Feeding soyhulls to high-yielding dairy cows increased milk production, but not milking frequency, in an automatic milking system

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ABSTRACT

To attract a cow into an automatic milking system (AMS), a certain amount of concentrate pellets is provided while the cow is being milked. If the milking frequency in an AMS is increased, the intake of concentrate pellets might increase accordingly. Replacing conventional starchy pellets with nonstarchy pellets increased milk yield, milk fat, and milk protein and decreased body weight. The hypothesis was that a nonroughage by-product rich in digestible neutral detergent fiber, such as soyhulls and gluten feed, could replace starchy grain in pellets fed in an AMS. Sixty cows were paired by age, milk yield, and days in milk, and were fed a basic mixture *ad libitum* [16.2 ± 0.35 (mean $\pm$ SE) kg of dry matter intake/d per cow] plus a pelleted additive (6 to 14 kg of dry matter/d per cow) that was consumed in the AMS and in a concentrate self-feeder, which could only be entered after passing through the AMS. The 2 feeding regimens differed only in the composition of the pelleted additives: the control group contained 52.9% starchy grain, whereas the experimental group contained 25% starchy grain, plus soyhulls and gluten feed as replacement for part of the grain. Wheat bran in the control ration, a source of fiber with low digestibility, was replaced with more digestible soyhulls and gluten. During the first 60 d in milk, a cow received 10 to 12 kg of concentrate pellets. After 60 DIM, concentrate feed was allocated by milk production: ≤ 25 kg/d of milk entitled a cow to 2 kg/d of concentrate feed; > 25 kg/d of milk entitled a cow to receive 1 kg/d of additional concentrate feed per 5 kg/d of additional milk production, and > 60 kg/d of milk entitled a cow to receive 9 kg of concentrate. The concentrate feed was split between the AMS and concentrate self-feeder. The 2 diets resulted in similar frequencies of voluntary milking (3.12 ± 0.03 to 2.65 ± 0.03 visits/d per cow vs. 3.16 ± 0.00 to 2.60 ± 0.01 visits/d per cow). Average milk yields were higher in

the experimental group (42.7 ± 0.76 to 39.09 ± 0.33 kg/d per cow vs. 39.69 ± 0.68 to 37.54 ± 0.40 kg/d per cow) and percentages of milk protein (3.02 ± 0.06 to $3.12 \pm 0.05\%$ vs. 3.07 ± 0.04 to $3.20 \pm 0.04\%$) and milk fat (3.42 ± 0.17 to $3.44 \pm 0.08\%$ vs. 3.38 ± 0.13 to $3.55 \pm 0.06\%$) were similar in the 2 groups. The results suggest that the proposed pellets high in digestible neutral detergent fiber can be allocated via the AMS to selected high-yielding cows without a negative effect on appetite, milk yield, or milk composition while maintaining a high milking frequency.

Key words: robotic milking, individual feeding, milking frequency, starchy pellet

INTRODUCTION

During the last 7 yr, more than 6,000 milking robots have been sold, mainly in northwestern Europe, Canada, Japan, and Israel, and this increasing use of automatic milking systems (AMS) stimulated the study of pellets in which digestible NDF was substituted for starchy grain. Halachmi et al. (2006) listed several options for inviting a lactating cow to an AMS. The first option involved forced cow-traffic, with a cow being guided to the AMS on her way to or from the forage lane, pasture, or water trough. Nevertheless, studies in the late 1990s (Halachmi, 1999; Ketelaar-De Lauwere et al., 1999) showed that this system could interfere with visits to the forage lane and could reduce the DMI of specific high-yielding cows. Consequently, all AMS farms in Israel were designed around the free cow-traffic concept or they used semiforced traffic, in which the feeding forage lane was always accessible (Halachmi, 2004). This concept was further studied by Hermans et al. (2003) and Melin et al. (2005).

