Effects of Feeding High Forage Diets and Supplemental Fat on Feed Intake and Lactation Performance in Dairy Cows

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ABSTRACT : Fifty mid-lactation Holstein cows were used in a six-week feeding trial to study effects of high-forage, high-fat diets on dry matter intake and production performance. Cows were divided into 10 replicates, each consisting of five cows. Each cow was assigned to a control (diet 1) or one of the four experimental diets (high-forage (75%), high-fat (7.5%) (diet 2); high-forage, medium-fat (5%) (diet 3); medium forage (65%), high-fat (diet 4); medium-forage, medium-fat (diet 5)), or a control diet containing about 50% forage and 2% fat. All diets were isonitrogenous (17.7% crude protein). The forage mixture consisted of 20% alfalfa hay, 40% alfalfa haylage, and 40% corn silage. Supplemental fat included 80% rumen-protected fat and 20% yellow grease. Dry matter intake was decreased ($p<0.01$) in cows fed experimental diets (18.4, 20.9, 19.9, and 22.6 kg for cows fed diets 1-4, respectively vs. 27.5 kg for cows fed the control diet). Daily milk production was lower ($p<0.05$) for cows consuming experimental diets (30.5, 31.3, 31.0, and 32.5 kg for cows fed greater for cows consuming experimental diets (1.74, 1.55, 1.60, and 1.53 kg milk/kg dry matter intake for cows fed diets 1-4, respectively, vs. 1.26 kg milk/kg dry matter intake for cows fed the control diet). *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 4 : 457-463)*

Key Words : High Forage Diets, Supplemental Fat, Feed Intake, Milk Production and Composition

INTRODUCTION

During early lactation, high producing dairy cows are normally in negative energy balance because feed intake is limited by physical capacity of the rumen. Dry matter intake is the major factor affecting both energy intake and production performance of cattle fed forages (Waldo and Jorgensen, 1981). Increasing the metabolizable energy density of diets through higher levels of grain predisposes cows to different metabolic disorders. such as rumen acidosis and milk fat depression (Grummer et al., 1987). Inadequate energy intake causes in decreased milk production and increased susceptibility of cows to metabolic disorders such as ketosis, fatty liver, and downer cow syndrome. The challenge for dairy nutritionists is to formulate diets to feed to lactating cows that will maintain health and maximize milk yield while minimizing cost.

There has been an increasing interest in feeding fats to dairy cows far several years and a wide variety of fat sources are used to increase the energy density of diets fed to cows in early lactation or to high-producing cows in negative energy balance. Increasing dietary energy density by feeding supplemental fat may enhance both lactation performance (Shaver, 1990) and metabolic efficiency of lactating cattle (Kronfeld et al., 1980). Changes in endocrine status have been observed in dairy cows fed high-fat diets. Fat and forages complement each other by optimizing energy intake and rumen function (Palmquist, 1987). The optimum effective fiber content of diets containing supplemental fat needs to be determined.

Considerable research has involved investigating the effects of varying ratios of forage and grain fed to dairy cows on milk production and composition. Little research work has been done to explore the possibility of combining high proportions of forage with high fat to attain an acceptable energy intake for high producing cows. The objectives of the current study were to develop schemes of feeding to utilize maximal amounts of forage in diets of dairy cows and determine amounts of fat that can be fed in combination with high levels of forage, and to compare the milk production and composition of cows fed high-forage, high-fat diets.

