Effects of Different Forms of Canola Oil Fatty Acids Plus Canola Meal on Milk Composition and Physical Properties of Butter

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ABSTRACT

Twenty multiparous Holstein cows were used in a 16-wk trial. A block of 10 cows received a control diet, based on corn silage, and the other block of 10 cows successively received four diets with 1) an extruded blend of canola meal and canola seeds, 2) canola meal and whole canola seeds, 3) canola meal and ground canola seeds, or 4) canola meal and calcium salts of canola oil fatty acids. Canola fat represented about 2% of dietary dry matter. Compared to control cows, treated cows had similar dry matter intake, milk production, and daily milk output of true protein or fat. Protein contents of milk was decreased by all treatments, with a lower effect of extruded or whole canola seeds. Milk fat contents was lowered by all treatments, extruded seeds and calcium salts resulting in most important effects. All treatments lowered the percentage of fatty acids with 12 to 16 carbons in milk fat, increased $C_{18:0}$ and *cis*-$C_{18:1}$ percentages, and the proportion of liquid fat in butter between 0 and 12°C. Calcium salts and, to a lesser extent extruded seeds, resulted in most important improvements of milk fatty acid profile and butter softness, whereas whole seeds had low effects.
(**Key words:** canola fatty acids, milk fatty acids, butter, dairy cows)

Abbreviation key: C = control; **CaS** = calcium salts, **CaSCFA** = calcium salts of canola fatty acids, **CS** = canola seeds, **ECS** = extruded canola seeds, **FA** = fatty acids, **GCS** = ground canola seeds, **RBH** = ruminal biohydrogenation, **WCS** = whole canola seeds.

INTRODUCTION

Dietary sources of lipids can be added to the diet of lactating dairy cows to increase energy intake, or to modify milk production, milk fat content and milk fatty acids (**FA**) profile. Increase of *cis*-$C_{18:1}$ to $C_{16:0}$ ratio is favorable for human health concerns regarding hypercholesterolemia (19), and improves the melting characteristics of butter (32). This increased ratio can be obtained by addition into the diet of vegetable fats (18).

Lipids from canola seeds (**CS**) have potentially interesting characteristics to achieve these modifications, because they contain only about 6% $C_{16:0}$ and as high as 58% *cis*-$C_{18:1}$, which is a much higher *cis*-$C_{18:1}$ to $C_{16:0}$ ratio than other common oilseeds (20). Moreover, the addition of 1 to 2 kg of full fat CS to the diets of lactating cows does not produce detrimental digestive effects (30). The effects of CS lipids on milk composition have already been tested with different forms: free oil (5, 22), whole raw CS (5, 23), chemically treated whole CS (1, 3), ground or crushed CS (1, 21, 23, 28), and calcium salts (**CaS**) of FA from CS (11, 17). Levels of dietary incorporation ranged from 3 to 17% for CS, and from 2 to 6% for oil of CaS. On the contrary, the effect of extrusion of CS on milk composition has only been studied in goats (8), and few experiments have been drawn on effects of FA from CS on physical characteristics of butter (12, 17, 29).

The objective of this experiment was to compare the effects of four different forms of dietary FA from CS (whole, ground, extruded and CaS) at a low level of incorporation, on milk production, milk composition and rheological properties of butter.

MATERIALS AND METHODS

Cows, Diets, and Management

Twenty multiparous lactating Holstein cows were grouped into two blocks of 10 cows. Each block contained five second-lactation and five third- (or more) lactation cows. Cows had gone beyond the second month of lactation so that they did not to mobilize body reserves of lipids, which could interfere with dietary FA. Each block was matched for parity, milk production and composition, and BW. At the beginning of the trial, cows in the control block averaged 40.9 ± 6.1 kg/d of milk, 3.66 ± 0.42% of milk fat, 3.08 ± 0.15% of milk true

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Table 1. Ingredient and nutrient composition of diets[1] (DM basis).

