in the few cows (2 or 3 cows/d) that had not visited the robot for more than 8 h. Robot use during the experimental period was low enough to allow also a low-social-rank cow to visit a milking stall without the need to fight her way to the robot (Figure 1). Robot use was the time ratio between (robot busy)/(robot busy + robot idle). The daily pattern of robot use is illustrated in Figure 1; the slowdown from 0300 to 0400 h is a known cow-behavior phenomenon that is mentioned in the AMS literature (Halachmi, 2000). The maximum milking frequency set in the robot software of any cow was 5 times/d. Cows visited the AMS voluntarily, but the CSF was accessible only after passing the milking stall.

Table 2. Chemical composition and in vitro digestibility of the 2 types of pellets fed in the robot and concentrate self-feeder (CSF), and of the basic mixture served along the feeding lane

	Experimental pellets ¹	Control pellets ²	Basic mixture ³	SEM
Dietary component (% of DM $\pm$ SD)				
DM (% of TMR)	89.8 $\pm$ 1.0	88.9 $\pm$ 1.2	64.1 $\pm$ 1.1	—
OM (% of DM)	92.5 $\pm$ 1.1	93.2 $\pm$ 1.1	90.5 $\pm$ 1.6	—
CP (% of DM)	19.5 $\pm$ 0.1	19.5 $\pm$ 0.1	15.7 $\pm$ 0.2	—
NDF from roughage (% of DM)	—	—	24.1 $\pm$ 0.2	—
Total NDF (% of DM)	38.5 $\pm$ 1.1	25.9 $\pm$ 1.2	42.6 $\pm$ 1.4	—
Calcium (% of DM)	1.02 $\pm$ 0.04	1.02 $\pm$ 0.04	0.90 $\pm$ 0.05	—
Phosphorus (% of DM)	0.51 $\pm$ 0.01	0.55 $\pm$ 0.01	0.45 $\pm$ 0.02	—
Calculated NE _L (Mcal/kg of DM)	1.96	1.96	1.63	—
In vitro digestibility, %				
DM (% of TMR)	81.3 ^a	82.4 ^a	74.2 ^b	1.21
NDF (% of TMR)	76.8 ^a	66.1 ^b	63.3 ^b	1.42

^{a-c}Means in the same row followed by different superscripts differ at $P < 0.05$.

¹Experimental pellets = pellets containing soy hulls and gluten feed as starchy grain and medium digestible NDF replacer, served in the automatic milking system (AMS) and CSF at 7 kg/cow per d.

²Control pellets = pellets containing 49% starchy grain served in the AMS and CSF at 7 kg/cow per d.

³Basic mixture = mixed ration served for ad libitum intake along the feeding lane to both groups.

Facilities, Sampling, Chemical Analyses, and In Vitro Digestibility Measurements

The robot and the CSF (Lely Industries, Maasland, the Netherlands) were equipped with 2 feeding channels (1 for control and 1 for experimental pellets), an electronic identification system for individual cows, and computerized control and recording of their entry into the feed stalls, all of which enabled the monitoring of the intake of pellets by each cow in the group. Both control and experimental pellets were allocated at the same rates of 250 g/min in the robot and 300 g/min in the CSF; they were calibrated weekly and whenever a new batch of concentrates was delivered. The cows were free to eat the BM anywhere along the feeding lane. The

Figure 1. Average robot use throughout day and night.

average BM intake was calculated from daily weights of BM and of orts left in the feeding lane.

The BM and both kinds of pellets were sampled weekly. A part of the weekly sample was assayed in triplicate for DM content (drying at 105°C for 24 h) and ash (4 h at 600°C); other dry samples (60°C oven for 96 h) were analyzed for CP according to the Kjeldahl method (AOAC, 2000). The NDF, ADF, and acid detergent lignin were determined by sequential analysis, without sodium sulfite, with heat-stable amylase, and expressed exclusive of residual ash (van Soest et al., 1991). An Ankom 220 apparatus (Ankom, Fairport, NY) was used for extraction and filtering.

