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Evening primrose (*Oenothera paradoxa*) oil cake or ground rape seed supplement to diets for dairy cows

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ABSTRACT

The effect of adding evening primrose oil cake or ground full fat rape seed supplements to the diet on animal performance, hormone and metabolite levels in blood plasma, and milk fatty acid composition was compared in an experiment on 21 Black-and-White Lowland cows divided into 3 groups of 7. The animals were fed control basic diet (group C) or diets supplemented with evening primrose cake (group P) or full fat rape seeds (group R). Daily milk production in cows of group P was 0.9, and of group R 1.8 kg (FCM) higher than in cows of the control group. The milk fat contents were 3.99, 4.02 and 3.97%, and protein contents 2.98, 2.93 and 2.81% in groups C, R and P, respectively. The plasma cholesterol level was 20% lower in group C and 26% lower in group P than in group R. The content of C_{18}-acids, including polyunsaturated acids, in the milk fat of cows of group P and R was similar and higher than in controls.

KEY WORDS: evening primrose oil cake, rape seeds, dairy cows, milk

INTRODUCTION

Rape seeds have been found to be a good source of protein and energy for cattle, and rape seed oil can favourably influence fatty acid proportions in milk fat (Huhtanen and Poutiainen, 1985; Murphy et al., 1990; Strzetelski et al., 1992a, 1993a).

Evening primrose oil cake, a by-product obtained by squeezing the oil from evening primrose seeds in a cold process, is characterised by a relatively high level of protein rich in cystine and methionine, and fat which contains a high proportion of biologically active γ-linolenic acid (Hudson, 1984; Horrobin, 1990; Stasiniewicz et al., 1998).

The aim of the present study was to compare the effect of feeding dairy cows diets containing ground rape seeds on milk fat composition and some blood hormone and metabolite levels with those of cows fed a diet with evening primrose oil cake.

MATERIAL AND METHODS

Animals and feeding

The experiment lasting from day 7 to 100 of lactation was carried out on 21 Black-and-White Lowland cows divided into 3 groups of 7 according to an analogue method taking into account HF blood share (av. 25%), lactation rank, milk yield at the peak of last lactation. Groups of animals were completed during 2 months. Cows were fed, according to the INRA (IZ, 1993) system, the basal ration composed of maize silage, partly substituted in the summer with fresh grass and meadow hay with free access to a salt lick. Soyabean meal was used as a feed equalizing milk production with protein and energy of the basal ration in all groups. The animals were additionally given concentrate mixtures composed of ground barley and wheat, soyabean oilmeal, wheat bran and mineral mixture (Table 1) with full fat rape seeds (Group R) or evening primrose (*Oenothera paradoxa*) oil cake (Group P). The amount of fat introduced with rape seeds or evening primrose

TABLE 1

Compound feed composition, %

Component	Groups		
	C	R	P
Ground barley	58	50.5	16
Ground wheat	14	14	14
Soyabean oilmeal	21	15	3
Wheat bran	3	3	3
Ground full fat rape seeds	–	13.5	–
Evening primrose oil cake	–	–	60
Mineral mixture[1]	4	4	4

[1] composition, %; limestone 50; common salt 25; $CaHPO_4$ 25
in 1 kg, g: Ca – 241.5; Na – 96; Cl – 149; P – 44

oil cake was thought to be equal, about 50 g/kg of concentrate mixture. Milk yield was measured daily, the milk protein and fat contents were determined in representative samples every 3 days. Blood samples for determination of hormones and metabolites were collected from the jugular vein on experimental day 6, 35, 64 and 93 before the morning feeding.

Chemical analysis and statistics

Proximate analysis of feeds was carried out according to AOAC (1990), the nutritive value of feeds and diet formulation according to the INRA system using INWAR 1.0 and INRAtion ver. 2.03 software systems (1993). The protein and fat contents in milk were determined with Milko-Scan 133B equipment, individual fatty acids in milk, evening primrose oil cake and in rape seeds as methyl esters using GLC Philips PV 4500 equipment with 10 EGSS-X Gas Chrom column. Growth hormone (bST), prolactin (PL), thyroxine (T_4) and triiodthyronine (T_3) and such metabolites as cholesterol, were assayed using Corniay Chol PAP 50 kits, urea and creatine with a diagnostic Biochemtest POCH kit, and free fatty acids by a colorimetric method (Duncome, 1964) in heparinized blood plasma samples or samples preserved with sodium ethylenediaminetetraacetate.