MATERIALS AND METHODS

Fifty multiparous mid-lactation Holstein cows were used to evaluate the effect of feeding high forage diets with supplemental fat on feed intake and lactation performance. These cows were approximately of the same age, body size and almost of the same body weight. The five experimental diets to be evaluated in the present study were as follows:

Diet 1 : 50% Forage and 2% added Fat (Control)
Diet 2 : 75% Forage and 7.5% added Fat
Diet 3 : 75% Forage and 5% added Fat
Diet 4 : 65% Forage and 7.5% added Fat
Diet 5 : 65% Forage and 5% added Fat

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Table 1. Ingredient composition of experimental diets

Ingredient	Diet number (forage:fat)[1]				
	1 (Control)	2 (75:7.5)	3 (75:5.0)	4 (65:7.5)	5 (65:5.0)
	(% of DM)				
Alfalfa hay	10.00	15.01	14.99	13.03	13.00
Alfalfa haylage	19.99	30.03	29.98	26.07	26.00
Corn silage	19.99	30.03	29.98	26.07	26.00
Whole cottonseed	3.92	3.95	5.81	3.85	3.94
Corn ground, shelled	32.54	4.35	6.09	11.85	14.97
Soybean meal	10.49	4.15	4.50	6.02	5.91
Fish meal	-	2.37	1.31	2.37	1.97
Yellow grease	0.40	1.50	1.05	1.50	1.01
Protected fat (EB-100)	1.60	6.00	4.20	6.00	4.06
Molasses	-	1.38	0.94	1.97	1.97
Dical. phosphate	1.18	0.49	0.47	0.69	0.59
TM salt	0.39	0.40	0.37	0.39	0.39
Selenium 200	0.10	0.04	0.04	0.05	0.10
Magnesium oxide	0.10	0.10	0.09	0.10	0.04
vitamin A, D, E & K premix	0.03	0.20	0.19	0.03	0.03

[1] Percentage of dietary dry matter.

Table 2. Nutrient composition of experimental diets

Ingredient	Diet number (forage:fat)[1]					
	Daily requirements[2]	1 (Control)	2 (75:7.5)	3 (75:5.0)	4 (65:7.5)	5 (65:5.0)
DM (kg)	22.95	23.19	23.01	24.26	23.02	23.07
DM (%)	-	60.60	52.20	52.20	55.20	55.20
NE_l (Mcal/kg DM)	1.69	1.74	1.85	1.76	1.89	1.80
CP (%)	17.71	17.75	17.75	17.77	17.75	17.74
EE (%)	3.00	5.35	10.18	8.13	10.52	8.14
ADF (%)	18.50	19.20	25.60	26.30	22.90	22.90
NDF (%)	28.30	30.00	36.70	37.60	33.50	33.60
NSC (%)	-	38.90	27.37	28.50	30.23	32.52
Ca (%)	0.83	0.85	1.07	1.00	1.02	0.96
P (%)	0.47	0.56	0.45	0.44	0.50	0.48
Mg (%)	0.25	0.29	0.31	0.32	0.30	0.27

[1] Percentage of dietary dry matter. [2] NRC (1989)

The four experimental diets B through E contained forage i.e. 20% alfalfa hay, 40% alfalfa haylage, and 40% corn silage on a DM basis. The added fat contained 80% protected fat (Energy Booster EB 100, Milk Specialties Company, Dundee, IL) and 20% yellow grease. Diets were formulated to meet the requirements of a mature Holstein cow producing 90 lb of milk with 3.4% fat (table 1). All diets were isonitrogenous and ranged from 1.74 to 1.89 Mcal of NE_l per kg of dry matter (table 2).

The cows were randomly alloted to the five experimental diets such that each diet received ten cows. The cows were fed the experimental diets for a period of six weeks. Within the 6 wk experimental period cows were maintained on the normal herd diet. During wk 2, cows were shifted step wise to the control and the experimental diets. Durins wk 3 through wk 6 they were fed control or their respective experimental diets, which were provided as TMR.

Feed intake was measured by weighing TMR offered at each feeding and removing and weighing orts the next moring. Samples of forages (alfalfa hay, alfalfa haylage, and corn silage) were taken during wk 2, 4 and 6 of each replication and stored at -20℃ for further analysis. Additional samples of these forages were taken weekly to determine DM in order to adjust the forage to concentrate ratio to on as fed basis. Dry matter was determined by drying forage samples in a hot air convection oven at 55℃ for 48 hours. Forage to concentrate ratio was adjusted weekly to provide a constant amount of dry matter from forage and concentrate for each diet. Orts were composited and sampled weekly for wk 3, 4, 5 and 6. At the end of each replication all weekly orts samples were composites to one sample per cow. Concentrate samples were taken after each batch was mixed.