	Control	ECS	WCS	GCS	CaSCFA
Ingredient, g/kg					
Corn silage	719	684	689	697	702
Alfalfa hay	47	46	46	44	43
Wheat	41	41	40	39	38
Concentrate,[2] 47% CP	88	...	...	...	...
Extruded blend	...	85	...	...	...
Canola meal	...	...	42	41	60
Canola seeds	...	...	42	41	...
Calcium soaps of canola oil fatty acids	...	...	...	...	22
Soybean meal	...	39	38	37	36
Concentrate,[2] 21% CP	88	88	86	84	82
Mineral-vitamin mix[3]	17	17	17	17	17
Nutrient analysis, g/kg					
CP	146	138	138	137	134
NDF	399	408	411	412	393
Crude fiber	189	190	189	190	186
Total fatty acids	18	37	37	36	36
Fatty acids, g/kg of total fatty acids					
$C_{16:0}$	150	95	90	90	132
$C_{18:0}$	27	19	19	19	28
cis-$C_{18:1}$	175	354	371	368	340
$C_{18:2}$	429	316	317	318	310
$C_{18:3}$	69	88	86	85	57

[1]ECS = Extruded blend of canola meal and canola seeds, WCS = canola meal and whole canola seeds, GCS = canola meal and ground canola seeds, and CaSCFA = canola meal and Ca salts of canola fatty acids.

[2]Commercial supplement (F-82000, RAGT Sanders, Albi, France).

[3]Contains 5% P, 14% Ca, 6% Na, 4 g of Zn/kg, 3.2 g of Mn/kg, 3 g of Fe/kg, 0.8 g of Cu/kg, 250,800 UI of vitamin A/kg, 62,700 UI of vitamin D_3/kg, and 112 UI of vitamin E/kg.

protein, and 656 ± 72 kg of BW. Cows in the treated block averaged 40.5 ± 4.6 kg/d of milk, 3.66 ± 0.30% of milk fat, 3.05 ± 0.14% of milk true protein and 663 ± 48 kg of BW. Cows were placed in open pens (one pen for each block) and had free access to water. They were kept under similar conditions of space, roof area and shade. The experimental trial was 16 wk long.

Control cows were fed a basal diet (**C**) containing forages (ad libitum corn silage and 1.5 kg of alfalfa hay), wheat meal, and a soybean meal-based protein concentrate (Sandimaïs, RAGT Sanders, Albi, France) throughout the 16-wk experimental trial (Table 1). The treated cows successively received one of four experimental diets in which an experimental concentrate had been substituted for the protein concentrate of the control diet. The first month, they were fed a blend of canola meal and CS extruded (**ECS**) at 130°C exit temperature (Extruder Clextral, BC 45, Firminy, France), the second, canola meal plus whole CS (**WCS**), the third, canola meal plus ground CS (**GCS**) and the fourth, canola meal plus CaS of canola FA (**CaSCFA**, Volac Ltd., Orwell, SG85QX, Royston, UK). An additional supply of soybean meal was given (1.1 kg per cow per day) to provide amount of CP closest to the C diet. The diets also contained 1% (DM basis) mineral-vitamin mix. These basal diets were formulated to meet the requirements for energy (31) and for protein, using the French protein digested in the intestine system (38) of mature cows producing 25 kg d^{-1} of milk. For higher production, each cow additionally received 1 kg of concentrate (Sandiplus, RAGT Sanders, Albi, France) per 2.5 kg of milk over that allowed with the basal diet. Forages and orts were weighed every morning before a.m. feeding, to determine daily forage intake of each block. Concentrates were distributed in five equal meals per day via a free access computerized feed allocation system and individual intakes were recorded daily. Feed samples were collected weekly throughout the experiment, dried in a forced-air oven at 60°C, ground through a 1-mm screen using a hammer mill and stored until further analysis in 100-ml plastic bottles. The calculated chemical composition of each diet is presented in Table 1.

Cows were milked twice daily at 0600 and 1700 h. Milk production was recorded electronically at each milking. Total milk from each individual control and experimental cow was collected at the last week of each experimental period. Samples were taken for subsequent analysis of milk fat and true protein. Cream was separated from the rest of milk using a centrifugal separator (Elecrem model 147 077, F-44270 Machecoul, France) and stored overnight (12 h) at 4°C prior to butter manufacture. The following day, the cream was left at ambiant temperature (18°C) until 12°C and churned into butter in a laboratory drum churn (Menager Elba model 10, F-50100, Cherbourg, France). Butter milk was washed from the butter with cold water (10°C) and excess moisture was removed by draining and working the butter by hand manipulations during 10 min. Butter was stored at 4°C for 48 h. Subsequently, it was packed in a plstic container and frozen at –20°C until analysis.

