Feeding Behavior and Performance of Dairy Cows Fed Pelleted Nonroughage Fiber Byproducts

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ABSTRACT

The potential of pellets made of soy hulls (SH) and corn gluten feed (CGF) to replace starchy pelleted supplement in diets of lactating cows was measured in a feeding regime comparable to automatic milking systems. Twenty-four cows were divided into 2 equal groups and fed for 7 wk in individual feeders monitored by computer on one of the 2 experimental diets. Both diets contained 75% basic total mixed ration plus an additional 25% of pelleted supplement (17% CP), being either high starch pellets (HST) in treatment, or pellets made of SH + CGF (2:1) (SHCG) in treatment. In vitro dry matter digestibility was higher in the HST pellets, whereas neutral detergent fiber (NDF) digestibility was higher in the SHCG pellets. The NDF content was higher in the SHCG diet. Individual cow behavior at the feeding lane was analyzed during the experimental period. Average number of meals and daily eating duration of the SHCG cows were significantly greater, as compared with the HST group. However, intake per meal and rate of eating were greater in the HST cows, whereas meal duration was similar in both groups. Feeding behavior resulted in significantly higher daily dry matter and NDF intake by the SHCG cows (27.1 and 11.1 kg, respectively) as compared with the HST group (24.8 and 7.61 kg, respectively). Consequently, significantly higher milk fat content, milk fat yield, and 4% FCM yield were obtained in the SHCG cows. Milk and milk protein yields were similar in both treatments. Data suggest potential advantages of the SHCG pellets for herds using automatic milking systems.

(Key words: pelleted soy hulls and gluten feed, starchy grain, feeding behavior, performance of dairy cow)

Abbreviation key: AMS = automatic milking systems, CGF = corn gluten feed, ECM = economically corrected milk, HST = high starch pellets, SH = soy hulls, SHCG = SH + CGF 2:1, pellets.

INTRODUCTION

By-product feeds, such as soy hulls (SH) and corn gluten feed (CGF), are sold at competitive prices and contain a variety of energy substrates for ruminal microbes (Van Laar et al., 1999; Miron et al., 2001). This motivated at least 15 studies aimed at using SH as substitutes for starchy grains in TMR of lactating cows (Cunningham et al., 1993; Ipharraguerre et al., 2002; Ipharraguerre and Clark, 2003). Most of these studies have shown that replacing up to 25% corn grain by SH tended to decrease production of milk protein but increased milk fat percentage, resulting in higher or similar yields of FCM by lactating cows. In some of these studies, DMI tended to decrease as SH replaced 18 to 25% of corn grain in diets of lactating cows (Cunningham et al., 1993; Pantoja et al., 1994; Elliot et al., 1995), whereas in other studies replacement of 10 to 23% of grain with SH tended to increase DMI (Bernard and McNeil, 1991; Stone, 1996; Ipharraguerre et al., 2002). The conflicting DMI data motivates further investigation about the effect of replacing up to 25% dietary starch by nonroughage NDF-rich by-products on the feeding behavior of lactating cows. There is also limited information on the effectiveness of nonroughage NDF-rich by-products containing 17% CP for replacing a mixture of readily fermentable starchy grains and soybean meal (17% CP) in rations of lactating cows producing over 40 kg of milk/d (Ipharraguerre and Clark, 2003).

Beyond the context of TMR, an additional issue of interest is whether pellets composed of nonroughage NDF-rich by-products, served as a supplement to high-producing cows, can effectively replace starchy pellets. This issue is of special interest in dairy herds using automatic milking systems (AMS). In AMS, pellets

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made of starchy grains and containing 17% CP are usually fed individually into the robot at a level of up to 25% of DMI, in order to attract the cows to enter the AMS voluntarily. The rest of the diet (~75% of daily intake) is served free choice as a basic TMR (containing 17% CP) along the feeding lane (Morita et al., 1996; Halachmi, 1999; Wagner-Storch and Palmer, 2003). Concentrates feeding of cows being milked in AMS may allow the consumption of a high quantity of starchy grains within a short period of time. This in turn could affect not only the appetite and feeding behavior of the cows but also the rate and extent of NDF digestibility by ruminal bacteria (Miron et al., 1996; Morita et al., 1996; Friggens et al., 1998), leading to further reduction in voluntary DM and NDF intake and possibly on the utilization for milk fat production.