Cows were milked three times a day, and total milk production was recorded at every milking. Milk samples were taken on the last day of wk 1, 3, 4, 5 and 6 and composited weekly to provide one sample per cow per week. Feed efficiency for milk production was calculated using milk energy (Tyrell and Reid, 1965) and published NRC values for the digestibile energy (DE) content of feed ingredients by using the following formula:

$$\text{Feed efficiency (FE \%)} = \frac{\text{Milk energy (Mcal/d)}}{\text{DE of feed consumed (Mcal/d)}}$$

Body weights of cows were determined for the first 3 d of wk 3 and again for the last 3 d of wk 6. Changes in body weight were used to estimate gain or loss of body energy. Body condition scores were obtained during wk 1, 3 and 6. Condition scores were determined each time by the same three individuals using a 5 pt. Scale.

Composite milk samples from all individual cows for a given week were analyzed for milk fat, protein, and total solids by using an infrared analyzer (Milk-O-Scan 203, Foss Food Technology, Eden Prairie, MNr). Energy corrected milk was calculated as described by Tyrrell and Reid (1965). Forages, concentrates, and orts were analyzed for moisture, crude protein, ADF, NDF, fat, starch, Ca, P, Mg and K.

The data were subjected to analysis of variance by using general linear model procedures of SAS (SAS Institute, 1990). Three orthogonal linear contrasts were constructed to test differences between control and the treatments, forage levels, and fat levels.

RESULTS AND DISCUSSION

Characteristics of cows

Body weight changes within the diets from wk 3 to wk 6 were not different. However, comparison of body weights of cows fed diets containing different levels of forage and different levels of fat revealed significant differences ($p<0.01$). Because cows were past peak lactation, not much change in body weight was expected. Cows on the two 75% forage diet lost about 2.5 kg of body weight during the experimental period. This loss could be attributed to a decrease in the dry matter intake for these high forage diets. These cows, in an attempt to maintain production levels probably utilized body reserves which caused a decrease in body weight. Cows consuming 65% forage diets gained 3 and 6 kg for high (7.5%) and medium (5.0%) fat diet respectively. Cows fed the control diet maintained body weight during the experiment, however, milk production from these cows was higher compared with that of treated cows (34.2 vs. 31.3 kg/d). This increased milk production was maintained through increased DM intake (27.5 vs. 20.5 kg/d).

Few studies have reported the effects of supplemental fat on body weight changes in cows. Cervantes (1992) reported an average cumulative gain of 11 kg for cows fed calcium salt of fatty acids (CSFA) for 5 wk. Schneider et al. (1988) found no effects on body weight of Jersey and Holstein cows in early lactation supplemented daily with 0.45 or 0.50 kg of CSFA, respectively. Similarly West and Hill (1990) reported no body weight changes with cows of the same breed averaging 95 d in milk.

All cows fed the four experimental diets had a higher body condition score (BCS) at wk 6 than that of cows fed the control diet (3.17 vs. 3.02. $p<0.07$). Differences in body condition scores of cows fed diets containing different levels of forage were not significant, whereas differences in body condition scores (3.30 vs. 3.04) of cows fed diets with different levels of fat were highly significant ($p<0.01$). Cows fed diets containing 75% forage lost body condition when changed from the normal herd diet to their respective experimental diets. However, they recovered this body condition by the end of the experimental period, indicating that these cows needed longer adjustment periods for diets containing 1.5 times more forage than their normal diet. The BCS of cows consuming the control or one of the four experimental diets and among those consuming diets with different levels of forage were nonsignificant; however, body condition scores of cows fed diets with different levels of fat differed significantly ($p<0.01$).