Analyses

Feed and orts were analyzed for DM (105°C; 24 h), and CP in feeds was determined according to the AOAC (4). Fiber was estimated by the procedure described by Van Soest et al. (37). Milk fat and true protein contents were determined by infrared analysis (Milkoscan 605, Foss Electric, F-75001, Paris). Fatty acids contents and FA profile were determined in feeds and milk by GLC as previously described (17). Thermal analysis of the butter samples was performed using a differential scanning calorimeter (Perkin-Elmer model DSC 1: Norwalk, CT). The samples were held for 5 min at 70°C; the temperature was then reduced until –60°C at a rate of 5°C/min. After 2 min at this temperature, the thermogram was recorded by heating at a rate of 5°C/min up to 60°C. The proportion of liquid fat was determined via integration of the curve, assuming identical enthalpies of fusion for all triglycerides.

Statistical Analysis

Validity of the differences was analyzed by the general linear model of SYSTAT (Version 5.03 for Windows, SYSTAT Inc., Evanston, IL). Statistical significance was declared at $P < 0.05$ for all comparisons.

All data were analyzed via Student's *t* test. A first series of analysis compared, within each period, values of cows from the treated block and the control block. A second series of analysis compared, between periods, the different treatments.

The variances for these analysis were estimated using the model

$$Y_{ijk} = \mu + B_i + P_j + (B \times P)_{ij} + C_k(B_i) + e_{ijk}$$

where Y_{ijk} is the dependent variable, μ is overall experiment mean, B_i is mean effect of block, P_j is mean effect of period, $(B \times P)_{ij}$ is mean effect of interaction between block and period, C_k (B_i) is mean effect of cow nested within block effect, and e_{ijk} is random residual. Because treatment effect was partly confounded with block and period effects, this model was only used for the estimation of variances within cows (MSE of e_{ijk}), and between cows, calculated as (39):

$$(\text{MSE of } C_k(B_i) - \text{MSE of } e_{ijk})/\text{number of periods} + \text{MSE of } e_{ijk}$$

Differences between control and treated cows within each period, excepted for data relative to milk production and composition, were analyzed by the variance between cows. Differences of milk production and milk composition between control and treated cows within each period were calculated as

$$(T_i - C_i) - (T_0 - C_0)$$

where T_0 and C_0 represent mean values for the two blocks of cows before the beginning of the experiment. These differences were analyzed by variance within cows.

Differences between treatments in different periods were calculated as:

$$(T_i - C_i) - (T_j - C_j)$$

where T_i and T_j represent mean values for treated cows during periods i and j, and C_i and C_j represent mean values for control cows during the same periods. These differences were analyzed by variance within cows.

Feed consumption values were not individual values, but values relative to each block. For Student's *t* test, we used mean values calculated from the last 5 d of each period, and variance was estimated with the model

$$Y_{ij} = \mu + B_i + P_j + (B \times P)_{ij} + e_{ij}$$

RESULTS AND DISCUSSION

Intake

Intake of forages and total DM were not significantly affected by treatments (Table 2). These results were consistent with previous observations with whole CS (5) or crushed CS (1). Intake of forage tended to decrease during the last two periods ($P = 0.25$), which can be explained by the higher level of concentrate in the treatment diets. A lower DMI could have been due to the potential negative effect of feeding supplemental fat on ruminal digestion. Such an effect can be expected to be most important with oils or ground seeds because of direct contact between lipids and ruminal microorganisms, and to be very low with CaS of canola FA, which do not affect ruminal digestion (17). This potential negative effect can also depend on the amount of added fat and affect ruminal digestion and DMI differently (30). In our experiment, the lack of effect of diet on forage or total DM intakes, even with unprotected forms, can be explained by the low amount of lipids in the total diet.

Milk Yield and Milk Composition

Milk yield was not different between control and treated cows (Table 2), as previously observed (1, 5). Diets ECS and GCS resulted in significantly higher values than WCS diet. The hull of CS is very lignified, and is resistant to degradation in both the rumen and the small intestine (24) so that many whole seeds were not digested and were lost in the feces of cows receiving WCS diet. This incomplete digestion possibly resulted in a low energy intake which affected milk production.

