Short communication: Effects of dietary fat supplements and forage:concentrate ratio on feed intake, feeding, and chewing behavior of Holstein dairy cows

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ABSTRACT

Feed intake and feeding behavior of dairy cows fed diets that varied in fat supplementation and forage:concentrate (F:C) ratio were investigated. Eight multiparous Holstein dairy cows were used in a replicated 4 × 4 Latin square experiment with 21-d periods. Treatments were 1) no supplemental fat and 34:66 F:C ratio; 2) 2% hydrogenated palm oil and 34:66 F:C ratio; 3) 2% yellow grease and 34:66 F:C ratio; and 4) 2% yellow grease and 45:55 F:C ratio. Cows were fed ad libitum twice daily as total mixed ration with free access to water. Dry matter intake (DMI) was not affected by fat supplementation regardless of fat source, whereas increased F:C ratio (from 34:66 to 45:55) lowered DMI by 7.5%. Meal interval, eating rate, and meal size were lower for cows fed yellow grease, and eating rate was less for cows fed the 45:55 F:C ratio diet. Chewing activity was not affected by fat supplementation, but was greater for cows fed the 45:55 F:C ratio diet. Results suggest that supplementation of 2% hydrogenated palm oil or 2% yellow grease had little effect on DMI and chewing behavior of Holstein dairy cows fed a 34:66 F:C ratio diet. The 2 fat sources can replace each other, depending on the availability or cost. Results also showed that DMI and chewing activity can be effectively manipulated by changing the F:C ratio of diet.

Key words: fat, forage:concentrate ratio, feed intake, chewing behavior

Supplementation of dietary fats is a common practice for increasing energy density in diets fed to high-producing dairy cows. Hydrogenated palm oil and yellow grease are readily available fat sources, but hydrogenated palm oil is more expensive than yellow grease. Yellow grease is higher in unsaturated fat and contains more linoleic acid than does hydrogenated palm oil

(Kargar, 2006). However, given the known activity of yellow grease in the rumen and the fact that it has a high ratio of unsaturated fatty acids, the need to examine use of different levels of forages in the diets in order to avoid milk fat depression and any other adverse effects seemed inevitable. Chewing activity varies with dietary fiber content (Beauchemin and Rode, 1997; Oba and Allen, 2000), particle size (Mooney and Allen, 1997), or forage to concentrate (F:C) ratio (Yang et al., 2001). Adding fat to dairy rations affects ruminal fiber digestion and passage rate, which could affect ruminal digesta pool size and chewing activity (Harvatine and Allen, 2005). Effect of fat sources on chewing behavior has not been extensively studied. Furthermore, supplementation with unsaturated fat may decrease intake through production of fatty acids that act as a physiological signal to decrease meal size or increase meal interval (Harvatine and Allen, 2006). Increased proportions of unsaturated fatty acids in supplemental fat increased hypophagic effects of fat (Jenkins and Jenny, 1989; Pantoja et al., 1994).

The objective of this study was to determine the effects of supplementing yellow grease or hydrogenated palm oil in a low F:C ratio diet as well as supplementing yellow grease in a high F:C ratio diet on DMI, meal pattern, and chewing activity of Holstein dairy cows.

Eight multiparous Holstein dairy cows (55 ± 9 DIM; mean ± SD) were randomly assigned in a replicated 4 × 4 Latin square design experiment with 21-d periods including 16 d of adaptation and 5 d of data collection. Cows were milked 3 times daily at 0330, 1300, and 2130 h and housed individually in box stalls (4 m × 3 m) with free access to water.