The hypothesis is that 17% CP-pelleted supplement made of nonroughage by-product rich in readily digestible NDF fraction, such as SH plus CGF (2:1), can successfully replace the starchy pelleted supplement (17% CP) while increasing dietary NDF intake and utilization for milk fat production.

The objective of this study was to examine this hypothesis by conducting in vitro digestibility measurements of either high starch pellets (**HST**) or pellets composed of SH + CGF 2:1 (**SHCG**), and by assessing feeding behavior and milking performance of high-producing dairy cows fed these 2 types of pellets as supplements (at 25% of dietary DM) to a basic TMR.

MATERIALS AND METHODS

Cows, Diets, and Sampling Procedures

Twenty-four lactating multiparus Holstein cows (2.8 ± 0.10 lactations) were divided into 2 groups of 12 cows each, similar in average (mean $\pm$ SE) stage of lactation (59 ± 5.3 DIM), daily milk yield (44 ± 0.85 kg), and BW (584 ± 7.2 kg) at onset of the experiment. The computerized monitoring feeding system used for this study was described previously by Halachmi et al. (1998). It was equipped for electronic identification of individual cows and electronic control and recording of their entry into the feed stalls. TMR feeders mounted on weighing balances facilitated the monitoring and analysis of the voluntary feed intake and feeding behavior of each cow in the group. The DMI could be measured only for cows registered by the electronic system. To overcome possible effects of the location of a feeding position, the 2 rations were assigned to groups of 6 adjacent feeding positions; each group of 6 control TMR positions is followed by a group of 6 experimental TMR positions. All the cows, experimental and control animals, were kept in one shaded corral as a single group, had free access

Table 1. Composition of diets fed during the experiment.

Ingredients	Dietary treatment ¹	
	SHCG	HST
Pellets supplement, % of dietary DM		
Ground barley grains	—	16.7
Ground corn grains	—	5.3
Soybean meal	—	3.0
Soyhulls	16.7	—
Corn gluten feed	8.3	—
Basic TMR, % of dietary DM		
Barley grains	9.38	9.38
Ground corn grains	9.38	9.38
Wheat bran	8.25	8.25
Soybean meal	5.74	5.74
Sunflower meal	5.74	5.74
Cotton grains	3.75	3.75
Sunflower oil	0.37	0.37
Minerals plus vitamins mix ²	2.56	2.56
Wheat silage	16.7	16.7
Corn silage	5.63	5.63
Vetch hay	3.75	3.75
Oat hay	3.75	3.75
Dietary DM content (%)	67.2	67.2

¹SHCG = NDF-rich pellets containing SH + CGF, 2:1, added as 25% of diet. HST = High starch pellets containing barley + corn and soybean meal, 2:1, added as 25% of diet.

²Minerals and vitamins mixture contained (g/kg DM): ammonium sulfate, 31.2; calcium chloride, 500; Di calcium phosphate, 62.5; magnesium oxide, 62.5; sodium bicarbonate, 312.5; and trace minerals + vitamins mix, 31.3 (Miron et al., 1996).

to water, and were milked daily at 0500, 1300, and 2100 h. The experiment was operated in the beginning of winter during November to December 2002 for 7 wk. Each cow was fed individually for free choice intake, allowing for 10% orts, one of 2 experimental diets, each containing 75% (on a DM basis) of a basic TMR (1.63 Mcal of NE_L, 17% CP) served once daily at 1000 h plus a 25% supplement of either starchy or nonroughage NDF-rich pellets served in addition to the basic TMR in 3 meals at 0500, 1100, and 1700 h. The high-starch pellets were composed of barley and corn grain plus soybean meal (HST treatment), whereas the nonroughage NDF-rich pellets were composed of soy hulls plus corn gluten feed 2:1 (SHCG treatment) to achieve similar content of CP (17%) in both pellets. This CP level of the 2 pellets was essential to create a feeding regime similar to that of an AMS, while allowing the cows free-choice intake of the basic TMR. Detailed composition of the 2 types of pellets and of the basic TMR are shown in Table 1. The 2 pellets slightly differed in their calculated NE_L content (1.86 and 1.94 Mcal of NE_L/kg of DM in SHCG pellets and HST pellets, respectively) and were consumed within 10 to 30 min after serving. However, HST pellets were ingested more rapidly by cows, compared to the SHCG pellets. The NE_L values of the individual feeds used in this study were provided by