The concentration of milk protein was decreased with all treatments, with GCS and CaSCFA resulting in lower values than ECS and WCS diets. However, because of the trend toward increased milk yield, daily production of milk protein was not different between control and treated cows. Diets WCS and CaSCFA resulted in low daily milk protein output compared to ECS diet. A decreased milk protein content has been observed in most previous experiments with added fat. Addition of fat via oilseeds usually results in a relative reduction of milk protein content lower than 5% (41), but a relative decrease by 10% has already been reported with 5.5% (DM basis) ground CS (21). Diets with about 2% CaS of canola FA have been shown to decrease milk protein content by 4.5% (11). The great magnitude of milk protein depression during periods 3 and 4 in our experiment (8.7 and 9.7%, respectively), when cows were beyond the sixth month of lactation, could be due to an interaction between fat addition and lactation stage. Most previous experiments have been made during the first half of the lactation, but Casper et al. (7) have shown that, during the first 16 wk of lactation, the effect of added soybeans on milk protein increased with lactation stage.

The smaller decrease of milk protein content with diet WCS is possibly caused by their incomplete digestion, resulting in lower lipid supplementation. Lower effect was also observed with diet ECS. The addition of extruded soybeans into the diet has already been shown to result in lower protein content than a control diet, but in higher values than CaS of palm oil FA (25), which is consistent with our results with ECS diet. Extrusion of seeds rich in protein generally results in decreased ruminal degradation of protein, and increased duodenal flow of protein (6), which can result in a higher supply of AA for the mammary gland, particularly methionine which is abundant in canola proteins. Such a decrease in ruminal CP degradation due to extrusion of CS has not been observed by Deacon et al. (15), but these authors did not indicate the processing temperature. Because of its high fat content, extrusion of pure CS is difficult, and can result in important loss of fat. In experiments using blends of CS and other protein sources, extrusion has been found to decrease ruminal degradation of CP (8). In our trial, CS were extruded together with canola meal. Moist heat treatment of canola meal has also been shown to decrease ruminal degradation of CP and increase intestinal availability of AA (27). A supply of ruminally protected AA (13) or RUP (3) can alleviate the decrease in milk protein percentage associated with fat supplementation in Holstein cows.

Compared to control cows, the concentration of milk fat was significantly lowered by ECS and CaSCFA diets. Diet WCS did not affect the fat content, and GCS diet resulted in intermediary values. No significant difference between control and treated cows, or between treatments, could be observed for milk fat output. However, a trend ($P < 0.06$) toward lower values with ECS diet compared with control, and of ECS diet compared with WCS and GCS diets could be observed. Lack of effect of ground CS on milk fat content has already been published (1). On the contrary, 9% (DM basis) whole CS has been shown to decrease milk fat content (5). However, in this latter experiment, milk fat content of control cows was very low (2.7%) due to a very low fiber content of the diet (17.1% NDF vs 39.9 in our experiment), so that comparison of this result with ours is difficult.

Incorporation of 2% of CaS of FA from CS results in a decrease of milk fat content ranging from 2.6% (11) to 13.8% (12). These results and ours are quite different from effects of CaS of palm oil FA, which do not influence the milk fat concentration (9). However, the FA profile of these two sources of FA are different, and have already been shown to have different effects on milk fat (17). Effects of extrusion on milk fat content have not been published with CS. The incorporation of 16 or 17% extruded soybeans in the diet of dairy cows has no effect with a diet mainly based on alfalfa haylage (35) or a negative effect on milk fat content with a diet based on corn silage and alfalfa hay (25). As outlined by Scott et al. (36), the effect of extrusion of soybeans on milk fat content can depend on the basal diet, and depress milk fat when corn silage is the primary forage, as in the present experiment.

Table 2. Dry matter intake, production, and composition of milk for cows (n = 20) fed control diet and variation because of diets containing canola meal and canola fatty acids.