Although DM intake in cows fed the diets containing 75% forage was decreased, milk production per unit DM intake was higher than the cows fed diets containing 65% forage or those fed control diet. Cows on 75% forage diets lost condition at the begining of the experimental period by maintaining milk production at the expense of body condition. After adjusting to high forage, high fat diets, these cows retrained body condition by the end of the experiment.

Cows used in our study had an average initial BCS of 3.01 and a final BCS of 3.14. Waltner (1993) reported that BCS must be sufficient at calving to allow maximal milk production and health. They also found that excessive BCS loss at calving and during milk production results in depressed milk production and suboptimal performance.

Feed intake

Average intakes of DM, CP, ADF, NDF, and EE by the cows during the treatment period (wk 3 to wk 6) were 21.9, 4.63, 6.91, 7.71, and 1.79 kg/d respectively (table 3). Dry matter intakes in the control versus the four treatment groups were 27.5 vs. 20.5 (4.33 and 3.23% of body weight respectively) ($p<0.01$). Both forage levels and fat levels had significant effects ($p<0.01$) on DM intake. Cows fed diets containing 75% forage had decreased DM intake as compared with those fad 65% forage (19.7 vs. 21.3 kg/d). Similar changes in DM intakes were observed for cows fed diets containing 7.5% vs. 5.0% fat (19.2 vs. 21.8 kg/d respectively) (figure 1).

The DM intake response of cows to control and experimental diets was different (figure 1). There was an abrupt increase in DM intake by cows 136 the control diet from wk 1 to wk 3. Cows on all treatment diets decreased DM intake slightly when fed these diets during wk 3 following a 1 wk adjustment period. During wk 4, cows on diets containing 7.5% of supplemental fat had a lower DM intake than during wk 3, whereas cows fed diets with 5.0% fat improved DM intake during wk 4 as compared to wk

Table 3. Average feed intake by cows fed different experimental diets during wk 3, 4, 5 and 6 of the experimental period

Item	Diet number (forage:fat)[1]					Contrasts		
	1 (Control)	2 (75:7.5)	3 (75:5.0)	4 (65:7.5)	5 (65:5.0)	Control vs. treatments	Forage levels	Fat levels
	Intake (kg/d)					Significance		
DM	27.5	18.4	20.9	19.9	22.6	**	**	**
CP	6.28	3.84	4.20	4.01	4.83	**	**	**
ADF	8.38	5.75	6.99	6.37	7.04	**	NS	**
NDF	8.63	6.95	8.14	6.93	7.92	**	NS	**
EE	1.72	1.75	1.58	2.01	1.86	NS	**	**
DE (Mcal/d)	92.4	62.8	70.0	69.3	76.5	**	**	**
Energy efficiency (%)	29.4	34.7	34.0	33.4	32.9	**	NS	**