In vitro digestibility of DM and NDF of the BM and of the pellets was analyzed in triplicate for each sample. The procedure included 48 h of incubation of 0.5 g of plant material with rumen fluid followed by a 48-h incubation with HCl and pepsin, according to the 2-stage fermentation technique of Tilley and Terry (1963).

Milk yield was recorded by automatic milk meters in the robot. Milk samples were collected over 24 h (2 to 5 sequential milkings/cow) at 2-wk intervals during the experimental period. Each set of milk samples from each cow was stored at 4°C in the presence of bromide compounds as preservative, pending infrared analysis for contents of fat, protein, lactose, and urea (AOAC, 2000), with a Milkoscan 4000 instrument (Foss Electric, Hillerød, Denmark).

Calculations and Statistical Analyses

The daily yield per cow of 4% FCM and the payment equation (economically adjusted milk = **EAM**) were cal-

culated according to equations used by the Israeli Cattle Breeders Association:

$$\begin{aligned} 4\% \text{ FCM (kg)} &= 0.4 \times \text{milk (kg)} + 15.0 \times \text{milk fat (kg)}; \\ \text{EAM (kg)} &= 9.436 \times \text{milk fat (kg)} \\ &+ 22.018 \times \text{milk protein (kg)}. \end{aligned}$$

All cows milked by the robot were paired into 2 groups by age, DIM, and milk yield. For management reasons (mainly end of lactation and entering a dry period), data of a few cows, together with those of their partners, were removed from the analysis; therefore, 25 pairs remained for statistical analysis. Statistical analyses were performed with the GLM procedure of SAS (SAS Institute, 1996). Dependent variables were milk yield, EAM, and fat and protein percentages. Independent variables were group (control vs. experimental pellets), cows nested within a group, DIM, DIM² and DIM³ (model 1). The statistical analyses examined the difference between 2 groups against the error term "cow nested within a group".

Model 1 was as follows:

$$Y_{ijk} = A_i + B_j (A_i) + \text{DIM} + \text{DIM}^2 + \text{DIM}^3 + e_{ijk}$$

where Y_{ijk} = milk, EAM, fat or protein percentage; A_i = group; $B_j (A_i)$ = cow nested within a group; DIM, DIM², DIM³ = DIM (where DIM, DIM², and DIM³ = linear, quadratic, and cubic functions of d in milk); and e_{ijk} = error term.

RESULTS

The 2 dietary treatments differed only in the compositions of the pellets supplemented in the robot and the CSF located behind it. As planned, total NDF content was higher in the experimental pellets than in the control pellets (38.5 and 25.9%, respectively; Table 2). Both groups received similar forage NDF (19.0%, calculated from Table 2) from the BM served in the common feeding lane. However, the experimental ration contained a higher proportion of NDF of nonroughage origin than the control diet, in which more NDF originated from BM roughage. These differences were reflected in similar DM and OM digestibility values of the 2 types of pellets, but higher NDF digestibility of the experimental than of the control pellets (Table 2).

The BM was fed ad libitum to cows along the feeding lane. According to group feeding measurements, each cow consumed, on average, 19.9 kg of DM/d from the BM. The differences between the 2 types of pellets in composition and digestibility affected the consumption behavior of the cows: in the robot, where they could

stay for a limited time, the cows ingested more starchy pellets than experimental pellets, but the cows on the experimental diet compensated for the lower intake of pellets in the robot by consuming more pellets in the CSF, where their stay was unlimited (Table 3). In summary, both dietary groups consumed similar total amounts of pelleted additives (approximately 5.4 kg of DM/cow per d), taken from the AMS and from the CSF that they entered afterwards.

Data on the cow behavior in the AMS (voluntary milkings/cow per d), milk yield, and milk composition during the entire experimental period are shown in Table 3: it can be seen that experimental and control treatments resulted in similar numbers of voluntary milkings (3.31 vs. 3.39 times/cow per d, respectively) in the robot; consequently, there were no significant differences between the control and experimental milk yields (35.4 vs. 35.8 kg/cow per d, respectively) and the 4% FCM yields (32.0 vs. 32.8 kg/cow per d, respectively). The distribution patterns of daily visits to the robot were, in general, similar for the 2 groups (Figure 2).