	Period 1		Period 2		Period 3		Period 4		
Constituent	C	ECS	C	WCS	C	GCS	C	CaSCFA	SEM
Intake, kg/d									
Forage	16.7	+0.3	17.3	−0.5	18.4	−1.0	17.0	−1.1	0.5
Dry matter	24.9	+0.5	24.2	+0.5	24.6	+0.0	23.0	+0.1	0.5
Milk production, kg/d	39.6	+1.8[b]	37.2	−2.0[c]	34.1	+0.7[b]	33.3	+0.5[bc]	0.6
Milk true protein									
%	3.19	−0.17[a,b]	3.17	−0.14[a,b]	3.23	−0.28[a,c]	3.20	−0.31[a,c]	0.03
g/d	1258	−12[b]	1171	−116[c]	1094	−73[bc]	1058	−89[c]	19
Milk fat									
%	3.86	−0.72[a,d]	3.81	−0.10[b]	3.93	−0.31[bc]	3.89	−0.63[a,cd]	0.09
g/d	1519	−239	1430	−90	1334	−88	1289	−197	40

[a]Treatment is significantly different from control within the same period ($P < 0.05$).

[b,c,d]Treatments effects with different superscript are significantly different ($P < 0.05$).

[1]C = Control diet, ECS = extruded blend of canola meal and canola seeds, WCS = canola meal and whole canola seeds, GCS = canola meal and ground canola seeds, and CaSCFA = canola meal and Ca salts of canola fatty acids.

Table 3. Proportions (% by weight) of milk fatty acids for cows (n = 20) fed control diet and variation because of diets[1] containing canola meal and canola fatty acids.

	Period 1		Period 2		Period 3		Period 4		
Fatty acid	C	ECS	C	WCS	C	GCS	C	CaSCFA	SEM
$C_{4:0}$	2.94	–0.10	4.63	–0.10	2.75	–0.12	6.07	–0.28	0.10
$C_{6:0}$	1.96	–0.17	2.63	–0.24	1.94	–0.12	3.27	–0.48[a]	0.03
$C_{8:0}$	1.57	–0.10	1.41	–0.17	1.47	–0.14	1.69	–0.30	0.04
$C_{10:0}$	3.73	–0.75[a]	3.19	–0.45	3.74	–0.43	3.48	–0.81[a]	0.12
$C_{12:0}$	4.41	–0.96[a]	4.08	–0.61[a]	4.43	–0.66[a]	3.63	–0.87[a]	0.11
$C_{14:0}$	13.54	–1.99[a,c]	13.17	–1.14[a,b]	13.83	–1.43[a,bc]	12.2	–1.81[a,bc]	0.15
$C_{15:0}$	1.35	–0.14[a]	1.35	–0.13[a]	1.39	–0.20[a]	1.23	–0.24[a]	0.03
$C_{16:0}$	32.75	–7.23[a,c]	32.38	–3.77[a,b]	36.33	–6.73[a,c]	31.4	–5.09[a,bc]	0.44
$C_{17:0}$	0.79	–0.04	0.76	–0.11	0.69	–0.08	0.78	–0.09	0.02
$C_{18:0}$	10.82	+2.69[a]	9.99	+1.88[a]	10.00	+3.29[a]	10.06	+2.90[a]	0.25
trans-$C_{18:1}$	1.62	+1.49[a,b]	1.43	+0.20[c]	1.31	+0.40[a,c]	1.56	+0.71[a,c]	0.04
cis-$C_{18:1}$	18.75	+5.62[a,bc]	16.55	+3,61[a,c]	17.24	+4.79[a,bc]	17.95	+6.28[a,b]	0.47
$C_{18:2}$	2.46	+0.02	2.31	+0.08	2.25	+0.00	2.16	+0.26	0.07
$C_{18:3}$	0.54	+0.25[a,b]	0.59	+0.09[c]	0.53	+0.12[bc]	0.60	+0.12[bc]	0.01
Total unsat. C_{18}	23.37	+7.37[a,b]	20.88	+3.98[a,c]	21.33	+5.31[a,bc]	22.27	+7.38[a,b]	0.52
Total C_{18}	34.19	+10.06[a,b]	30.87	+5.86[a,c]	31.32	+8.60[a,b,c]	32.33	+10.27[a,b]	0.32

[a]Treatment is significantly different from control within the same period ($P < 0.05$).