** $p<0.01$; NS=non significant.

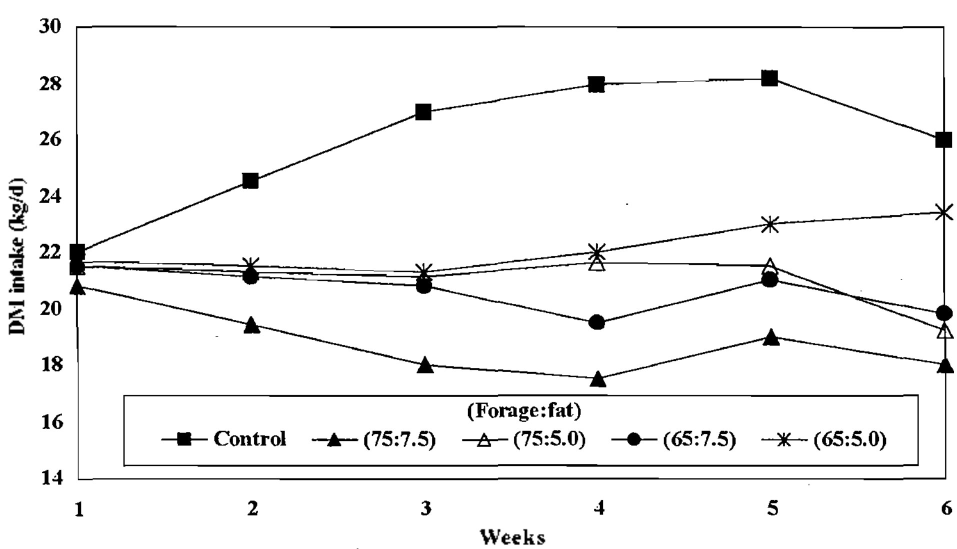

Figure 1. Dry matter intake by cows fed either the control or one of the four treatment diets during wk 3 to 6 (Pooled SEM=0.576). The numbers in parenthesis in the legend box are the percent forage (75 or 65) followed by the percent supplemental fat (7.5 or 5.0) in the diets.

3. During wk 5 and 6, DM intake of all cows on treatment diets was similar. This suggests that cows fed diets with high levels of fat needed more time to adjust to high fat diets compared to cows fed diets containing medium levels of fat or those fed control diets.

Previous studies (Mattias et al., 1982; Drackley et al., 1992) indicated that DM intake of lactating cows is minimally affected when supplemental fat is fed at 2 to 5% of the ration DM. Kowalcyzk et al. (1977) reported that feed consumption is decreased when higher concentrations of animal fat are added to dairy rations. Schauff and Clark (1990) found a linear decrease in DM intake when CSFA was added to diets at 6 or 9% of the dietary DM.

Total daily intake of CP, ADF, and EE varied with variation in DM intake. However, no differences were observed in ADF and NDF intake of cows consuming diets with different levels of forage, suggesting that NDF is an important factor in regulating intakes in cows. Intake of NDF during the experimental period remained fairly constant. There were no differences in average daily EE intake between cows fed the control or the four treatment diets. Increase in intake of EE in cows fed the control diet was due to increased feed intake. Digestible energy (DE) intake during wks 3 to 6 for all five diets was low as compared with the pretreatment period (74.1 vs. 73.8 Mcal/d), whereas DE intake of the control diet was higher than both pretreatment DE intake and that of experimental diets (table 3). DE intake for cows find the control and those fed the treatment diets, and for cows fed diets containing different levels of forage and fat were different ($p<0.01$). Comparing DE intake within diets from wk 3 to 6 revealed no difference. There was a noticeably greater difference in DE intake between control and treatment diets (92.4 vs. 69.7 Mcal/d), primarily due to high DM intake of the control diet.

Average energy efficiency for the four treatment diets was much higher than that of the control diet (33.8 vs. 29.4) (table 3). Higher DM intake by cows consuming the control diet resulted in less efficient utilization of feed energy. Milk production is a curvilinear function, and at higher levels of energy intake the rate of increase in milk yield per unit of energy intake declines because more energy is used for other metabolic functions. Firkins and Eastridge (1992) found improvement in the efficiency of milk production when concentrate in the diet was replaced with soy hulls and supplemental fat. There was no difference in the energy efficiency of cows fed diets containing different levels of forages, whereas cows fed diets containing different levels of fat were different ($p<0.01$).

Milk production and composition

Total daily milk production from cows fed control and experimental diets averaged 34.2 and 31.3 kg, respectively (table 4). Cows fed diets with higher (75%) levels of forage and higher (7.5%) levels of fat produced comparatively less milk (30.9 vs. 31.8 and 30.8 vs. 31.9 kg/d respectively). Differences in milk production between wk 3 and wk 6 probably were due to normal production decreases in late lactation (table 4, figure 2). Production of 4% FCM and ECM responded similarly to the control and different treatment diets.

Milk production per kg of DM intake was different ($p<0.01$) between all treatment and control groups. Average milk production per kg DM intake was highest for cows fed the 75% forage, 7.5% fat diet as compared to cows fed the control diet (1.74 vs. 1.26 kg milk/kg DMI, respectively). There was an overall decline with time in milk produced per kg DM intake for all diets; the response is in contrast to that describing DM intake. Because of the rapid increase in DM intake in cows fed control diets, milk production per kg DM intake went down Srom 1.91 kg to 1.32 kg during the period from wk 1 to wk 3. Cows fed the 75% forage, 7.5% fat diet had the highest milk production of all the treatment groups and came closest to maintaining their production level throughout the experimental period.