the manufacturers and used to summarize the NE_L content of the basic TMR and the 2 types of pellets.

Cow behavior was investigated at the feeding lane, and 21,262 cow visits to the feeding trough were analyzed. Feeding behavior data, including number of visits per day, duration of visits, and food consumption during each visit and each day, as well as the distribution of visits throughout the day, were recorded and analyzed for the individual cows, as described previously (Halachmi et al., 1998). In this study, a cow meal was defined as a visit to a trough that lasted at least 1 min while eating at least 0.2 kg of food.

Basic TMR and the 2 kinds of pellets were sampled daily. The basic TMR and pellet samples were pooled on a weekly basis to produce 7 composites. The DMI was determined by oven drying a portion of the basic TMR, and pellets pooled samples at 105°C for 24 h. The weekly pooled samples of basic TMR and 2 types of pellets were oven dried at 60°C for 48 h, ground through a 1 mm screen, and used for the extent and rate of in vitro digestibility evaluation of the DM and NDF fractions and for chemical analyses.

Milk yield was recorded daily by automatic meters (Afimilk, Israel). Milk samples were collected during 3 sequential milkings on Wednesdays of each week during the 7-wk experimental period. Each set of milk samples for each cow was stored at 4°C in the presence of a conservation pill until analyzed for fat content, protein, lactose, urea, and SCC by infrared analysis (Dairy Milk Association Lab., Caesaria, Israel, using Milkoscan 4000, Foss Electric, Hillerød, Denmark).

Chemical Analyses and In Vitro Digestibility

Samples of oven-dried basic TMR and the 2 types of pellets (7 pool samples collected on a weekly basis) were assayed in triplicate for DM and OM (7.007 and 7.009, respectively) (procedures, respectively, in AOAC, 1980), and CP was determined according to a Kjeldahl method (7.021 procedure in AOAC, 1980). The NDF, ADF, and ADL content were determined in the basic TMR, and pellets in triplicate, as well as NDF, analyzed in the in vitro residues according to the method of Van Soest et al. (1991) with α -amylase, without sodium sulfite, and by employing Ankom apparatus (Ankom Technology Corp., Fairport, NY) for extraction and filtering.

Extent of DM and NDF in vitro digestibility of the 2 pellets was analyzed in each weekly pooled sample in triplicate using 48 h of incubation with rumen fluid followed by an additional 48 h of incubation with HCl and pepsin, according to the 2-stage fermentation technique of Tilley and Terry (1963). Rumenal fluid free of saliva contamination was obtained before morning feeding via esophageal tube from 4 cows fed the SHCG

diet and 4 cows fed the HST diet, combined to create one pooled sample and used for the in vitro measurements. Rumen fluid pH was 6.70 in the SHCG cows and 6.53 in the HST cows. Rate of in vitro DM and NDF digestibility of the 2 types of pellets was measured similarly, except that the first stage of incubation was conducted in triplicate during 0, 6, 12, 24, 48, or 72 h of fermentation with rumen fluid followed by an additional 48 h of fermentation with HCl and pepsin. Rate of DM and NDF digestion was determined as the slopes of a first-order kinetic equation describing the regression between loge (residual fraction percentage-undigested fraction percentage) against time of incubation (h), as shown by Mertens and Loften (1980).