Milking frequencies within each group were not identically distributed (Figure 3). It can be seen (Figure 3) that cows in the control group were milked 2.5 to 4.5 times/d in 73% of the observations compared to only 53% for the experimental. However, 12% of the cows in the experimental group were voluntarily milked 5 times per day compared with only 4% in the control. This compensated for the lower percentage milked between 2.5 to 4.5 times/d, such that the averages were not significantly different (Table 3).

Throughout the lactation, the number of milkings/cow per day varied in both control and experimental groups, but there were no statistical differences between treatments (Figure 4).

DISCUSSION

Some observed differences in milking frequencies might be related to changes in visiting behavior of several cows for which the higher fiber pellets was less attractive.

The Nutritional Challenge of the AMS

Automatic milking systems are a challenge to nutritionists. Firstly, the TMR concept is not applicable, because a significant amount of the concentrates, instead of being included in the mixture, has to be used as an attractant to persuade the cow to visit the milking stall. Secondly, such supplementation may affect milking frequency. Thus, feeding practices for concentrates in AMS differ from that used with computer-controlled self-feeders in a conventional milking parlor where the

Table 3. Measurement of feed intake in robot and concentrate self-feeder (CSF), cow behavior, milk yield, and milk composition

	Treatments		P
	Control [mean (SE)]	Experimental [mean (SE)]	
Average basic mixture intake (kg of DM/cow)	19.9	19.9	
Average feed utilization (kg of milk/kg of DM)	1.40	1.41	
Actual pellet intake (kg of DM/cow)			
In the robot	3.14 (0.05)	2.98 (0.04)	<0.05
In the CSF	2.23 (0.02)	2.43 (0.03)	<0.05
Total	5.36 (0.07)	5.42 (0.05)	NS ¹
Voluntary milking/cow per d	3.39 (0.05)	3.31 (0.05)	NS
Milk yield (kg of milk/cow per d)	35.4 (0.40)	35.8 (0.40)	NS
Milk yield (kg of milk/cow per milking)	10.4 (0.72)	10.8 (0.71)	0.1
Milk fat (%)	3.37 (0.14)	3.44 (0.09)	NS
Milk protein (%)	3.14 (0.05)	3.11 (0.03)	NS
Milk lactose (%)	4.99 (0.03)	4.95 (0.02)	NS
Somatic cell count (×1,000)	135 (18.7)	226 (79.6)	NS
FCM	32.0 (1.11)	32.8 (1.50)	NS
Economically adjusted milk ²	31.3 (1.27)	34.0 (1.54)	NS

¹NS = Not significant, $P \geq 0.2$.

²Economically adjusted milk (adjusted by payment formula): $EAM \text{ (kg)} = 9.436 \times \text{milk fat (kg)} + 22.018 \times \text{milk protein (kg)}$.

milking frequency is constant regardless of the amount of concentrates supplemented. If a high milking frequency is desired, then concentrates have to be provided in a substantial amount to prevent frustration and to maintain the milking frequency. However, the provision of a large amount of starchy concentrates to keep this process going may have negative effects. On the other hand, each cow spends a limited time in the milking stall, which may be insufficient for it to consume all the allocated concentrates without leaving some for the next cow that enters the milking stall. Thus, a combination of self-feeders is required, both within and outside the milking stall, to allocate concentrates in

proportions that allow the cow to eat part of the concentrates while she is being milked (at the desired frequency) and the rest in the self-feeders that she enters after passing through the milking stall. When TMR is fed to the cows it is possible to include in it less palatable feed stuffs that have a nutritional or economic advantage, or both, but this possibility is severely limited when a substantial amount of more palatable feed is removed from the mixture. Feeding less palatable concentrates in the AMS creates the danger of not attracting the cows, which, in turn, would dictate the imposition of forced traffic to milk them sufficiently, with the negative consequences described above. This circle of milking frequency and amount of concentrates allocated has to be evaluated nutritionally, economically, and physiologically (according to the stage of lactation), a process that leads in the end toward precision feeding of the individual cow. However, for this we need, first and foremost, choices of concentrates that are palatable, nutritious, and economical.