Because cows used in our experiment were all mid lactation cows, no increases were observed for milk yield by feeding diets containing supplemental fat during the treatment over the pretreatment period. West and Hill (1990) reported that use of CSFA did not increase milk yield in Holstein and Jersey cows beyond 130 days in lactation. Ostergaard et al. (1981) also indicated that the largest increases in milk production are obtained by feeding inert fat to high producing cows during early stages of lactation. In another trial Jerred et al. (1990) observed an increase of 2.9 lb/d in milk by feeding 5% prilled fat during early lactation.

Response of total milk fat and protein production (table 4) differed between control and treated groups. Cows fed the control diet produced more total fat compared with those fed treatment diets, (table 4) i.e., 1.35 vs. 1.23 kg/d, respectively. Differences were mainly due to high milk production by cows fed the control diet. Total milk fat production declined as milk production decreased in all groups of cows. Total milk protein production per day was also different between the control and the treated groups (1.10 vs. 0.94 kg/d respectively). This was mainly due to changes in total milk production. No differences were noted in the milk fat percentage between control and treatment groups and between cows fed diets containing different levels of forage or fat.

Average milk protein percentage was different between control and treated groups (table 4). Cows fed the control diet produced milk with 3.22% protein, whereas those fed experimental diets produced milk with average protein content of 3.01%. There was a decrease of about 0.08% from pretreatment value in the protein content of milk from cows fed the 75% forage and 7.5% fat diet. For cows fed the other three treatment diets and control diet protein content of milk was higher than that during pretreatment period. The greatest increase in milk protein percent among treatment groups was observed in the diet containing 65% forage and 7.5% fat. Changes in milk protein content for cows the fed diet containing 75% forage, 7.5% fat was negative up to the 5th wk of experiment but tended to increase during 6th week. Cows fed diets with 75% forage and 5.5% fat had a declining milk protein content during the 4th week of the experiment; thereafter a significant increase in the protein content was observed during the last two weeks of the study. This suggests that a little longer experimental period of 8 to 10 weeks amy be necessary to determine changes in the protein content of milk from cows fed high forage high fat diets. The milk protein content of cows fed diets containing 65% forage and 7.5% fat was stable during first 4 weeks,

Table 4. Milk production and composition from cows fed different diets during the experimental period

Item	Diet number (forage:fat)[1]					Contrasts		
	1 (Control)	2 (75:7.5)	3 (75:5.0)	4 (65:7.5)	5 (65:5.0)	Control vs. treatments	Forage levels	Fat levels
	Intake (kg/d)					Significance		
Milk (kg/d)	34.2	30.5	31.3	31.0	32.5	**	NS	NS
4% FCM (kg/d)	33.8	29.8	31.2	30.5	32.0	**	NS	NS
ECM (kg/d)	36.6	31.5	33.1	32.7	34.1	**	NS	*
Milk/DMI (kg/kg)	1.26	1.74	1.55	1.60	1.53	**	NS	**
Milk fat (%)	3.98	3.83	3.98	3.95	3.94	NS	NS	NS
Milk fat (kg/d)	1.35	1.17	1.25	1.21	1.27	**	NS	*
Milk protein (%)	3.22	2.92	2.98	3.12	3.02	**	**	NS
Milk protein (kg/d)	1.10	0.89	0.94	0.96	0.98	**	*	NS
Lactose (%)	4.71	4.36	4.49	4.51	4.54	**	**	**
Total solids (%)	12.77	11.89	12.27	12.36	12.33	**	**	**

* $p<0.05$; ** $p<0.01$; NS=non significant.