Diets were formulated with 1) no supplemental fat and 34:66 F:C ratio (control); 2) 2% hydrogenated palm oil and 34:66 F:C ratio (HPO); 3) 2% yellow grease and 34:66 F:C ratio (YG); and 4) 2% yellow grease and 45:55 F:C ratio (YGHF; Table 1). Alfalfa hay was the sole source of forage in all diets. The diets were mixed daily and offered to cows as TMR ad libitum twice daily at 0730 and 1300 h, with approximately 5 to 10%

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Table 1. Ingredients and chemical composition of experimental diets¹ on DM basis

Item	Control	HPO	YG	YGHF
Ingredient, % DM				
Alfalfa hay ²	34.87	34.29	34.29	45.82
Beet pulp	11.30	11.47	11.47	11.08
Whole cottonseed	8.66	8.78	8.78	8.48
Ground barley	19.01	18.20	18.20	12.30
Ground corn	10.41	8.81	8.81	5.47
Soybean meal	13.56	14.14	14.14	12.93
Hydrogenated palm oil	—	2.00	—	—
Yellow grease	—	—	2.00	2.00
Sodium bicarbonate	0.92	1.01	1.01	0.78
Vitamin-mineral mix ³	1.00	1.01	1.01	0.98
Calcium carbonate	0.20	0.20	0.20	0.20
Salt	0.08	0.08	0.08	0.08
Chemical composition				
DM, %	74.80	74.57	75.81	75.00
OM, % of DM	65.54	65.31	66.81	64.96
CP, % of DM	18.03	18.35	18.36	18.13
NDF, % of DM	31.56	31.80	31.53	34.67
ADF, % of DM	20.18	20.81	20.59	24.41
Forage NDF, % of DM	15.14	14.89	14.89	19.90
Ether extract, % of DM	4.15	6.15	6.00	5.47
NE _L , ⁴ Mcal/kg of DM	1.55	1.63	1.62	1.60

¹Control = no added fat and 34:66 forage:concentrate ratio; HPO = 2% hydrogenated palm oil and 34:66 forage:concentrate ratio; YG = 2% yellow grease and 34:66 forage:concentrate ratio; YGHF = 2% yellow grease and 45:55 forage:concentrate ratio.

²Alfalfa hay consisted of (DM basis) 95.2% DM, 85.0% OM, 14.2% CP, 43.4% NDF, 34.2% ADF, and 3.1% ether extract.

³Vitamin-mineral mix contained (DM basis) 250,000 IU/kg of vitamin A; 50,000 IU/kg of vitamin D₃; 1,500 IU/kg of vitamin E; 2.25 g/kg of Mn; 120 g/kg of Ca; 7.7 g/kg of Zn; 20 g/kg of P; 20.5 g/kg of Mg; 186 g/kg of Na; 1.25 g/kg of Fe; 3 g/kg of S; 1.25 g/kg of Cu; 14 mg/kg of Co; 56 mg/kg of I; and 10 mg/kg of Se.

⁴Calculated from NRC (2001).

of refusals. Diets were formulated to be isonitrogenous and to meet or exceed the NRC (2001) nutrient allowances.

Amount of TMR offered and refusals were monitored daily. Feed ingredients, TMR, and refusals were sampled daily during the data collection period and pooled within period. Samples were dried at 60°C in a forced-air oven for 48 h and ground through a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and DM content of pooled TMR, forage, and refusals was determined.

Forage and TMR samples were analyzed in triplicate for N using the Kjeldahl method (Kjeltec 1030 Auto Analyzer, Tecator, Höganäs, Sweden), ether extract (EE) and ash (AOAC, 2002), and NDF using heat stable α -amylase and sodium sulfite and ADF (Van Soest et al., 1991).

Eating and ruminating activities, measured in minutes, were monitored visually over a 24-h period. Activities were noted every 5 min, and each activity was assumed to persist for the entire 5-min interval between observations. To estimate time spent eating or ruminating per kilogram of DM, NDF, and forage NDF intakes, average intake within the experimental period was used. A period of rumination was defined as at

least 5 min of ruminating activity followed by at least 5 min without ruminating activity. Total chewing time was calculated as the sum of eating and ruminating time (Maekawa et al., 2002).