A second option, the “candy concept,” used a sweetened feed in the AMS intended to attract the cow. Nevertheless, field tests showed that the cows became accustomed to the sweet taste, so that its attraction declined within a few weeks (Halachmi et al., 2006). The third option was to provide the minimal amount of concentrate pellets at milking that would attract the cows into the AMS (Halachmi et al., 2005). Therefore,

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increased milking frequency in AMS could lead to increased intake of concentrate. Most Israeli AMS use the third option, and cows are usually attracted to the AMS by allocation of no more than 1.2 kg of feed/milking, which is 4 to 5 kg/d of starchy pellets. Unfortunately, this feeding regimen has not been very effective for high-yielding cows (50 to 60 L/d) or for encouraging frequent visits to the AMS (Halachmi et al., 2005). In practice, the minimum amount that can be fed in the AMS without adversely affecting voluntary visits of high-yielding cows is as yet unknown (Rodenburg et al., 2004; Halachmi et al., 2005). Increasing the amount of pellets fed in the AMS or in a concentrate self-feeder (CSF) located where cows leave the AMS is desirable to improve the dietary energy balance (Halachmi et al., 2008) and increase visiting frequency (Halachmi, 2009) and milk yield (Halachmi et al., 1998, 2005; Halachmi, 2004). Nevertheless, the increased intake of starchy pellets within a short time could impair the digestibility of dietary NDF and reduce its rate of digestion by ruminal bacteria (Miron et al., 2004a,b). This impaired appetite might reduce the voluntary intake, leading to reduced milk and milk fat production (Miron et al., 2004a). Thus, the supplementation of concentrates in the AMS is a question not only of quantity, but also of milk quality. The current practice is to attract cows to the AMS by using starchy pellets; therefore, high levels of supplementation for high-yielding cows might impair nutritional efficiency.

A fourth option, suggested by Halachmi et al. (2006), was to increase the amount of pellets supplied in the AMS and to change the pellet composition by replacing a starch-rich grain with a by-product higher in digestible NDF. Our present hypothesis was that a nonroughage by-product high in a readily digestible NDF fraction, such as soyhulls (SH) and corn gluten feed, could successfully replace starchy grain in pellets supplied to cows in an AMS by increasing NDF utilization for milk fat production. Under milking parlor conditions, different studies (Ipharraguerre and Clark, 2003; Miron et al., 2004a) demonstrated that when SH was substituted with 35% of grains in the diet, DMI and milk production were increased. Miron et al. (2004a) suggested that because SH are higher in fiber content than grains, they might promote chewing, decrease the risk of acidosis and the inhibitory effect of starchy grain on rumen cellulolytic bacteria, promote better NDF digestibility in the rumen, and result in improved health and milk production. Nevertheless, there is a lack of information on the effectiveness of increased allocations of digestible NDF-rich pellets in motivating high-yielding cows to visit an AMS.

The AMS presents a challenge to nutritionists (Halachmi et al., 2006); the TMR concept ceases to

be applicable, because a significant amount of the concentrate has to be used as an attractant for visiting the AMS. If a high milking frequency is desired, then a substantial amount of concentrate needs to be provided to prevent frustration among the cows and to maintain a satisfactory milking frequency. However, the provision of a large amount of starchy concentrates to further this process could have negative effects. Moreover, when a TMR is fed, it is possible to include less palatable feedstuffs that have a nutritional economic advantage, but this possibility is limited when a substantial amount of more palatable feed is removed from the mixture. Feeding less palatable concentrates in the AMS incurs the risk of not attracting the cows. Therefore, the objective of the present study was to quantify the effects of replacing starchy grain pellets with pellets high in digestible NDF (6 to 14 kg/d per cow) on the AMS behavior of high-yielding cows and on their milking performance.

MATERIALS AND METHODS

Animals

The experimental period was 6 mo (October 2006 through March 2007) after a 4-mo basal period. Sixty Israeli Holstein cows milked by AMS were individually paired, matched in lactation number, DIM, milk yield, BW, and visiting frequencies. One cow from each pair was then randomly selected and randomly matched to 1 of the treatment groups, whereas the second cow was placed in the second treatment group. Therefore, the cows were divided randomly into 2 dietary treatment groups of 30 cows each. All the cows were >10 DIM when paired and were in at least their second lactation in the AMS; they were familiar with the AMS. Treatment started while some cows were in late lactation, but analysis included only data from calving onward.

