SHORT COMMUNICATION

The effect of feeding soybean oil to mid-lactation dairy cows on milk production and composition and on diet digestion

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Veira, D. M., Charmley, L. L., Charmley, E. and Lee, A. J. 2001. **The effect of feeding soybean oil to mid-lactation dairy cows on milk production and composition and on diet digestion.** Can. J. Anim. Sci. **81**: 425–428. Mid-lactation Holstein cows were used to test the effect of feeding 3% soybean oil (SBO) on total mixed ration intake, apparent digestibility, milk production, and milk composition. Effect of SBO on rate and extent of rumen digestion was determined with nylon bags incubated in the rumen of fistulated cows. SBO reduced fibre digestion by 9% and degradability by 20%. Feeding of SBO caused a slight reduction in total mixed ration (TMR) intake, milk production, and milk protein production. However, these reductions were minor compared with the large reduction in fat production (0.2 kg d^{-1}).

Key words: Milk composition, soybean oil, digestibility, dairy cow.

Veira, D. M., Charmley, L. L., Charmley, E. et Lee, A. J. 2001. **Incidence de l'huile de soja sur la production et la composition du lait et sur la digestion des aliments chez les vaches laitières en milieu de lactation**. Can. J. Anim. Sci. **81**: 425–428. Les auteurs ont recouru à des vaches Holstein parvenues au milieu de la lactation pour vérifier les effets d'un supplément de 3 % d'huile de soja (HS) sur la prise alimentaire de la ration totale, la digestibilité apparente, la production laitière et la composition du lait. On a déterminé l'incidence de la HS sur la rapidité et l'importance de la digestion dans le rumen au moyen de sacs de nylon incubés dans le rumen de vaches fistulées. La HS diminue la digestion des fibres de 9 % et leur dégradabilité de 20 %. L'addition de HS entraîne une faible réduction de la prise alimentaire de la ration totale, de la production de lait et de la quantité de protéines dans le lait. Néanmoins, ces baisses sont mineures comparativement à celle de la quantité de lipides produits (0,2 kg par jour).

Mots clés: Composition du lait, huile de soja, digestibilité, vache laitière

Human health concerns have created interest in reducing the fat concentration of milk. There are nutritional strategies that can be used to reduce milk fat concentration. However, when these involve increasing dietary concentrate intake or reducing forage particle size, the health of the cow is often compromized (Griinari et al. 1998). The "low milk fat syndrome" is usually taken to be indicative of acidotic conditions in the rumen and can eventually lead to off-feed, laminitis and other health problems. Another nutritional manipulation that can reduce milk fat concentration is the feeding of unsaturated fats (Palmquist and Jenkins 1980). However, this strategy can also result in reduced milk protein concentration (Palmquist and Jenkins 1980) and milk volume (Eastridge et al. 1988). As protein has become the most valuable component of milk, methods that reduce its production are undesirable.

Most of the previous experiments in which unsaturated fats were fed to lactating cows involved animals in early lactation (Eastridge et al. 1988). During this phase, cows are often in negative energy and N balance due to low dry matter (DM) intake and high milk production. Moreover, milk protein concentration is low relative to that in mid- and late-lactation phases (Palmquist and Jenkins 1980). We hypothesized that during early lactation, supplementary unsaturated fat would impair rumen microbial protein synthesis and lead to further reductions in milk protein concentration and production. However, if supplementary fat was fed in mid- to late-lactation, when protein nutrition of the cow is less critical, then its effects on milk protein would be minimal. In this experiment we tested this hypothesis by feeding SBO to cows that had been lactating for at least 20 wk.

Thirty multiparous mid-lactation Holstein cows were used. The 18-wk production trial was divided into three

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Abbreviations: **ADF**, acid detergent fibre; **DM,** dry matter; **NDF,** neutral detergent fibre; **SBO,** soybean oil; **TMR,** total mixed ration

Table 1. Chemical composition and apparent digestibility of the total mixed ration fed with or without soybean oil and degradability of alfalfa suspended in the rumen of dairy cows fed the two treatments