Data were analyzed using the MIXED procedure of SAS (SAS Institute, 2003). The model included the fixed effects of square, period, and treatment. Cow within square was the specified term for the repeated measures, whereas the best covariance structure was compound symmetry based on the smallest Bayesian criterion. Preplanned statistical contrasts were used to test the effect of fat supplementation (control vs. HPO + YG), the effect of source of fat supplement (HPO vs. YG), and the effect of F:C ratio within diets supplemented with yellow grease (YG vs. YGHF). Differences between treatments were declared significant at $P \leq 0.05$ and means were compared using the Tukey multiple comparison test.

Dry matter intake was influenced by neither fat supplementation nor source of fat, but was lower for cows fed the YGHF diet than for cows fed the YG diet (Table 2). Lowered DMI for cows fed the YGHF diet resulted from the increase of F:C ratio. Intakes of NDF and ADF were not different between control and HPO or YG diets, but intake of ADF decreased with

Table 2. Effects of dietary fat supplements and forage:concentrate ratio on intake of nutrients

Intake, kg/d	Treatment ¹ LSM					P-value ²		
	Control	HPO	YG	YGHF	SE	Fat	Fat source	Forage
DM	27.3	26.5	27.2	25.3	1.11	0.81	0.76	0.002
OM	24.7	24.0	24.7	22.7	1.00	0.53	0.19	<0.001
CP	4.9	4.9	5.0	4.6	0.20	0.84	0.25	<0.001
NDF	8.6	8.4	8.6	8.8	0.35	0.60	0.48	0.31
ADF	5.5	5.5	5.6	6.2	0.23	0.59	0.54	<0.001
Forage NDF	4.1	4.0	4.1	5.0	0.17	0.16	0.32	<0.001
Ether extract	1.1	1.6	1.6	1.4	0.06	<0.001	0.97	<0.001

¹Control = no added fat and 34:66 forage:concentrate ratio; HPO = 2% hydrogenated palm oil and 34:66 forage:concentrate ratio; YG = 2% yellow grease and 34:66 forage:concentrate ratio; YGHF = 2% yellow grease and 45:55 forage:concentrate ratio.

²Contrasts probability. Fat = effect of fat supplementation (control vs. HPO + YG); fat source = effect of source of fat supplementation (HPO vs. YG); forage = effect of forage:concentrate ratio (YG vs. YGHF).

the YG diet compared with YGHF diet. As expected, cows fed fat-supplemented diets had higher intake of EE, except for cows fed the YGHF diet, in which lower EE intake was attributed to reduced DMI and lower EE content in the YGHF diet. In agreement with Grummer (1988), Schauff and Clark (1989), and Eastridge and Firkins (1994), fat supplementation had no effect on DMI. Intake of NE_L (as estimated from NRC, 2001) tended to increase ($P = 0.10$) with fat supplementation. Results confirmed that supplemental fat increases energy density of diets and can enhance energy intake by dairy cattle (Palmquist and Jenkins, 1980; Coppock and Wilks, 1991).

Meal patterns, including number of bouts per day, meal length, and meal interval, were not affected by the treatments, except for the meal interval of cows fed the YG diet, which was 12 min shorter than that of the cows fed the HPO diet (Table 3). Supplementation of fat had no effect on eating rate and meal size (DMI divided by bouts/d), whereas cows fed the HPO diet had higher eating rate and meal size than cows fed the YG diet. In addition, eating rate was greater for cows fed the YGHF diet than for cows fed the YG or control diets, whereas meal size was not different. The increase of eating rate with the YGHF diet was attributed to increased F:C ratio rather than yellow grease supplementation because feeding the YG diet did not change the meal pattern. The lower eating rate of cows fed the YGHF diet agrees with the report by Beauchemin (1991) for cows fed diets containing alfalfa hay as forage source. Friggens et al. (1998) also observed that eating rate in cows fed a high F:C ratio (73:27) diet was lower than that of cows fed a low F:C ratio (41:59) diet, when ryegrass was the sole source of dietary forage. It was suggested that the differences in short-term feeding behavior of cows in eating rate may be related partly to differences in the physical properties of the diets. However, Harvatine and Allen (2006) suggested that