The results were subjected to statistical analysis using one way analysis of variance (results of production, milk and fat composition) or bifactorial (hormones and metabolites in blood) according Statgraphics Plus 6.0 (1992) software.

RESULTS

The crude fat content in compound feed for experimental groups was above 3 times higher than in the control feed. One kg of mixture for group R contained about 55 g of rape seed oil and for group P – 49 g of evening primrose oil, which gave 78 and 87% of total crude fat in mixtures, respectively (Table 2). Feed rations contained, depending on the season of feeding, on average, kg/day: of maize silage – 27, or maize silage – 2.0 and fresh grass – 15; meadow hay – 3 to 4; concentrate mixture – about 7.5; soyabean oilmeal – 1.0.

Daily intake of nutrients, except crude fat, was similar in all groups: 16.5 ± 0.15 kg dry matter, 2536 ± 58 g crude protein, 1559 ± 42 g PDI, (PDIN – PDIE)/UFV = = 6.5 ± 3.5 g. Fat intake with the ration for the control group (614 g) was less than in the experimental groups: 907 g in group R and 797 g in group P, of which 37 and 31% of the fat was from rape seeds or evening primrose oil cake, respectively.

The milk yield, fat and protein content in milk did not differ significantly among groups ($P>0.05$), though cows from groups R and P produced 1.7 and 1.0 kg, respectively, more milk than those in group C (Table 3). There was a tendency

TABLE 2

Nutrient content and nutritive value of feed

Feed	Nutrients, %					In 1 kg of DM according to INRA system[1]		
							PDI, g	
	DM	CP	EE	CP	Ash	UFL	PDIN	PDIE
Ground barley	86.32	11.44	1.85	4.00	2.49	1.17	86.76	105
Ground wheat	86.66	12.01	1.87	2.20	1.72	1.24	94.76	114
Soyabean oilmeal	87.84	42.98	1.92	5.44	7.12	1.17	345.21	239
Wheat bran	87.78	14.36	3.28	5.93	3.77	0.93	108.32	96
Ground full fat rape seeds	93.94	20.95	41.04	6.74	4.6	1.15	129.04	26.9
Evening primrose oil cake	87.53	20.83	8.11	23.22	7.94	0.63	154	130
Maize silage	21.84	1.75	1.35	5.08	1.37	0.89	49	63
Meadow hay	83.95	10.09	1.96	28.91	5.79	0.62	73	73
Fresh grass	19.2	2.38	0.86	5.37	1.69	0.77	78	77
Compound concentrate for groups:								
C	87.1	17.77	1.83	3.83	6.97	1.12	140	130
R	87.8	17.12	7.12	4.13	6.94	1.13	130	111
P	87.4	17.74	5.58	15.12	9.26	0.82	134	120

UFL – unit for milk production; PDI – protein truly digested in the small intestine; PDIN – dependent on NH_3-N amount; PDIE-PDI – dependent on energy amount

TABLE 3

Milk yield and composition and nutrient efficiency

Item	Groups			SE
	C	R	P	
Milk yield, kg/day				
initial: mean of first week of lactation	20.00	19.16	19.57	2.88
final: mean of 14 weeks of lactation	18.70	20.57	18.17	2.86
mean experimental period	21.96	23.69	22.97	2.97
FCM	21.93	23.76	22.86	3.02
Milk fat, %	3.99	4.02	3.97	0.24
Milk protein, %	2.98	2.93	2.81	0.13
Nutrient utilization per 1 kg of milk				
dry matter, kg	0.76[a]	0.70[a]	0.71[a]	0.06
crude protein, g	113.56[a]	107.20[a]	113.56[a]	9.34
PDI, g	72.87[b]	64.28[a]	68.40[a]	4.98
UFL	0.64[b]	0.58[a]	0.58[a]	0.05

a, b – $P \leq 0.05$

towards higher fat and lower protein contents in the milk of cows receiving the diet with rape seeds, while the lowest level of fat and protein was found in the milk of cows of group P. Feed efficiency was somewhat better in group R and P than in group C, however, significant differences was found for PDI only ($P<0.05$). Feed efficiency in group R was slightly better than in group P.