Calculations and Statistical Analyses

The daily yield per cow of 4% FCM was calculated ($4\% \text{ FCM [kg]} = 0.4 \times \text{milk [kg]} + 15.0 \times \text{milk fat [kg]}$), and the payment equation (termed economically calculated milk [ECM]) was calculated according to the equation used by the Israeli Dairy Milk Association (2003): $\text{ECM (kg)} = 9.436 \times \text{milk fat (kg)} + 22.018 \times \text{milk protein (kg)}$.

Differences between the 2 pellets regarding the extent and rate of DM and NDF in vitro digestibility were analyzed statistically (T test) (Little and Hills, 1978).

Data of feeding behavior of the individual cows included number of meals/d, meal duration (min), feeding duration (min/d), extent of feed consumption per meal (kg), rate of meal eating (g/min), and daily DM and NDF intake. Additionally, performance data included milk yield and composition, and BW were reduced to means per cow in the 35 d of the experimental period after a 14-d adaptation period to the diets. These data were analyzed by ANOVA using the general linear model procedure of SAS (1996). Data in Tables 3 and 4 are presented as means of the dietary groups $\pm$ standard error of the means. Repeated measures analysis on a weekly basis showed a lack of any effect of the duration of the trial on the significance of behavior and performance data.

RESULTS AND DISCUSSION

Composition of Diets and In Vitro Digestibility of Pellets

The 2 rations differed in the composition of the pellets added (as 25% of the dietary DM), being either high starch pellets in the HST group replaced by pellets composed of SH + CGF in the SHCG group (Table 1). Total NDF content was higher in the SHCG pellets than in the HST pellets (50.1 and 18.8%, respectively), and this was reflected by a higher NDF content of the

Table 2. Chemical composition of diets and in vitro digestibility of the pellets.

	Dietary treatment		SEM	<i>P</i>
	SHCG ¹	HST ¹		
Dietary component, % of DM				
OM	92.1	91.7		
CP	17.0	17.0		
NDF from roughage	14.6	14.6		
NDF	40.8	30.7		
ADF	23.4	15.8		
ADL	3.2	3.0		
Calculated NE _L (Mcal/kg DM)	1.69	1.71		
Extent of in vitro digestibility, %				
DM of added pellets	83.7 ^a	85.3 ^b	0.43	0.03
NDF of added pellets	81.0 ^a	65.7 ^b	0.55	0.02
Rate of in vitro digestibility, %/h				
DM of added pellets	5.16 ^a	5.97 ^b	0.19	0.03
NDF of added pellets	5.09 ^a	4.33 ^b	0.17	0.03

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

¹SHCG = NDF-rich pellets containing soy hulls + corn gluten feed, 2:1, added as 25% of diet. HST = High starch pellets containing barley+ corn and soybean meal, 2:1, added as 25% of diet.

SHCG ration compared with the HST diet (40.8 and 30.7%, respectively) (Table 2). Both diets contained a similar level of forage NDF (14.6%) (Table 2); however, in the SHCG ration, most NDF was of nonroughage origin (about 64%), whereas in the HST diet, about half of the NDF originated from roughage. This difference in dietary NDF content and origin exerted not only quantitative but also qualitative difference between the 2 diets, since the extent and rate of NDF in vitro digestibility of the added SHCG pellets (81.0 and 5.09%/h, respectively) were significantly higher ($P < 0.03$) than those of the HST pelleted supplement (65.7 and 4.33%/h) as shown in Table 2. The higher NDF digestibility of the SH pellets is a result of the high digestibility of soy hulls and corn gluten feed NDF-polysaccharides compared with that of NDF obtained from barley and corn grains (Ben-Ghedalia et al., 1987; Miron et al.,

2001). On the other hand, the extent and rate of DM in vitro digestibility were higher in the HST pellets (85.3 and 5.97%/h, respectively) than in the SHCG pellets (83.7 and 5.16%/h, respectively) (Table 2). Thus, although the calculated energy and CP content of the 2 diets were almost similar (1.69 to 1.71 Mcal of NE_L/kg DM and 17% CP), the above-mentioned quantitative and qualitative differences between the 2 kinds of pellets affected feeding behavior of the cows and their performance, as shown below.