changes in meal size are normally attributed to satiety, whereas changes in meal frequency or meal interval are attributed to hunger situation. It is speculated that supplementing unsaturated fat during a meal would stimulate satiety and thus result in decreased meal size that was not compensated for by increased meal number. Our result that feeding the YG diet, containing more unsaturated fatty acids than the HPO diet, reduced eating rate and meal size likely agrees with the above suggestion. The discrepancy of the effects on meal interval between the control and YG diets or between the control and HPO diets is not clear because the cows were fed high-quality feeds and the feeds were available at all times. Additionally, although meal size decreased in cows fed the YG diet, shorter meal intervals likely compensated such that DMI was not affected. No differences in rumination patterns were observed among treatments. Results indicate that fat supplementation or F:C ratio had minimal effects on rumination pattern under current feeding situations.

Time spent for eating and ruminating, expressed as either minutes per day or minutes per unit of DMI or NDF intake, was not affected with fat supplementation (Table 4). Consequently, total chewing time (eating + ruminating) was not different between the control and HPO diets or the control and YG diets. The results are consistent with the report of Harvatine and Allen (2006) that supplementation of fat did not affect eating time and number of meals. In contrast, Harvatine and Allen (2005, 2006) observed that saturated fat supplementation increased ruminating and total chewing time. The changes in rumination time may be related to differences in feed intake, digestibility, or stimulation by gut peptides (Harvatine and Allen, 2006). In our study, DMI was not affected by fat supplementation and the formulation of the control, HPO, and YG diets was similar except for the fat supplementation; thus, no effective stimulation of rumination was expected.

Table 3. Effects of dietary fat supplements and forage:concentrate ratio on meal patterns

Item	Treatment ¹ LSM				SE	P-value ²		
	Control	HPO	YG	YGHF		Fat	Fat source	Forage
Meals								
Bouts/d	15	14	16	15	0.9	0.76	0.26	0.41
Length, min/meal	25	25	25	29	1.8	0.91	0.83	0.15
Interval, min	72	81	69	75	4.8	0.60	0.04	0.29
Eating rate, kg of DM/min	0.074	0.079	0.074	0.064	0.004	0.29	0.03	<0.001
Meal size, kg of DM	1.90	1.97	1.76	1.84	0.12	0.55	0.001	0.23
Rumination								
Bouts/d	16	17	16	15	1.1	0.73	0.84	0.38
Length, min/meal	27	26	27	31	2.7	0.90	0.92	0.13
Interval, min	67	62	67	75	7.1	0.71	0.55	0.36
Chews/bolus	69	66	65	67	3.0	0.15	0.69	0.54

¹Control = no added fat and 34:66 forage:concentrate ratio; HPO = 2% hydrogenated palm oil and 34:66 forage:concentrate ratio; YG = 2% yellow grease and 34:66 forage:concentrate ratio; YGHF = 2% yellow grease and 45:55 forage:concentrate ratio.

²Contrasts probability. Fat = effect of fat supplementation (control vs. HPO + YG); fat source = effect of source of fat supplementation (HPO vs. YG); forage = effect of forage:concentrate ratio (YG vs. YGHF).

Total chewing time (min/d) of cows fed the YGHF diet was not different from that of cows fed either the control or YG diets (Table 4). In contrast, chewing index was higher when it was expressed as minutes per kilogram of DMI, but it was lower when it was expressed as minutes per kilogram of forage NDF intake for the YGHF diet than for the other diets. The increase of chewing index (min/kg of DMI) with the YGHF diet was mainly attributed to increase of eating time (min/kg of DMI) rather than rumination time. In contrast, lowered chewing time (min/kg of forage NDF intake) resulted from both eating and ruminating times. Fur-

thermore, change of chewing index with the YGHF diet was likely attributable to increase of forage proportion rather than yellow grease supplementation because cows fed the YG or control diets had no difference in chewing activity. Conversely, Onetti et al. (2004) suggested that cows fed supplemental tallow spent more time ruminating as intakes of DM and NDF decreased compared with cows fed the same diet without tallow. In our study, the interaction between fat supplementation and dietary F:C ratio was not determined.