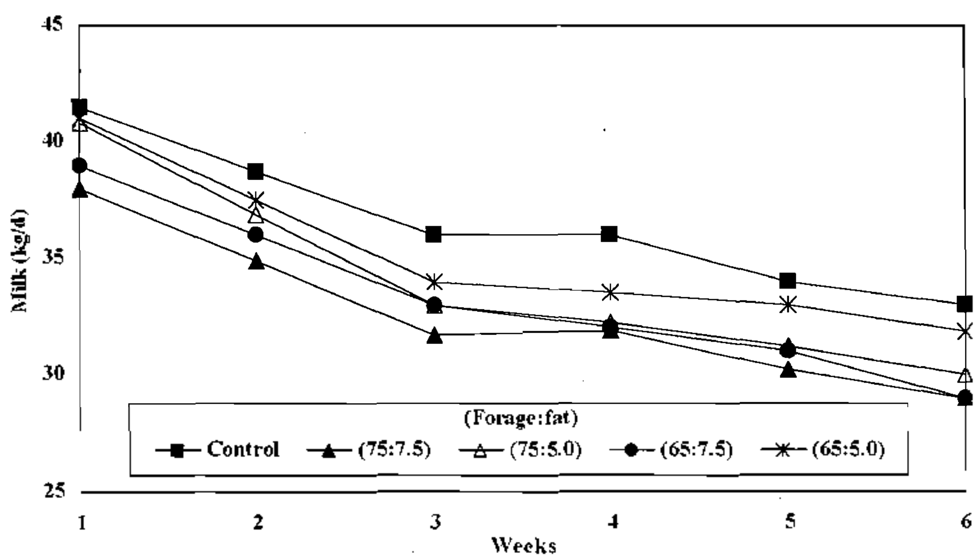

Figure 2. Milk production by cows fed either the control or one of the four treatment diets during the experimental period (wk 3-6) (Pooled SEM=0.350). The numbers in parenthesis in the legend box are the percent forage (75 or 65) followed by the percent supplemental fat (7.5 or 5.0) in the diets.

decreased during the 5th week and an increase was observed in the 6th week of the experiment. Shaver (1990) indicated that reductions in milk protein percentage due to fat feeding were about 0.08 to 0.15 percentage units for various fat sources, whereas an increase of 0.11% in milk fat content was reported. Canale et al. (1990) found no effect of feeding 2.5 to 5% protected fat on milk fat production, whereas an increase of 0.04% in protein percentage was observed. DePeters et al. (1987) observed a decrease in percentage of fat, solids, lactose, and protein in milk of cows fed 7% supplemental fat. Palmquist and Moser (1981) suggested that increased plasma fatty acids may be responsible for milk protein depression by decreasing concentrations of circulating growth hormone. Grummer (1988) found a depression of milk protein when cows were fed 3.38 or 3.35% of ration DM as calcium salts of palm oil fatty acids, but no depression occurred when prilled fat was added to the diet at the same level. There was no difference in changes in lactose contents of milk from cows fed different diets during wk 3 to wk 6 of the experiment. Total solid contents of milk were significantly different among different treatment groups (table 4). Cows fed the control diets produced milk with 12.77% solid solids, and the four treatment groups averaged 12.21% solids. Cows consuming diets with dirfferent levels of forage or fat differed in total solid contents of their milk.

CONCLUSION

Fat feeding allows incorporation of high levels of forages without lowering the energy density of diets. Commercially perpared inert or by-pass fats are relatively inactive in the rumen and do not affect normal rumen function. Combination of high levels of forages and fats can decrease dependence on row crops, soil erosion, and build-up of nitrates in the soil and improve the health status of dairy cows.

REFERENCES

Canale, C. J., P. L. Burgess, L. D. Muller and G. A. Varga. 1990. Calcium salts of fatty acids in diets that differ in neutral detergent fiber (NDF): Effect on lactation performance and nutrient digestibility. J. Dairy Sci. 73: 1031.

Cervantes-Nunez, A. 1992. Effect of supplementation with nicotinamide and long-chain fatty acids on milk production and composition of lactating cows. Ph.D. Diss. Iowa State Univ., Ames. IA.