Treatments and Diets

All cows were fed a TMR ad libitum, distributed along the feeding lane, plus a supplement of pelleted additive supplied by dual-channel feeders in the AMS and in the CSF, accessible after passing through the AMS. A significant amount of the concentrate was transferred from the TMR to the AMS. In our case, 14 kg of concentrates was transferred from the TMR to the AMS (Table 1). The average basic mixture (BM) intake was calculated from the daily weights of BM and of orts left in the feeding lane. Ad libitum intake was kept above 8 to 10% of the daily amount. Fewer orts were found with an additional amount of BM on successive days. The 2 feeding regimens differed only

Table 1. Concentrate feed allocation: maximum amounts for both treatment groups

DIM	Automatic milking system	Self-feeder, kg/d per cow	Total
0 < DIM < 30	5	5	10
31 < DIM < 60	5	7	12
61 < DIM	5	2–9	7–14
15 d before drying	4	2	6

in the composition of the pellets fed in the AMS and the CSF: pellets for the control group contained 52.9% starchy grain, whereas pellets for the experimental group contained 25% starchy grain plus SH and gluten feed as grain replacements (Table 2).

The high-starch pellets (control treatment) contained 52.9% starchy grains and contained the same variety of protein-rich feeds regularly used in Israel, including soybean meal, sunflower meal, corn gluten meal, corn gluten feed, and wheat bran. The experimental pellets contained SH and corn gluten feed in place of part of the starchy grain, and these feeds plus soybean meal were used to replace wheat bran, which is high

in medium-digestible NDF (Miron et al., 2001; NRC, 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 (19.1%) and NE_L (1.95 Mcal/kg of DM) in both types of pellets. The BM contained less grain and more roughage than a typical TMR as fed to lactating cows in conventional (non-AMS) Israeli herds; it contained 15.7% CP and 1.71 Mcal of NE_L/kg of DM. The BM was prepared in a commercial mixing wagon; its composition is shown in Table 3.

The NE_L values of the individual feeds used were provided by the pellet manufacturers (Zemach Central Feed Mill, Jordan Valley, Israel; Ambar Feed Mill Central Agriculture Cooperative Society Ltd., Hefer, Israel) and were used to summarize NE_L content of the BM and the 2 types of pellets.

During the first 2 mo (0 to 60 DIM), each cow received 10 to 12 kg of concentrate feed (Table 1). Five kilograms of feed was provided in the AMS and the rest was provided in the CSF. After 60 DIM, concentrate feed was allocated according to daily milk production: 25 L of milk allowed 2 kg of concentrate feed in the CSF; 25 to 60 L allowed 1 kg/5 L of milk; and 60 L or more

Table 2. Composition of the pellets fed in the automatic milking system (AMS) and in the subsequent concentrate self-feeders (CSF) located behind the AMS, and of the basic mixture served along the feeding lane

Item	Dietary treatment ¹	
	Experimental	Control
Basic mixture served, ² kg of DM/d per cow	16.2	16.2
Pellets fed in the AMS and CSF, kg of DM/d per cow	6–14	6–14
Pellet composition, % of pellet DM		
Ground barley grain	6.5	6.5
Ground corn grain	18.8	34.4
Ground sorghum grain	7.8	7.8
Ground wheat grain	0	5.2
Soyhulls	30.0	0
Corn gluten feed	9.1	9.1
Distillers dried grains	8.5	8.5
Wheat bran	0	9.5
Soybean meal	7.2	7.2
Sunflower meal	5.6	3.5
Gluten meal	0.67	0.67
Canola meal	0	2.0
Protected fat	2.5	2.3
Vitamin + mineral mix ³	3.33	3.33

¹Experimental pellets = pellets containing soyhulls as a replacer for starchy corn and wheat grain and medium-digestible NDF (wheat bran), served in the AMS plus CSF at a level of 6 to 14 kg/d per cow (details in Table 1). Control pellets = pellets containing 52.9% starchy grain served in the AMS plus CSF at a level of 6 to 14 kg/d per cow (details in Table 1).

²The basic mixture was a mixed ration served for ad libitum intake along the feeding lane to both groups; it contained wheat silage, 325 (kg/ton of DM); clover hay, 125 (kg/ton of DM); oat hay, 20 (kg/ton of DM); ground corn grains, 210 (kg/ton of DM); and control pellets, 320 (kg/ton of DM).

³Vitamin + mineral mix (g/kg of DM pellets): sodium chloride, 5.75 g; calcium chloride, 5.75 g; calcium carbonate, 6.12 g; dicalcium phosphate, 3.75 g; sodium bicarbonate, 9.57 g; trace mineral + vitamin mix, 2.36 g. The trace mineral + vitamin mix contained (g/kg of DM mix) Zn, 24 g; Fe, 24 g; Cu, 12.8 g; Mn, 24 g; I, 1.44 g; Co, 0.32 g; Se, 0.32 g; vitamin A, 16,000,000 IU; vitamin D₃, 3,200,000 IU; vitamin E, 48,000 IU.