The average hormone concentrations in blood plasma of group R animals was higher than in the control group C (Table 4), in particular of prolactin and bGH (32 and 70%, respectively), the concentration of these hormones in animals of group P was 23 and 33% higher than in group C. The plasma cholesterol level was 20 and 26% higher ($P<0.05$) in group R than in groups C and P, respectively. The plasma urea level was 35% higher ($P<0.05$) in group R and 46% higher in group P ($P<0.01$) than in animals of the control group C; differences between groups R and P were not statistically significant. Creatinine and free fatty acid levels in plasma were not significantly higher, 7 and 39%, in group R and, 15 and 17%, in group P, respectively, than in the control group ($P>0.05$).

Significantly higher levels of urea, cholesterol but lower levels of creatinine and free fatty acids ($P<0.01$) were found in blood samples withdrawn on 6 day after calving than in samples taken in subsequent periods (Table 4).

The evening primrose oil contained less oleic ($C_{18:1}$) and α-linolenic ($C_{18:3\ n3}$) but more linoleic ($C_{18:2\ n6}$) and γ-linolenic ($C_{18:3\ n6}$) acids than the oil of rape seeds. A decrease of short chain fatty acids and increase of long chain fatty acids particularly of ω-poly-unsaturated acids in milk fat in the groups fed evening primrose oil cake and rape seeds compared with the control group was found.

TABLE 4

Hormone and metabolite level in the blood plasma

Indices	Groups			Post partum day of blood sampling				
	C	R	P	6	35	64	93	SE
Hormones								
prolactin mg/ml	19.16^{a}	25.36a	23.63^{a}	18.39^{a}	18.07^{a}	26.83^{b}	27.58^{b}	12.59
T_3, ng/ml	1.30^{a}	1.45^{a}	1.21^{a}	1.25^{a}	1.29^{a}	1.36^{a}	1.17^{a}	0.48
T_4, ng/ml	32.69^{a}	39.72^{a}	34.72^{a}	37.92^{a}	34.27^{a}	33.90^{a}	35.15^{a}	15.56
bGH, ng/ml	0.82^{a}	1.40^{a}	1.09^{a}	1.47^{a}	1.15^{a}	0.97^{a}	0.90^{a}	1.95^{a}
Blood metabolites:								
chlesterol, mmol/L	3.51^{a}	4.22^{b}	3.35^{a}	2.30^{Aa}	4.14^{Bb}	4.28^{Bb}	4.04^{Bb}	0.76
urea, mmol/L	4.21^{Aa}	5.68^{ABb}	6.15^{Bb}	4.40^{a}	5.69^{Bb}	5.83^{b}	5.49^{b}	1.34
creatinine mmol/L	87.36^{a}	93.86^{a}	100.92^{a}	117.51^{Aa}	83.65^{Bb}	84.87^{Bb}	90.16^{Bb}	18.05
free fatty acids (FFA) mmol/L	188.13^{a}	260.90^{a}	219.93^{a}	346.54^{Aa}	234.38^{ABb}	169.59^{Bb}	141.43^{Bb}	99.59

a, b – $P<0.05$; A, B – $P<0.01$

DISCUSSION

Enrichment of diets for dairy cows with different types of fat provides an opportunity to increase milk production and to improve the proportion of fatty acids in milk fat, but, at the same time, if fed in larger amounts can provoke a negative effect on nutrient digestion and development of micro-organisms in the rumen (Garnsworthy, 1997). In our experiment the slightly, but not significantly, higher daily milk production in cows fed diets containing ground rape seeds or evening primrose oil cake than in animals of the control group could result from increased fat intake. Fat was in this case an additional source of energy for cows having a restricted ability for feed intake in the first period of lactation (Murphy et al., 1990; Strzetelski et al., 1993a). Supplementing the diet for lactating cows with fat containing unsaturated fatty acids does not always increase performance. The reason is thought to lie in the fact that the unsaturated fatty acids released in the rumen from dietary fat are harmful to bacterial development, thus lowering digestion of cellulose (Kowalczyk et al., 1977), and that they are subsequently biohydrogenated to detoxify them.