Feeding Behavior

Feeding behavior data of 21,262 visits of the cows in their individual feeding lot were analyzed, and average results are summarized in Table 3 and Figures 1, 2, and 3. Figures 1 and 2 show that, during short meals

Table 3. Feeding behavior and intake of cows fed the experimental diets.

Variable	Dietary treatment		SEM	<i>P</i>
	SHCG ¹	HST ¹		
Meals per day	14.0 ^a	10.3 ^b	0.94	0.02
Meal duration, min/meal	15.9	15.6	0.92	0.49
Eating duration, min/d	223 ^a	161 ^b	8.95	0.01
Meal intake, kg DM/meal	1.93 ^a	2.41 ^b	0.11	0.03
Consumption rate, g DM/min	121 ^a	154 ^b	6.81	0.03
NDF intake, kg/d	11.1 ^a	7.61 ^b	0.27	0.01
DMI, kg/d	27.1 ^a	24.8 ^b	0.30	0.03
Predicted DMI, ² kg/d	25.6 ^a	24.2 ^b	0.47	0.04

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

¹SHCG = NDF-rich pellets containing soy hulls + corn gluten feed, 2:1, added as 25% of diet. HST = High starch pellets containing barley+ corn and soybean meal, 2:1, added as 25% of diet.

²Predicted DMI calculated according to NRC (2001), based on individual FCM production, BW, and DIM of the cows in both groups.

Table 4. Performance of cows fed the experimental diets.

Variable	Dietary treatment		SEM	P
	SHCG ¹	HST ¹		
Milk yield, kg/d	44.9	44.3	0.49	0.34
Milk fat, %	3.31 ^a	2.79 ^b	0.05	0.01
Milk protein, %	3.05	3.18	0.03	0.09
Milk lactose, %	4.81 ^a	4.97 ^b	0.03	0.02
Milk urea, %	0.031 ^a	0.028 ^b	0.0007	0.01
Milk fat, kg/d	1.49 ^a	1.24 ^b	0.03	0.01
Milk protein, kg/d	1.37	1.41	0.02	0.14
4% FCM yield, kg/d	40.3 ^a	36.3 ^b	0.53	0.03
ECM yield, kg/d ²	44.1	42.6	0.56	0.13
Average BW, kg	586	586	3.79	0.48
Average BCS	2.60	2.56	0.04	0.39

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

¹SHCG = NDF-rich pellets containing soy hulls + corn gluten feed, 2:1, added as 25% of diet. HST = High starch pellets containing barley + corn and soybean meal, 2:1, added as 25% of diet.

²ECM = Economically corrected milk.

(up to 15 min), the eating speed of the 2 diets was about the same, but in longer meals, the cows fed HST tended to consume more feed per meal. For example, in meals that lasted 40 min, the cows fed HST consumed about 14 kg of wet food (9.4 kg DM), whereas the cows fed SHCG ate only about 8 kg of wet food (5.4 kg DM) (Figure 1). Thus, in the SHCG group, 90% of the meals ended with the consumption of up to 5 kg of wet food/meal (3.36 kg DM), whereas in the HST group, 90% of the meals ended with ingestion of up to 6 kg of wet food/meal (4.03 kg DM) (Figure 2).

The distribution of meals during the day is shown in Figure 3, and data summarizing average number of meals per day, duration of meals, and DM consumed

per meal and day are shown in Table 3. Cows fed the SHCG pellets ate significantly more meals per day than cows fed HST (14.0 vs. 10.3 meals/d, $P < 0.02$) (Table 3 and Figure 3); however, duration of average meal was similar in both groups (about 16 ± 0.92 min). The difference in number of meals per day was reflected by longer ($P = 0.01$) accumulated times in the feeding lane of the cows fed SHCG (223 min/d) compared with the HST group (161 min/d). However, in both groups, most of the meals occurred during the day between 0500 to 1800 h, and the distribution of feeding through the day was dominated by permanent events, including return from milking (0500, 1300, and 2100 h); pellets submission events at 0500, 1100, and 1700 h; and the dispensing time of basic TMR at 1000 h, as reflected by spikes of meals shown in Figure 3. The extra meals of the SH

Figure 1. Consumption speed; wet feed intake per meal versus duration of meal. Average wet intake per meal was 2.87 kg in soy hull (SH) corn gluten and 3.59 kg in high starch pellet treatments ($P = 0.03$, $n = 3852$ meals).