Table 3. Chemical composition and in vitro digestibility of the 2 types of pellets fed in the automatic milking system (AMS) and concentrate self-feeder (CSF), and of the basic mixture served along the feeding lane

Dietary component, % of DM $\pm$ SD	Treatment pellets ¹		Basic mixture ²
	Experimental	Control	
DM, %	89.8 $\pm$ 1.0	88.9 $\pm$ 1.2	64.1 $\pm$ 1.1
OM, %	95.6 $\pm$ 1.1	95.6 $\pm$ 1.1	91.5 $\pm$ 1.6
CP	19.1 $\pm$ 0.1	19.1 $\pm$ 0.1	15.7 $\pm$ 0.2
NDF from roughage	—	—	24.7 $\pm$ 0.2
Total NDF	28.5 $\pm$ 1.1	22.1 $\pm$ 1.2	34.2 $\pm$ 1.4
Fat	7.1 $\pm$ 0.2	6.5 $\pm$ 0.1	4.0 $\pm$ 0.1
Starch and soluble carbohydrate ³	40.9	47.9	37.6
Calculated NE _L , Mcal/kg of DM	1.95	1.95	1.71
In vitro digestibility, %			
DM	81.3 ^a	82.4 ^a	74.2 ^b
NDF	76.8 ^a	66.1 ^b	63.3 ^b

^{a,b}Means in the same row with different superscripts differ at $P < 0.05$.

¹Experimental pellets = pellets containing soyhulls and gluten feed as a replacer for starchy grain and medium-digestible NDF, served in the AMS plus CSF at a level of 6 to 14 kg/d per cow. Control pellets = pellets containing 52.9% starchy grain served in the AMS plus CSF at a level of 6 to 14 kg/d per cow.

²Basic mixture = mixed ration served for ad libitum intake along the feeding lane to both groups at a maximal level of 16.2 kg of DM/d per cow.

³Starch and soluble carbohydrate content were calculated as follows: Starch + Soluble carbohydrate% = OM% – CP% – NDF% – Fat%.

allowed 9 kg in addition to the 5 kg in the AMS. The maximum amount of pellets fed via the AMS and the CSF was up to 14 kg/d per cow (approximately 50% of daily DMI). The minimum amount of concentrate in the AMS was held constant at 5 kg/d because this material filled the role of keeping the cow eating throughout the milking process. The pellets were allocated for entire days under the practice of linear accumulation of the feed allowance: for example, a cow that was allowed 7 kg/d of pellets, and those that had not visited the AMS for 10 h would receive $(7/24) \times 10 = 2.9$ kg. In setting the AMS parameters, the number of feed cycles was set to 24 and the number of feed periods was set to 1. The amount of pellets per meal ranged from 1 to 3 kg. The CSF dispenser was calibrated to provide 300 g/min, and the AMS feed rate was 250 g/min. Allocated feed that was not consumed was transferred to the next day's allocation; up to 4 kg could be transferred, and the transfer operation was designated as "add balance = 4 kg" in the AMS management software.

Management

All the cows were kept together in a single pen. Individual cows could be recognized only by their associated feeding parameters in the management software. Thus, both the control and experimental groups were exposed to identical conditions, housing and microclimate in the barn, management practices, and cow handling by the workers, and the same AMS was shared by both groups. The barn was designed to enable cows to move freely

between the BM feeding lane and resting areas. Cows visited the AMS voluntarily but could access the CSF only after passing through the milking stall; they were motivated to visit the AMS because that was their only way of accessing the pellets, either in the AMS or in the CSF. Halachmi et al. (1998, 2000a,b) coined the phrase "semiforced cow-traffic" to describe this situation. The maximum milking frequency of any cow, specified in the AMS software, was 5 times per day. The barn was designed to hold 65 to 75 cows in milking, with approximately 20 m²/cow, and was equipped with a cow cooling system near the AMS. Every day at 0600 h, the BM was distributed by a mixer wagon. At 0530 h and again between 1200 and 1300 h each day, the farm workers led in the few cows (2 or 3 cows) that had not visited the AMS for more than 8 h. The AMS utilization during the experimental period was less than 83%, to allow cows with low social rank to visit a milking stall without the need to fight their way to the AMS.