The merely slight tendency towards increasing the fat level in milk of cows receiving ground rape seeds, compared with control cows, suggests that though the rape seed cell structure caused a slower release of oil in the rumen (Jigl et al., 1988) it nevertheless contributed to the biohydrogenation of acids in the rumen only to small degree. A higher proportion of polyunsaturated acids was indeed found in milk fat in groups R and P, however, it is not excluded that the form of *trans*-acids were created limiting the *de novo* synthesis of fatty acids in the mammary gland (Banks et al., 1990). The lower content of fat in the milk of animals fed rations with evening primrose oil cake than in the group fed rape seeds could be due to the high level of tannins in evening primrose (Hanczakowski and Szymczyk, 1993; Stasiniewicz et al., 1998). Complexes of tannins with bound protein are poorly degraded in the rumen and digested in the intestine.

Evening primrose oil contains a relatively high level of unsaturated fatty acids, so even if the part of them escaping rumen dehydrogenation was absorbed and incorporated into the carcass or milk fat it should improve the fat quality of these products. A similar content of γ-linolenic acid in the milk of cows receiving rape seeds or evening primrose oil cake despite the 9% content of this acid in evening primrose oil as compared with its 0.66% content in rape seed oil (Stasiniewicz et al., 1998) suggests that the attempt to enrich milk fat in γ-linoleic acid by supplementing the diet with a fat containing a high level of this acid was not effective. The reason for the low incorporation of γ-linolenic acid into milk fat could be that this acid was dehydrogenated in the rumen to large extent. Moreover, it can not be excluded that an excess of this acid was utilized for prostaglandin synthesis (Horrobin, 1990).

TABLE 5

Individual fatty acids content in feeds and milk fat, %

Acid	Evening primrose oil cake	Rape seeds	Milk fat			SE
			C	R	P	
C_{8}	–	–	0.84^{a}	0.97^{a}	0.83^{a}	0.13
C_{10}	0.06	–	2.13^{a}	2.34^{a}	2.04^{a}	0.28
C_{11}	–	–	0.35^{a}	0.30^{a}	0.26^{a}	0.06
C_{12}	0.05	0.01	3.53^{Aa}	2.84^{Bb}	2.53^{Bb}	0.38
$C_{12:1}$	0.05	–	0.13^{Aa}	0.09^{ABb}	0.09^{Bb}	0.02
C_{13}	–	–	0.25^{Aa}	0.017^{Bb}	0.16^{Bb}	0.03
C_{14}	0.08	0.08	12.46^{a}	10.13^{b}	10.18^{b}	1.14
$C_{14:1}$	0.06	–	0.40^{a}	0.35^{a}	0.39^{a}	0.05
C_{15}	0.09	0.02	1.65^{a}	1.33^{b}	1.29^{b}	0.19
$C_{15:1}$	–	–	1.65^{Aa}	1.19^{Bb}	1.30^{Bb}	0.15
C_{16}	5.47	4.36	38.95^{Aa}	27.71^{Bb}	28.99^{Bb}	2.58
$C_{16:1}$	0.18	0.32	2.72^{Aa}	2.33^{Bb}	2.32^{Abb}	0.20
C_{17}	0.20	0.05	0.98^{a}	0.80^{b}	0.95^{a}	0.08
C_{18}	1.89	1.49	9.04^{Aa}	13.86^{Bb}	13.54^{Bb}	1.17
$C_{18:1}$	6.35	58.65	19.78^{Aa}	29.29^{Bb}	28.42^{Bb}	2.48
C_{19}	0.13	–	0.54^{a}	0.73^{b}	0.67^{ab}	0.09
$C_{18:2\ n6}$	73.10	20.50	1.59^{Aa}	2.23^{Bb}	2.38^{Bb}	0.16
$C_{18:3\ n6}$	9.01	0.66	0.25^{Aa}	0.41^{Bb}	0.42^{Bb}	0.07
$C_{18:3n3}$	0.45	10.85	1.11^{Aa}	1.41^{Bb}	1.51^{Bb}	0.12

a, b – $P<0.05$; A, B – $P<0.01$

Palmquist and Moser (1981) and Casper and Schingoethe (1989) reported that feeding cows with elevated levels of fat may limit amino acid absorption and delivery for milk synthesis and this could be the reason for the lower level of protein in the milk of cows fed evening primrose oil cake or rape seeds than in the control group.

Dietary fat is easily hydrolysed in the rumen by bacterial lipase. The free fatty acids pass with digesta into the small intestine and are absorbed and utilized as an energy source or incorporated to some degree into the carcass or milk fat. The level of free fatty acids in the blood (Table 4) suggests that absorption of fatty acids from the intestine was higher in cows fed rape seed and evening primrose oil cake than in control cows, but it is rather difficult to conclude on this basis about their biohydrogenation in the rumen or incorporation into milk fat since the proportion of individual free fatty acids in the blood was not determined in our experiment.