Figure 2. Profile of meals distribution versus meal size.

Figure 3. Diurnal feeding pattern: number of meals distribution over hours of an average day. Peaks are found at feeding time of basic TMR (1000 h) and added pellets (0500, 1100, and 1700 h) and after return from milking (0500, 1300, and 2100 h). Average daily number of meals was 14.0 and 10.3 in the soy hull corn gluten feed and high starch pellets treatments, respectively ($P = 0.02$, $n = 840$ meals).

group occurred generally at peak times of feeding and milking mentioned above (Figure 3). This result is contrary to the study of Halachmi (1999), who found that in AMS the cows eventually balanced their meals through the day and night almost equally over the 24-h period. The conflict between studies can be explained by the different triggers that motivated cows to approach the feeding lane. In the present study, the triggers were external stimulating events, including feeding and return from milking, together with social stimulation of other cows, as demonstrated by Metz and Mekking (1978). In the study by Halachmi et al. (1999), the predominant triggers were restriction parameters dictated by the AMS.

The amount of feed consumed per meal by cows fed the 2 types of pellets (Figure 2 and Table 3) was significantly different ($P = 0.03$). The cows fed HST ingested more food per meal than the SHCG group (2.41 and 1.93 kg of DMI per meal), and this probably reflects both the advantage of the HST pellets in the rate of DM digestibility and NE_L content (Table 2), and the fact that the HST pellets were of greater palatability to the cows and were consumed more willingly than the SHCG pellets.

The feeding behavior data in this experiment were in agreement with the study of Friggens et al. (1998), who found that cows fed a high-concentrate TMR had fewer but longer visits to the feeders and ate more feed per visit than did cows consuming a low-concentrate TMR. However, in contrast to our experiment, in the study of Friggens et al. (1998), dietary forage level dif-

fered between the 2 TMR, and therefore the cows fed the high-concentrate TMR had higher daily DMI than those fed the low-concentrate TMR.

Although feed-consumption rate per meal was higher in the HST group (Table 3), the accumulative DM and NDF intake per day were significantly higher in the cows fed SHCG (27.1 and 11.1 kg/d, respectively) compared with the HST group (24.8 and 7.61 kg/d, respectively). This difference reflects the longer daily eating duration and higher number of meals per day of cows fed SHCG (Table 3 and Figure 3). The increase in DMI of the SHCG group in this study (Table 3) is in contrast to some previous studies that showed reduced or similar DMI in cows fed SH as a replacement for 18 to 25% of corn grains (Firkins and Eastridge, 1992; Cunningham et al., 1993; Pantoja et al., 1994; Elliot et al., 1995). Possible explanations of the gap between studies are unique factors that were used in the present study, including lower content of roughage (<30%) (Table 1); pelleted supplements instead of TMR feeding system; the use of SH to replace fermentable barley in the diets instead of corn grain; and the higher level of milk production (over 44 kg/d) (Table 4) in the present study.

Three possible explanations are suggested for the differences in voluntary feed intake between the 2 dietary treatments (Table 3): (1) the higher extent and rate of NDF digestion of the SHCG pellets compared with the HST pellets (Table 2) may speed up passage from the rumen and enhance the feed intake of cows fed SHCG (Allen, 1997); (2) consumption of large quantities of starchy pellets per meal by the cows fed HST may inhibit the activity of ruminal cellulolytic population and further decrease the rate and extent of forage-NDF digestion of the basic TMR fed. This inhibitory effect of starchy feeds on NDF digestion occurs also in well-buffered rations of ruminant and is known as the "carbohydrate effect" (Ben-Ghedalia and Solomon, 1987; Miron et al., 1996); and (3) the higher rate and extent of DMI per meal (Figure 1 and Table 3) and DM digestibility of the HST pellets (Table 2) may supply more metabolites to the blood of the cows fed HST that may further reduce hunger feeling and inhibit short-term cow appetite, while increasing the interval between meals and reducing the number of meals per day and accumulated daily duration of feeding, as shown also in the study of Friggens et al. (1998).