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

The AMS and the CSF are products of the Lely Industry (Maasland, the Netherlands). Each was equipped with 2 feeding channels (1 for the control pellets and 1 for the experimental pellets), an electronic identification instrument, and computerized control and recording of the entry of cows into the feed stalls. All of these features enabled monitoring of pellet intake by individual cows in the group. Both the control and

experimental pellets were allocated at the same rates of 250 g/min in the AMS 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 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) and cell wall components. Neutral detergent fiber, ADF, and acid detergent lignin were determined by sequential analysis, without sodium sulfite, with heat-stable amylase, and were 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 determined in triplicate for each sample. The procedure included a 48-h 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 AMS. Milk samples were collected over 24 h (2 to 5 sequential milkings of each 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 preservative bromide compounds 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

All milk-recording samples were taken into account (repeated measurement). The daily yield per cow of 4% FCM and the payment equation to determine economically corrected milk (**EcCM**) were calculated according to the practice of the Israeli Cattle Breeders Association:

$$4\% \text{ FCM (kg)} = 0.4 \times \text{milk (kg)} + 15.0 \\ \times \text{milk fat (kg), and}$$

$$\text{EcCM (kg)} = 9.436 \times \text{milk fat (kg)} + 22.018 \\ \times \text{milk protein (kg)}.$$

The data were organized with Statistics Toolbox software (MatLab; Mathworks, 1999). Statistical analyses were performed with the general linear model procedure (SAS Institute, 1996):

$$Y_{ijkl} = A_i + B_j(A_i) + C_k + (A_i \times C_k) + \text{DIM} \\ + \text{DIM}^2 + \text{DIM}^3 + e_{ijkl},$$

where Y_{ijkl} is milk, EcCM, or fat or protein percentage; A_i is the control vs. experimental group; $B_j(A_i)$ is cow nested within a group; C_k is stage of lactation; $(A_i \times C_k)$ is the treatment $\times$ stage of lactation interaction; DIM (10, 60 d), DIM² (61, 120 d), and DIM³ (121, 180 d) are the DIM linear, quadratic, and cubic terms; and e_{ijkl} is the error term.

RESULTS AND DISCUSSION

The milk yield of the experimental group was higher than that of the control group throughout the lactation (Figure 1 and Table 4). No significant differences were recorded in concentrate feed intake (Table 5), willingness to consume pellets (Table 6), or milking frequency (Figure 2 and Table 7).

The higher milk yield could have been caused by the following: 1) consumption of the BM was higher at the feeding lane, which would be consistent with the findings of Bach et al. (2007); 2) because SH are higher in fiber content than grains, it may have promoted chewing, thereby decreasing the risk of acidosis and the inhibitory effect of starchy grain on rumen cellulolytic bacteria and resulting in improved digestibility of the NDF fraction in the BM ingested because of the improved conditions created in the rumen (Miron et al., 2004a); 3) SH maintained the high intake of energy and nutrients from the pellets, supporting high milk production; and 4) the allocation of nutrients to BW gain was decreased (Table 8). Nutritional values of SH to support milk production and rumen health and metabolism are well known (Ipharraguerre and Clark, 2003; Miron et al., 2004a,b). Soyhulls contain approximately 60% NDF originating from the primary cell wall, which is highly digestible (Miron et al., 2001). Soyhulls contain nearly 3 times more lysine and methionine (both rate-limiting AA for milk production) than corn grain. In contrast, wheat bran added to the control diets (~9.1%) contained approximately 50% NDF; however, its NDF polysaccharides were less digestible in the rumen than SH NDF carbohydrate (Miron et al., 2001). Further research, within the context of the AMS, barn design, and method of feed, is warranted.

Table 5 shows that cows in both treatments consumed similar amounts of concentrate feed. The cows actually consumed approximately 85 to 92% (Table 6) of the allocated feed; their feed consumption declined slightly in the course of the lactation, from 92 to 85% of the control pellets and from 88 to 85% of the experimental pellets.