[b,c]Treatments effects with different superscript are significantly different ($P < 0.05$).

[1]C = Control diet, ECS = extruded blend of canola meal and canola seeds, WCS = canola meal and whole canola seeds, GCS = canola meal and ground canola seeds, and CaSCFA = canola meal and Ca salts of canola fatty acids.

Decrease in milk fat content when dietary FA are given can result from mammary uptake of *trans*-$C_{18:1}$ (39). In our experiment, the *trans*-$C_{18:1}$ content of milk fat was low, because FA from CS contain mainly monounsaturated FA and *trans* FA result from ruminal biohydrogenation (**RBH**) of dietary polyunsaturated FA. The slightly higher *trans*-$C_{18:1}$ content of milk fat with ECS diet (see Table 3) cannot explain the important decrease in milk fat content because diets with added soybeans, resulting in much higher milk *trans*-$C_{18:1}$ content have not resulted in large decreases of milk fat content (10).

Milk FA Profile

A general trend toward a decreased proportion of FA with less than 18 carbons was observed with all treatments (see Table 3). The effects were significant with ECS and CaSCFA diets for $C_{10:0}$, and with all treatments for $C_{12:0}$, $C_{14:0}$ and $C_{16:0}$. Conversely, proportion of total C_{18} was significantly increased by all treatments, ECS and CaSCFA diets gave larger increases than WCS diet. A similar trend toward lowered proportions of FA with less than 18 carbons when 18 carbon FA are added into the diet is usual (2, 18). This effect is due to an inhibition of FA synthesis in the mammary gland (14, 16). Significant decreases in the proportions of FA with less than 12 carbons have previously been observed with crushed CS (11% of diet DM; 1), extruded soybeans (16% of diet DM; 35), or CaS of canola oil FA (4% of diet DM; 11). In our experiment, fat sources were added in small amounts, and because the effect of CS fat addition is linearly related to the amount of added fat (11, 28), effects on short chain FA were smaller and nonsignificant. Modifications of relative proportions of short and long chain FA were lower with diet WCS, which is consistent with previous observation by Kennelly et al. (23), and is probably due to the lower digestibility of these seeds.

Within C_{18} FA, all treatments had similar significant effects on $C_{18:0}$, which is consistent with previous studies using whole CS (23), crushed CS (1) or CaS or FA from CS (11). On the contrary, polyunsaturated FA were not significantly modified by treatments. The addition of CS has produced increases in polyunsaturated FA only with protected seeds (3) or with higher levels of incorporation than in our experiment (11, 17, 23).

All treatments increased *cis*-$C_{18:1}$ proportion, with a great effect of CaSCFA diet, a low effect of WCS diet, probably due to a low digestibility, and intermediary values with ECS and GCS diets. In previous experiments with added ground CS, the total $C_{18:1}$ content of milk (g/100 g of milk fat) was increased from 14.3 to 24.4 with 5.5% incorporation (DM basis) (21), from 18.9 to 24.7 with 6% incorporation (23), and from 20.1 to 33.6% with 11.2% incorporation (1). In our experiment, GCS diet only increased *cis*-$C_{18:1}$ by 4.8%, due to the low level of incorporation (4.2%; DM basis). With CaS of FA from CS, our results were in the same range than previously observed (11).

The *cis*-$C_{18:1}$ in milk comes partly from arterial *cis*-$C_{18:1}$, and partly from mammary desaturation of arterial $C_{18:0}$. In diets with added FA from canola oil, most of the arterial $C_{18:0}$ derives from RBH of dietary *cis*-$C_{18:1}$. The efficiency of transfer of dietary *cis*-$C_{18:1}$ from diet to milk can be supposed to be higher when this transfer is direct than when it involves RBH and subsequent mammary desaturation, because only 50% of $C_{18:0}$ is taken up in the arterial flow is desaturated into *cis*-$C_{18:1}$ by the mammary gland (16). The extent of RBH of canola dietary *cis*-$C_{18:1}$ is lesser on FA from CS as CaS (26) than on FA from a control diet, enhancing direct transfer from diet to milk, and explaining high *cis*-$C_{18:1}$ values with CaSCFA diet.