Milk Yield and Composition

Average milk and milk-protein yields were similar in the cows fed the SHCG pellets as compared with the HST group (44.9 and 1.37 kg/d vs. 44.3 and 1.41 kg/d, respectively) (Table 4), possibly due to the advantage of the SHCG diet with respect to voluntary DMI (Table

3) that was compensated for by the advantage of the HST group in rate and extent of DM digestibility and calculated NE_L content (Table 2). Notwithstanding, average concentration of milk fat and, accordingly, also yields of milk fat and 4% FCM were significantly greater in the SHCG group compared with the cows fed HST (3.31%, 1.49 kg/d, and 40.3kg/d vs. 2.79%, 1.24 kg/d, and 36.3 kg/d, respectively). Consequently, ECM yield tended to be greater in the cows fed SHCG compared with the cows fed HST (44.1 vs. 42.6 kg/d, $P = 0.13$). The advantage of the SHCG cows in FCM production may be due to the higher daily NDF intake and higher extent of NDF *in vitro* digestibility of that ration as compared with the HST group (Tables 3 and 2). More digestible cellulose and hemicellulose usually result in the production of more acetate by rumen cellulolytic bacteria (Chesson and Forsberg, 1997), which can be used as a precursor for milk-fat synthesis in the mammary gland. Thus, the positive effect on milk-fat yield obtained in the present study in the SHCG cows may have been the result of both the ingestion of more digestible NDF, cellulose, and hemicellulose components and the favorable conditions for microbial fiber degradation in the rumen of the cows fed the SHCG pellets.

Support for these performance data is given from previous studies that showed that replacement of corn grain with SH (18 to 20% of dietary DM) tended to increase FCM yield in lactating cows (Pantoja et al., 1994; Elliot et al., 1995; Ipharaguerre et al., 2002).

Despite the success of the SHCG pellets to replace HST pellets in the present study, the fact that the HST pellets were consumed more willingly and faster than the SHCG pellets suggests that more efforts should be invested in increasing the palatability of the SHCG pellets before applying this alternative in AMS.

Prediction of DMI

Measuring individual feeding behavior of high-producing cows fed 2 diets differing in source and content of NDF provides an opportunity to evaluate the NRC model for predicting DMI of cows based only on their milk and FCM yields, DIM, and BW data, while ignoring diet composition (NRC, 2001). Table 3 shows the predicted average DMI of cows fed the 2 dietary treatments calculated for each cow according to the model of NRC (2001) in comparison to the actual DMI measured in this study. Data show that the NRC model was quite successful in predicting DMI of the cows fed HST (predicted DMI 24.2 kg/d vs. actual DMI 24.8 kg/d, with a linear coefficient of regression = 0.88). However, when starchy grains were replaced by nonroughage highly digestible NDF by-products, prediction of DMI

in the cows fed SHCG was underestimated by 5% and at a lower accuracy (linear coefficient of regression = 0.16).

Thus, it is suggested that prediction of intake based on cow performance, regardless of diet composition (NRC, 2001), is quite accurate for cows fed conventional diets, including the HST diet of the present study but not for rations based on bulky concentrates, such as the SHCG pellets.

CONCLUSIONS

Inclusion of SH + CGF as starchy-grains replacement in pelleted supplement fed to high-producing cows increased the number of meals per day and daily eating duration, while increasing daily DM and NDF intake. Consequently, milk and protein yields were maintained while milk-fat and FCM production by lactating cows were enhanced. This was probably the result of supplementation of more digestible NDF and the creation of favorable conditions for microbial fiber degradation in the rumen of cows fed the SHCG pellets (Tables 3 and 2). Data support our hypothesis, suggesting that the SHCG pellets may be recommended for AMS as a replacement for the conventional starchy pellets currently used, while avoiding possible reduction in FCM production.

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