Many authors reported that the level of cholesterol in the blood of cows fed diets supplemented with fat increases significantly (Jahreis and Richter,1994) but it is not the case when evening primrose oil cake is given with the diet (Manku, 1988; Horrobin, 1990; Biernat and Grajeta, 1992). This was confirmed in our experiment where the concentration of free fatty acids in blood was slightly lower ($P>0.05$) but cholesterol in cows given evening primrose oil cake was significant-

ly lower ($P<0.05$) than in cows fed rape seeds. The cholesterol concentration in the blood of control animals was even slightly higher than in animals receiving evening primrose oil cake. The authors mentioned above suggested that a high proportion of γ-linoleic acid in evening primrose oil might prevent a rise in cholesterol in the blood of cows despite the increased level of fat in the diet.

It is characteristic that the free fatty acid level in the blood decreased similarly as reported by Hart et al. (1978) and Strzetelski et al. (1993b) with duration of lactation. The cholesterol level in the blood increased with duration of lactation as an effect of the physiological status of animal and of the level of lipoproteins in blood (Blum et al., 1983; Pyska, 1984).

The higher level of urea and creatinine in the blood of cows fed evening primrose oil cake indicate a lower efficiency of microbial protein synthesis in the rumen. In cows fed rape seeds the increase of urea and creatinine concentration in the blood was much smaller relating to these in animals of resting groups, which was probably caused by a lower proportion of ground barley as a source of energy for microbial growth in the feed mixture for this group (Huhtanen and Poutiainen, 1985; Strzetelski et al., 1992b).

A higher level of creatinine and lower urea in blood of cows at the beginning of lactation and decreasing concentration of creatinine and increasing of urea concentration with duration of lactation could result from limited feed intake after calving and more intensive nitrogen catabolism, which can suggest more intensive utilization of protein reserve.

The slightly higher milk production of cows given rape seeds or evening primrose oil cake compared with the control group could be related to the higher concentration of bGH and prolactin in blood. An increase of bGH in the blood in animals fed a diet with a high proportion of fat was often reported (Bauman, 1982; Bines and Hart, 1982). There were no differences in the thyroid hormone concentrations in blood between the group of animals, which also reflects small differences in milk production and fat level, confirming the known interaction between the level of thyroid hormones in blood and fat content in milk (Ślebodziński, 1970). However, it is necessary to take into consideration that the blood hormone level fluctuates during the day, therefore the results obtained for the hormone levels should be interpreted with caution as in our experiment the blood samples were taken only once per day.

CONCLUSIONS

Evening primrose oil cake as a major component (60%) of concentrate feed mixture had no negative effect on milk yield and composition in dairy cows compared with rape seeds. Feeding cows with evening primrose oil cake did not gene-

rate a rise in blood cholesterol levels as opposed to rape seeds. Feeding evening primrose oil cake did not increase linoleic and γ-linolenic acid in milk fat although their content in this feed was much higher than in rape seeds.

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STRESZCZENIE

Makuch z wiesiołka (*Oenothera paradoxa*) lub śruta z nasion rzepaku w żywieniu krów mlecznych

Dwadzieścia jeden krów rasy nizinnej czarno-białej, podzielonych na 3 grupy po 7, żywiono dawką pokarmową z dodatkiem makuchu z wiesiołka (Grupa P) lub śrutowanych nasion rzepaku (Grupa R) lub bez tych dodatków (Grupa C – kontrolna). Średnia dzienna produkcja mleka (FCM) w grupach P i R była większa odpowiednio o 1,0 i 1,7 kg niż w grupie C (22 kg). Zawartość tłuszczu w mleku wynosiła w grupach C, R, P odpowiednio 3,99; 4,02 i 3,97%, a białka 2,98; 2,93 i 2,81%. Poziom cholesterolu w osoczu krwi zwierząt był niższy w grupie C o 16, a w grupie P o 20 % niż w grupie R. Zawartość poszczególnych kwasów C_{18}, w tym kwasów wielonienasyconych, w tłuszczu mleka krów grupy P i R była podobna i istotnie większa ($P \leq 0,01$) niż w grupie C.