Pellets Rich in Digestible NDF vs. Starchy Pellets in AMS

Pellets rich in digestible NDF were found to have significant advantages over starchy pellets in terms of milk fat and FCM production in a previous experiment (Miron et al., 2004b; Zenou and Miron, 2005). Nevertheless, in the present study, average milk yields and concentrations of fat, protein, and lactose were similar in cows fed the 2 types of pellets (Table 3). This contrast between studies is possibly due to differences between

Figure 2. Cow behavior in terms of average voluntary milking per cow per day in the control (triangles) and in the experimental (squares) groups.

Figure 3. Milking frequency distribution of cows fed control (left) and experimental (right) pellets. The herd was milked by a robot; there were 54 cows in the herd. Note: the number of milkings was defined as the average over 2 wk, and was rounded to nearest number of milkings per day.

the seasons, average DIM, compositions of pellets, and level of intake—differences that affected the performance of the cows, which produced 45 kg of milk/d in the previous study compared with 35 kg/d in the present study.

Differences in NDF content and digestibility between the 2 types of pellets used in the present study, as summarized in Tables 1 and 2, would be expected to explain any differences in observed lactation performance or feeding behavior. The slight superiority of the cows on the experimental diet in milk fat content and FCM production may have been due to the higher daily NDF intake and the higher in vitro digestibility of the NDF of the experimental ration as compared with the

control ration (Tables 1 and 2). Greater contents of digestible cellulose and hemicellulose usually result in the production by rumen cellulolytic bacteria of more acetate (Chesson and Forsberg, 1997), which can serve as a precursor for milk fat synthesis in the mammary gland. Thus, in the present study, we found slightly better FCM production by the cows on the experimental diet. These performance data are consistent with those from previous studies, which showed that replacement of corn grain or barley in TMR with soy hulls (18 to 20% of dietary DM) tended to increase the milk fat content and FCM yield in lactating cows, and reduced milk protein content and yield (Ipharraguerre and Clark, 2003; Miron et al., 2004a,b). A similar reduction

Figure 4. Number of voluntary milkings per cow per day (y-axis) throughout the lactation period (x-axis). Cows fed control (left) vs. cows fed experimental (right) pellets. Each point represents the average number of milkings per day, based on data for a single individual cow collected over 2 wk and rounded to nearest number of milkings per day. The thick line indicates the trend line.

in milk fat content was obtained previously in cows that were fed BM along the feeding lane plus starchy pellets in the TMR compared with that obtained under a conventional TMR feeding regimen (Miron et al., 2004b).

The present study showed that the composition of the experimental pellets that formed up to 21% of dietary DM was adequate to make their palatability and voluntary intake similar to those of conventional starchy pellets. The experimental pellets were comparable with the control pellets with respect to their effects on milk and ECM production. Thus, the experimental pellets could be supplied as an alternative to starchy pellets in AMS, especially in cases in which increased milk fat production is desirable.

Although differences among days can be observed in Figure 2, the patterns of daily visits to the robot (Figure 2) and, consequently, those of daily milk yield (Table 3) were, in general, similar with the 2 types of pellets. These findings validate the hypothesis tested in this study: the conventional starchy pellets fed in the AMS can be replaced with pellets rich in digestible NDF without impairing the cows' motivation to visit a milking stall voluntarily.

The confirmation of this hypothesis suggests an alternative way to encourage cows that have been selected according to various criteria (beginning of the lactation period, higher fat or protein producers, etc.) to be milked more frequently and to consume more pellets in the AMS without suffering the inhibitory effect of receiving large amounts of starch-rich pellets on the TMR and being fed roughage along the feeding lane.

CONCLUSIONS

The inclusion of soy hulls and corn gluten feed, in place of starchy grains and feeds containing medium values of NDF digestibility, in pellets fed to robotically milked high-yielding dairy cows did not adversely affect the voluntary milking frequency or the milk yield and composition. The findings suggest similar palatability of both types of pellets, indicating that the experimental pellets may be recommended for use in an AMS as a replacement for the conventional starchy pellets. This would allow larger allocations of pellets in the robot, which could increase the number of milkings per day while still maintaining milk fat content at adequate levels.

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