Table 4. Milk yield and milk composition

Measure of performance	DIM	Treatment, mean $\pm$ SE		<i>P</i> -value ¹
		Control	Experimental	
Milk yield, kg	10 < DIM < 60	39.7 $\pm$ 0.68	42.7 $\pm$ 0.76	0.001
	61 < DIM < 120	42.4 $\pm$ 0.45	44.5 $\pm$ 0.43	0.001
	121 < DIM < 180	37.5 $\pm$ 0.40	39.1 $\pm$ 0.33	0.002
Fat, %	10 < DIM < 60	3.4 $\pm$ 0.13	3.4 $\pm$ 0.17	0.85
	61 < DIM < 120	3.3 $\pm$ 0.08	3.3 $\pm$ 0.09	0.87
	121 < DIM < 180	3.5 $\pm$ 0.06	3.5 $\pm$ 0.08	0.84
Protein, %	10 < DIM < 60	3.07 $\pm$ 0.04	3.02 $\pm$ 0.06	0.38
	61 < DIM < 120	3.1 $\pm$ 0.03	3.1 $\pm$ 0.05	0.75
	120 < DIM < 180	3.2 $\pm$ 0.04	3.1 $\pm$ 0.05	0.25
Milk fat, kg	10 < DIM < 60	1.3 $\pm$ 0.02	1.5 $\pm$ 0.03	0.001
	61 < DIM < 120	1.4 $\pm$ 0.01	1.5 $\pm$ 0.01	0.001
	121 < DIM < 180	1.3 $\pm$ 0.01	1.3 $\pm$ 0.01	0.41
Milk protein, kg	10 < DIM < 60	1.2 $\pm$ 0.02	1.3 $\pm$ 0.02	0.002
	61 < DIM < 120	1.3 $\pm$ 0.01	1.4 $\pm$ 0.01	0.005
	121 < DIM < 180	1.2 $\pm$ 0.01	1.2 $\pm$ 0.01	0.16
4% FCM, kg	10 < DIM < 60	35.99 $\pm$ 0.62	38.97 $\pm$ 0.69	0.001
	61 < DIM < 120	37.8 $\pm$ 0.40	39.8 $\pm$ 0.38	0.001
	121 < DIM < 180	34.9 $\pm$ 0.37	35.8 $\pm$ 0.30	0.068
EcCM, ² kg	10 < DIM < 60	39.4 $\pm$ 0.68	42.2 $\pm$ 0.75	0.001
	61 < DIM < 120	42.2 $\pm$ 0.45	44.1 $\pm$ 0.43	0.002
	121 < DIM < 180	38.9 $\pm$ 0.42	39.6 $\pm$ 0.34	0.22

¹Not significant, $P \geq 0.05$.

²Economically corrected milk (EcCM) was calculated according to the practice of the Israeli Cattle Breeders Association: EcCM (kg) = 9.436 $\times$ milk fat (kg) + 22.018 $\times$ milk protein (kg).

Figure 1. Milk yield (kg/d per cow) over DIM in the experimental (squares) and control (triangles) treatments. Lines represent trend lines. The trend lines were calculated by the smoothing algorithm of Whittaker (1923). Third-order differences and $\lambda = 10,000$ were implemented. Detailed equations of the algorithm of Whittaker (1923) are presented in the appendix of Halachmi et al. (2004).

Figure 2. Number of voluntary milkings over DIM in the experimental (squares) and control (triangles) treatments. Lines represent trend lines (Whittaker, 1923; Halachmi et al., 2004).

Table 7 shows the voluntary milking frequency during lactation; no significant difference between treatments was observed. This finding suggests there is no clear research evidence supporting the common speculation that starchy grain makes cows lazy and unwilling to attend the AMS for milking (Halachmi et al., 2005).

No abnormal health incidences and no deaths were reported, yet a difference in BW developed in the later stages of lactation (Table 8). Cows in the experimental group collectively lost between 960 kg [(619 – 587) kg $\times$ 30 cows = 960 kg] and 870 kg of BW by the end of the experiment. Cows in the experimental group collectively produced an additional 198.6 kg of milk by the

end of the experiment. This weight loss is an average 4.38 kg of BW per production of 1 kg of milk. The cows lost their BW during mid lactation.