	No soybean oil	3% soybean oil	SEM	*P* value
Total mixed ration composition				
Dry matter (g kg^{-1})	458	464	–	–
Crude protein (g kg^{-1} DM)	147	146	–	–
Acid detergent fibre (g kg^{-1} DM)	197	193	–	–
Ether extract (g kg^{-1} DM)	39.6	71.2	–	–
Ruminal degradability of DM				
Instantly degradable (a, %)	19.6	20.9	0.88	NS
Potentially degradable (a + b, %)	52.3	47.2	0.92	<0.001
Effective degradability at 5% outflow (%)	37.8	35.5	0.46	<0.05
Degradation rate (k)	0.062	0.061	0.012	NS
Ruminal degradability of neutral detergent fibre				
Instantly degradable (a, %)	10.5	12.3	0.87	NS
Potentially degradable (a + b, %)	44.3	36.6	1.10	<0.001
Effective degradability at 5% outflow (%)	26.4	23.8	0.49	<0.05
Degredation rate (k)	0.043	0.042	0.0058	NS
Apparent digestibility (%)				
Dry matter	67.6	63.9	1.04	0.07
Organic matter	68.9	65.0	1.07	0.07
Acid detergent fibre	52.8	43.6	2.01	0.04
Crude protein	62.7	61.4	1.37	0.42

periods of 4 (pre-supplementation), 10 (supplementation) and 4 wk (post-supplementation), respectively. The data from the supplementation period were divided into 5-wk periods (Treatment periods 1 and 2) for reporting purposes (Table 2). All cows were fed a TMR consisting of (DM basis) corn silage (27.5 %), alfalfa silage (27.5%) and a concentrate (45%). Half the cows were randomly assigned to a control concentrate, which they received throughout the trial. The composition (on a g kg^{-1} as-fed basis) of the control concentrate was as follows: ground corn (402), ground barley (215), cracked, roasted soybeans (200), soybean meal (100), monocalcium phosphate (15), Dynamate (5), limestone (24.5), potassium chloride (3.5), urea (3.0), cobalt iodized salt (17), magnesium oxide (5), and mineral and vitamin premix (10). The remainder of the cows received the control concentrate during the pre-SBO and post-SBO periods, but were fed the control concentrate supplemented with 74.5 g kg^{-1} soybean oil (SBO) during the supplementation periods. This resulted in SBO being fed at a level of 30 g kg^{-1} DM of TMR. The concentrate portion of the diet was mixed in 1-t batches during the experiment and mixed daily with the forage portion to make the TMR, which was fed twice daily to appetite. Feed intake and milk production were measured daily, and milk composition was determined on four consecutive milkings per week. Cows were milked twice per day at 0600 and 1600 h and weighed at the beginning and end of each period. The concentration of fat, lactose and protein in milk was determined by automated infrared analysis (Biggs 1967). Daily samples of the TMR were collected and pooled over 2-wk periods, mixed and sub-sampled for subsequent analysis. Dry matter of the TMR was determined by oven drying at 60°C until constant weight. The dried sample was ground through a 1-mm screen prior to subsequent analysis for acid detergent fibre (ADF) (Goering and Van Soest 1970), ether extract [method no. 920.39, Association of Official Analytical Chemists (AOAC)1990] and ash by combustion at 550°C. Crude protein was determined on undried samples of the TMR (method no. 984.13, AOAC 1990). The chemical composition of the diets fed is shown in Table 1.

In order to determine the effect of SBO supplementation on apparent digestibility, four mid-lactation cows not being used in the main trial were used in a cross-over design trial comprising two periods of 3 wk each. The amount of feed offered during the last 8 d of each period was restricted to 90% of that consumed in the previous week to ensure complete consumption. Total faecal output was collected during the last 5 d of each period. An additional four dry, pregnant rumen fistulated cows were used to measure in situ rumen digestion. Two cows were fed the control diet and the other two the SBO-containing diet. The cows were fed their respective diets for 14 d prior to incubation of bags. Duplicate polyester bags (10 cm by 5 cm, pore size 54 µm) containing approximately 5 g ground (2 mm screen) alfalfa hay were incubated in the rumen of each cow for 0.1, 2, 5, 8, 16, 24, 48 and 168 h. On removal from the rumen, the bags were rinsed in cold running water for 10 min, then dried at 60°C before their contents were analyzed for neutral detergent fibre (NDF) (Goering and Van Soest 1970). Rate and extent of disappearance of DM and NDF were calculated according to procedures of Ørskov and McDonald (1979). Significance of parameters was assessed as described by Charmley et al. (1999).