Our result is consistent with the report of Woodford et al. (1986) that time spent eating by dairy cows gen-

Table 4. Effects of dietary fat supplements and forage:concentrate ratio on chewing activity

Item	Treatment ¹ LSM				SE	P-value ²		
	Control	HPO	YG	YGHF		Fat	Fat source	Forage
Eating time								
min/d	373	349	376	406	18.0	0.54	0.16	0.12
min/bout	25	25	24	29	1.7	0.85	0.69	0.09
min/kg of DMI	13.9	13.4	14.1	16.5	0.9	0.80	0.39	0.01
min/kg of NDF intake	44.4	42.0	43.5	47.7	2.7	0.43	0.55	0.10
min/kg of forage NDF intake	92.0	89.8	94.9	83.0	5.9	0.94	0.33	0.03
Ruminating time								
min/d	417	432	423	434	26.7	0.68	0.76	0.72
min/bout	28	31	27	31	2.0	0.64	0.11	0.17
min/kg of DMI	15.7	16.6	15.7	17.6	0.95	0.66	0.45	0.13
min/kg of NDF intake	50.0	51.9	50.0	50.6	3.08	0.78	0.64	0.88
min/kg of forage NDF intake	103.5	111.1	105.2	87.7	6.09	0.46	0.42	0.02
Total chewing time								
min/d	789	781	799	841	35.9	0.96	0.63	0.27
min/bout	53	57	51	59	3.3	0.86	0.25	0.09
min/kg of DMI	29.6	29.9	29.8	34.0	1.6	0.85	0.93	0.01
min/kg of NDF intake	94.4	93.9	93.5	98.3	4.8	0.86	0.93	0.35
min/kg of forage NDF intake	195.5	200.9	200.1	170.7	10.0	0.54	0.93	0.005

¹Control = no added fat and 34:66 forage:concentrate ratio; HPO = 2% hydrogenated palm oil and 34:66 forage:concentrate ratio; YG = 2% yellow grease and 34:66 forage:concentrate ratio; YGHF = 2% yellow grease and 45:55 forage:concentrate ratio.

²Contrasts probability. Fat = effect of fat supplementation (control vs. HPO + YG); fat source = effect of source of fat supplementation (HPO vs. YG); forage = effect of forage:concentrate ratio (YG vs. YGHF).

erally increased with increasing intake of forage fiber. Although DMI was lower for the high F:C ratio (45:55) diet compared with low F:C ratio (34:66) diets, cows fed the high F:C ratio diet spent more time eating, indicating that chewing activity might be determined largely by F:C ratio of the diet. As suggested by Oba and Allen (2000), it is concluded that although it is widely agreed that the physical form of ration influences chewing activity of dairy cows, metabolic mechanisms to regulate chewing activity have not been identified exactly.

In conclusion, addition of hydrogenated palm oil or yellow grease increased energy density of dairy cow diets and tended to increase intake of NE_L but did not affect intake of nutrients. Supplementation of hydrogenated palm oil or yellow grease had minimal effects on meal patterns and chewing activity of Holstein dairy cows under current feeding conditions. The 2 fat sources can replace each other, depending on availability or cost. Cows fed the YGHF diet had lower feed intake and higher chewing index (min/kg of DMI) but lower chewing time per kilogram of forage NDF intake. Results indicate that change of F:C ratio can be an effective way to manipulate DMI and chewing activity, whereas further study is warranted to determine whether yellow grease and F:C ratio have interaction.

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