Comparison with Previous Publications

Halachmi et al. (2005), who used starchy grains and compared the effects of allocating 1.5 or 7 kg/d of concentrate per cow at the AMS, found no differences in milking attendance. When Halachmi et al. (2006) compared starchy grains with pellets rich in digestible NDF, they found that for concentrate allocations up to 5.5 kg/d per cow, the incentive offered by the provision

Table 5. Cow feed intake in the automatic milking system and concentrate self-feeder (pellet intake, kg/d per cow)

DIM	Treatment, mean $\pm$ SE		<i>P</i> -value ¹
	Control	Experimental	
10 < DIM < 60	10.2 $\pm$ 0.39	10.2 $\pm$ 0.46	0.97
61 < DIM < 120	10.8 $\pm$ 0.46	11.4 $\pm$ 0.44	0.16
120 < DIM < 180	10.0 $\pm$ 0.39	10.8 $\pm$ 0.42	0.09

¹*P* $\geq$ 0.05.

Table 6. Ratio of concentrate feed eaten and allocated pellets (actual intake per planned allocation ratio)

DIM	Treatment, mean $\pm$ SE		<i>P</i> -value ¹
	Control	Experimental	
10 < DIM < 60	0.92 $\pm$ 0.20	0.88 $\pm$ 0.17	0.28
61 < DIM < 120	0.89 $\pm$ 0.14	0.89 $\pm$ 0.15	0.85
120 < DIM < 180	0.85 $\pm$ 0.18	0.85 $\pm$ 0.15	0.98

¹Not significant, *P* $\geq$ 0.05.

Table 7. Number of voluntary milkings/day per cow in cows fed 2 different diets in an automatic milking system

DIM	Treatment, mean $\pm$ SE		<i>P</i> -value ¹
	Control	Experimental	
10 < DIM < 60	3.12 $\pm$ 0.03	3.16 $\pm$ 0.00	0.33
61 < DIM < 120	2.95 $\pm$ 0.04	2.95 $\pm$ 0.01	0.48
120 < DIM < 180	2.65 $\pm$ 0.03	2.60 $\pm$ 0.01	0.20

¹*P* $\geq$ 0.05.

of concentrate at an AMS was independent of the starch content of the grain; therefore, the possibility of feeding large amounts of concentrate at the AMS without causing rumen acidosis seemed realistic. They found no significant difference in milk yield (35.4 vs. 35.8 kg/d per cow). More recently, Bach et al. (2007) tried this approach and compared concentrate allocations of up to 3 kg/d per cow in the AMS with 8 kg/d per cow, but found no evidence of a stimulating effect. In addition, they found no differences in attendance at an AMS. In the present study, the concentrate allocation reached 14 kg/d, and a significant difference in milk yield favored the experimental group.

Pellets High in Digestible NDF Versus Starchy Pellets in the AMS

Pellets rich in digestible NDF had advantages over starchy pellets for milk fat and FCM production in milking parlor-oriented farms (Miron et al., 2004a; Zenou and Miron, 2005). However, a reduction in milk fat content was obtained in cows that were fed BM along the feeding lane and starchy pellets in the TMR, as compared with that obtained under a conventional TMR feeding regimen (Miron et al., 2004a).

The present study showed that the experimental pellets that formed up to 21% of dietary DM were sufficiently attractive to make their voluntary intake similar to that of conventional starchy pellets. The experimental pellets enhanced FCM and EcCM production. Thus, the experimental pellets can be supplied as an alternative to starchy pellets in an AMS in cases in which increased milk fat production is desirable. Substitution

Table 8. Cow BW (kg) during lactation in cows fed 2 different diets in an automatic milking system

DIM	Treatment, mean $\pm$ SE		<i>P</i> -value
	Control	Experimental	
10 < DIM < 60	573.8 $\pm$ 10.2	573.2 $\pm$ 10.8	0.96
61 < DIM < 120	619 $\pm$ 8.21	587 $\pm$ 6.7	0.001
120 < DIM < 180	608 $\pm$ 10.6	579 $\pm$ 6.4	0.005

of conventional starchy pellets fed at early lactation with pellets rich in digestible NDF led to more milk, but not to a greater frequency of milking in the AMS.

CONCLUSIONS

The inclusion of SH pellets high in digestible NDF in place of starchy grains fed to high-yielding dairy cows milked in an AMS 1) led to more milk, but not to a greater frequency of milking in the AMS; and 2) led to an increase in daily milk yields from 39.7 to 42.7 kg at 10 to 60 DIM, from 42.4 to 44.4 kg at 61 to 120 DIM, and from 37.54 to 39.09 kg at 120 to 180 DIM. This study adds evidence showing that what is fed in the AMS has no impact on milking frequency.

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