DePeters, E. J., S. J. Taylor, C. M. Finley and T. R. Famula. 1987. dietary fat and nitrogen composition of milk from lactating cows. J. Dairy Sci. 70:1192.

Drackley, J. K., G. C. McCoy and T. H. Klusmeyer. 1992. Production of milk components by cows fed diets containing tallow added by different methods. J. Dairy Sci. 75(Suppl. 1):172(abstr.).

Firkins, J. L. and M. L. Eastridge. 1992. Replacement of forage or concentrate with combination of soy hulls, sodium bicarbonate or fat for lactaing dairy cows. J. Dairy Sci. 75:2752.

Grummer, R. R. 1988. Influence of prilled fat and calcium salts of palm oil fatty acids on ruminal fermentation and nutrient digestibility J. Dairy Sci. 71:117.

Grummer, R. R., A. L. Jacob and J. A. Woodford. 1987. Factors associated with cariation in mile fat depression resulting from high grain diets fed to cows. J. Dairy Sci. 70:613.

Jerred, M. J., D. J. Carrol, D. K. Combs and R. R. Grummer. 1990. Effects of fat supplementation and immature alfalfa to concentrate ratio on lactation performance of dairy cattle. J. Dairy Sci. 73:672.

Kowalczyk, J., E. R. Orskov, J. J. Robinson and C. S. Stewart. 1977. Effect of fat supplementation on voluntary food intake and rumen metabolism in sheep. Brit. J. Nutr. 37:2510.

Kronfeld, D. S., S. Donoghue, J. M. Nyler, K. Johnson and C. A. Bradly. 1980. Metabolic effects of feeding protected tallow to dairy cows. J. Dairy Sci. 63:545.

Mattias, J. E., J. G. Ruesegger, L. H. Schultz and W. J. Tyler. 1982. Effect of feeding animal fat to dairy cows in early lactation. J. Dairy Sci. 65(Suppl. 1):151(Abstr.).

Ostergaard, V., A. Danfaer, J. Dangaard, J. Hindhede and I. Thysen. 1981. The effect of dietary lipids on milk production in dairy cows. Berentning Fra Statens Hudyr-Brugs Forsog No. 508, Copenhagen, DN.

Palmquist, D. L. 1987. Adding fat to dairy diets. Animal Health and Nutrition 42:32.

Palmquist, D. L. and E. A. Moser. 1981 Dietary fat effects on blood insulin, glucose utilization, and milk protein content of lactating cows. J. Dairy Sci. 64:1664.

SAS. 1990. Users guide: Statistics. SAS Institute. Inc., Cary, NC.

Schauff, D. J. and J. H. Clark. 1990. Feeding increasing dietary concentrations of calcium salts of long-chain fatty acids to Holstein cows. J. Dairy Sci. 73(Suppl. 1):242.

Schneider, P., D. Sklan, W. Chalupa and D. S. Kronfeld. 1988. Feeding calcium salts of fatty acids to lactating cows. J. Dairy Sci. 71:2143.

Shaver, R. D. 1990. Fat sources for high producing dairy cows. In: proc. symp. for the feedi industry. The National Renders Assoc., Rochester, NY.

Sniffen, C. and J. F. Ferguson. 1991. Body condition scoring guide. Church and Dwight Co., Inc., Princeton, NJ. pp. 1-2.

Tyrrell, H. F. and J. T. Reid. 1965. Prediction of the energy value of cows's milk. J. Dairy Sci. 48:1215.

Waldo, D. R. and N. A. Jorgensen. 1981. Forages for high animal production: Nutritional factors and effects of conervation. J. Dairy Sci. 64:1207.

Waltner, S. S., J. P. McNamara and J. K. Hillers. 1993. Relationship of body condition score to production variables in high producing Holstein dairy cattle. J. Dairy Sci. 76:3410.

West, J. W. and G. M. Hill. 1990. Effect of protected fat product on productivity of lactating Holstein and Jersey cows. J. Dairy Sci. 73:3200.