In the same way, extrusion of soybeans with 143°C exit temperature decreased the RBH of *cis*-$C_{18:1}$ by about 10%, and high roasting temperatures decreased RBH (34). In our experiment a lower exit temperature of extrusion could explain the lack of difference of *cis*-$C_{18:1}$ percentage between GCS and ECS diets.

Diet ECS resulted in larger increases of *trans*-$C_{18:1}$ than did diets GCS and CaSCFA, and diet WCS did not affect this value. High concentrations of *trans*-$C_{18:1}$ have already been observed when extruded soybeans are used in the diet of diary cows (10). Such an effect is probably related to a rapid ruminal release of FA from extruded seeds (34), due to the disruption of cell membranes. It could result in an immediate production of *trans*-$C_{18:1}$ from dietary polyunsaturated FA, with an increased ruminal content of this *trans*-$C_{18:1}$, because the last step of RBH, from *trans*-$C_{18:1}$ to $C_{18:0}$ is the limiting factor of this biological process (33).

Thermal Analysis of Butter

Percentages of solid fat (Table 4) were decreased between 0 and 12°C by all treatments, with CaSCFA resulting in higher values, WCS in lowest values, and ECS and GCS in intermediary values. From 18°C, treatment butters were no longer different from control butters, but a trend toward lower values was still observed.

Similarly, the addition of CaS of FA from CS into the diet has already been shown to increase liquid fat of milk fat or butter at 0°C (12), between 5 and 14°C (12, 17), but not at 20°C (12, 17). In these experiments, effects were more important, due to a twice higher level of incorporation of CaS than in the present trial. Decreased percentage of solid fat at low or medium temperatures, but not at 20°C have also been shown with dietary ground (29) or protected CS (2). The increased proportion of unsaturated FA with treatments is responsible for this effect, because of a linear relationship between percentage of liquid fat in butter and the iodine index of butter fat at 6 and 14°C (17).

Modification of the ratio of liquid to solid fat is an important factor to improve butter spreadability, so that this property of butter was improved at refrigeration temperature. Moreover, lack of differences between control butter and butter from treated cows when temperature was 18°C or more indicates that butter from treated cows did not exhibit oily characteristics at room temperature.

CONCLUSIONS

The addition of low amounts of CS seeds or CaS of FA from CS associated with canola meal improved dietetic characteristics of milk FA, and spreadability of butter at refrigeration temperature, but resulted in an important decrease in milk true protein and fat contents. Effects were low with WCS. Diet CaSCFA best improved milk FA, but ECS diet produced only slightly lesser effects but a much lower reduction of milk true protein content.

Table 4. Solid fat (% of butter fat) in butter for cows (n = 20) fed control diet and variation because of diets[1] containing canola meal and canola fatty acids.

	Period 1		Period 2		Period 3		Period 4		
Temperature	C	ECS	C	WCS	C	GCS	C	CaSCFA	SEM
−10°C	93.8	−2.7[a]	94.9	−1.5	94.3	−2.1[a]	93.4	−2.7[a]	0.4
0°C	83.5	−4.7[a,bc]	85.3	−2.6[a,c]	85.1	−4.7[a,bc]	83.2	−5.4[a,b]	0.8
6°C	73.1	−5.3[a,bc]	75.0	−2.8[a,c]	75.5	−5.6[a,bc]	73.0	−6.3[a,b]	1.1
12°C	60.4	−7.2[a,bc]	62.7	−4.0[a,c]	63.6	−7.5[a,bc]	61.1	−8.4[a,b]	1.4
18°C	37.0	−1.0	38.5	−1.6	40.5	−4.4	39.9	−4.4	1.5
24°C	22.6	−0.3[c]	23.6	−0.9[bc]	25.5	−2.7[bc]	25.8	−3.3[b]	1.1
30°C	9.5	+0.3	10.1	+1.2	11.7	−1.0	12.2	−1.7	0.9

[a]Treatment is significantly different from control within the same period ($P < 0.05$).

[b,c]Treatments effects with different superscript are significantly different ($P < 0.05$).

[1]C = Control diet, ECS = extruded blend of canola meal and canola seeds, WCS = canola meal and whole canola seeds, GCS = canola meal and ground canola seeds, and CaSCFA = canola meal and Ca salts of canola fatty acids.

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