Differences between treatments were tested for statistical significance by analysis of variance. The statistical model included fixed effects of treatment, period, and their inter-

Table 2. Effect of feeding soybean oil on dry matter intake, yield of milk and components and milk composition

	Pre-treatment	Treatment period 1		Treatment period 2		Post-treatment			Probability values		
	No SBO	No SBO	3% SBO	No SBO	3% SBO	No SBO	3% SBO	SEM	Treatment period 1	Treatment period 2	Post-treatment
Time on feed (wk)	4	5	5	5	5	4	4				
DM intake (kg d^{-1})	20.3	19.2	18.4	19.1	18	19.6	18.9	0.18	0.01	0.01	0.05
Yield (kg d^{-1})											
Milk	30.3	27.5	27.6	26.2	25	26.2	25.7	0.32	NS	0.01	NS
Fat	0.95	0.88	0.71	0.83	0.6	0.84	0.78	0.01	0.01	0.01	0.01
Protein	0.94	0.87	0.84	0.84	0.8	0.85	0.84	0.01	NS	0.01	NS
Lactose	1.49	1.33	1.33	1.27	1.2	1.27	1.25	0.02	NS	0.01	NS
Milk composition (%)											
Fat	3.15	3.24	2.6	3.22	2.44	3.24	3.07	0.05	0.01	0.01	0.05
Protein	3.08	3.19	3.08	3.18	3.22	3.26	3.25	0.02	0.01	NS	NS
Lactose	4.92	4.85	4.82	4.86	4.81	4.83	4.85	0.01	NS	0.05	NS

action. Where the interaction was significant, treatment by period least squares means were compared using *t*-tests. Differences reported in the text are significant ($P < 0.05$) unless otherwise stated. The work described was conducted in accordance with the guidelines laid down by the Canadian Council on Animal Care.

The addition of SBO to the TMR increased dietary fat concentration by 3.2 percentage units (Table 1). Crude protein and ADF concentrations were similar for each diet. Ruminal DM and NDF degradability of alfalfa hay were reduced by over 20% when SBO was added to the ration (Table 1). A similar, although smaller, response was seen for effective DM and NDF degradability (Table 1). Including SBO in the diet tended to reduce apparent total tract digestibility of DM and organic matter ($P < 0.10$), while apparent digestibility of ADF was reduced by over 9 percentage units from 52.8 to 43.6% (Table 1). The effects of unsaturated fats and oils on fibre digestion in the rumen have been well documented (Palmquist and Jenkins 1980). The negative effects on ADF and hence organic matter digestibility observed here are consistent with the reduced fibrolytic activity in the rumen following introduction of unsaturated fat to the diet. Over the 18 wk of study, milk production for cows on both treatments declined from approximately 30 kg milk d^{-1} to 26 kg d^{-1}. Milk composition in control cows remained unchanged over this time (Table 2).

There was no effect of treatment on body weight change of cows. All cows gained 5 kg over the 18-wk study. During the feeding of SBO, there was a small reduction in DM intake of about 5%, which was consistent with results of other studies where free oil was fed (Bateman and Jenkins 1998). Weekly feed consumption data showed that this reduced intake took about 2 wk to stabilize at the lower level. The reverse occurred when SBO was removed from the ration; it took about the same time for intake to stabilize at the pre-treatment level. This intake-depressing effect was likely due to the reduction in NDF digestibility. Supplementation with SBO had no effect on milk production during supplementation period 1, but reduced production by 4% during supplementation period 2. Differences between treatments in protein and lactose production and concentration were largely confined to supplementation period 2, except for protein concentration, which was reduced during supplementation period 1 alone (Table 2). In contrast, fat production and concentration were reduced during both supplementation periods and during the post-supplementation period. Thus, yield of fat was reduced by 0.20 kg d^{-1} during supplementation, equivalent to a 23% reduction.

This study used free SBO, whereas most other research in North America has concentrated on the feeding of soybean oil associated with the bean. When beans are fed, a large proportion of the oil remains unavailable in the rumen. Consequently, effects on rumen fermentation and metabolism are minimized. The influence of soybeans on production of milk and milk fat is usually positive in response to the increased energy intake (Charmley and Nicholson 1994). A proportion of the oil escapes biohydrogenation and is absorbed as unsaturated fatty acids and ultimately incorporated into milk fat (Charmley and Nicholson 1994).

When free oil is fed, reduced cellulolytic activity in the rumen is pronounced, as seen in this and other studies (Bateman and Jenkins 1998). Changes in the non-glucogenic ratio of VFA will depress acetate production and de novo synthesis of short chain fatty acids in the mammary gland (Griinari et al. 1998). Griinari et al. (1998) have also shown that when unsaturated oils are fed, direct inhibition of milk fat synthesis can result from the production of partially hydrogenated fatty acids, specifically *trans*-octadecenoic acids. Additivity of these two mechanisms can result in marked milk fat depression. We speculate that these conditions were in effect in the current experiment.

The fact that minimal reduction in milk protein concentration was observed was attributed, in part, to the absence of a diluting effect, which can arise when milk production is increased. It would appear that, although there were major effects on ruminal carbohydrate fermentation, any negative influence on microbial protein synthesis in the rumen was too small to influence metabolizable protein supply and hence milk protein production. The results show that although milk protein yield was affected, the influence was quite small, amounting to a 4% reduction. Previous research has shown that in cows in early lactation, SBO markedly reduces milk protein concentration and yield (Doherty and Mayne 1996). Clearly, this is undesirable, because protein is the most valuable milk component. Cows in mid- to late-lactation are generally not in negative protein balance; thus any negative influence on microbial protein synthesis in the rumen is likely to have less impact on milk protein than it might in an early lactation cow.

Research in the United Kingdom has shown that SBO fed over 3- to 4-wk periods reduces milk fat yield (Banks et al. 1980; Steele 1985; Doherty and Mayne 1996). This study confirmed that this effect is not transient; milk fat yield was reduced for as long as SBO was fed. Thus, the feeding of free SBO is a highly effective method of producing lower-fat milk. If SBO is to be recommended as a dietary ingredient to reduce milk fat, any effects on intake and, hence, milk production have to be minimized. In our study, the effects were relatively small. It is possible that a lower rate of SBO feeding would have further reduced these effects.

In conclusion, the feeding of free SBO can dramatically reduce fat concentration and production in milk of mid- to late-lactation cows. The effect appears to persist for as long as the oil is fed. However, there are also negative effects on diet digestibility and degradability that contributed to a modest reduction in DM intake and total milk production.

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Association of Official Analytical Chemists. 1990. Official methods of analysis. 15th ed. AOAC, Washington, DC.

Banks, W., Clapperton, J. L., Kelly, M. E., Wilson, A. G. and Crawford, R. J. M. 1980. The yield, fatty acid composition and physical properties of milk fat obtained by feeding soya oil to dairy cows. J. Sci. Food Agric. **31**: 368–374.

Bateman, H. G. and Jenkins, T. C. 1998. Influence of soybean oil in high fibre diets fed to non-lactating cows on ruminal unsaturated fatty acids and nutrient digestibility. J. Dairy Sci. **81**: 2451–2458.

Biggs, D. A. 1967. Milk analysis with the infra-red milk analyzer. J. Dairy Sci. **50**: 799–803.

Charmley, E. and Nicholson, J. W. G. 1994. Influence of dietary fat source on oxidative stability and fatty acid composition of milk from cows receiving a low or high level of dietary vitamin E. Can. J. Anim. Sci. **74**: 657–664.

Charmley, E., Savoie, P., McRae, K. B. and Lu, X. 1999. Effect of maceration at mowing on silage conservation, voluntary intake, digestibility and growth rate of steers fed precision chopped or round bale silages. Can. J. Anim. Sci. **79**: 195–202.

Doherty, J. G. and Mayne, C. S. 1996. The effect of concentrate type and supplementary lactic acid or soya oil on milk production characteristics in dairy cows offered grass silages of contrasting fermentation type. Anim. Sci. **62**: 187–198.

Eastridge, M. L., Cunningham, M. D. and Patterson, J. A. 1988. Effect of dietary energy source and concentration on performance of dairy cows during early lactation. J. Dairy Sci. **71**: 2959–2966.

Goering, H. K. and Van Soest, P. J. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications.) ARS, USDA, Washington, DC. Agricultural Handbook No. 379.

Griinari, J. M., Dwyer, D. A., McGuire, M. A., Bauman, D. E., Palmquist, D. L. and Nurmela, K. V. V. 1998. *Trans*-octadecenoic acids and milk fat depression in lactating dairy cows. J. Dairy Sci. **81**: 1251–1261.

Ørskov, E. R. and McDonald, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. (Camb.) **92**: 499–503.

Palmquist, D. L. and Jenkins, T. C. 1980. Fat in lactation rations: Review. J. Dairy Sci. **63**: 1–14.

Steele, W. 1985. High-oil, high-protein diets and milk secretion by cows. J. Dairy Sci. **68**: 1409–1415.