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Effects of gradual replacement of rapeseed cake with linseed cake in a grass silage-based diet for dairy cows

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Eight Finncattle cows were used in two replicated 4×4 Latin squares with 21-day periods to study the effects of replacing rapeseed cake with linseed cake in proportions of 0, 1/3, 2/3 and 1 (on air dry basis), the total amount of supplement being 1.5 kg/day (on air dry basis). The basal diet consisted of silage fed *ad libitum* and a 4.5 kg/day (on air dry basis) barley:oats (1:1) mixture.

The experimental diets had no effect on feed intake. Effective protein degrability (EPD) determined by the nylon bag method was higher for linseed cake than for rapeseed cake. Milk production decreased linearly ($P<0.01$), from 18.5 to 17.1 kg/day, when the proportion of linseed cake was increased. Milk fat content increased ($P<0.05$) by 3.4 g/kg but milk protein content tended to decrease ($P<0.10$) with an increase in linseed cake feeding. Despite clear differences in the fatty acid composition of linseed and rapeseed oils, experimental treatments had only minor effects on milk fatty acid composition.

Several factors, including the slightly higher ether extract content, higher EPD and/or lower amino acid content of linseed cake than rapeseed cake, the different fatty acid composition of the two supplements and the presence of antinutritional compounds in linseed cake, may be responsible for the impaired milk production with linseed cake feeding.

Key words: flaxseed, *Linum usitatissimum* L., milk production, milk fatty acid composition, oilseed cake

Introduction

Linseed or flaxseed *(Linum usitatissimum* L.*)* is one of the world's oldest and most versatile crops but its cultivation in Finland had almost ceased by the 1960s. A new interest in cultivating linseed, especially the oil linseed varieties, has emerged in the 1990s. Linseed oil and meal are recognised to be highly nutritious to humans whereas linseed oil can be used in paints and varnishes, and the fibre of oil linseed in techni-

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cally innovative developments in, for example, hard board production (van Kempen and Jansman 1994). Once the oil has been removed, linseed meal or cake can be used as animal feed. Rapeseed products are the most important protein supplements used in dairy cow feeding in Finland, and their effects on milk production have been extensively studied (e.g. Tesfa 1992, Tuori 1992). Knowledge of the value of linseed products is, however, more scarce. In a historical perspective, linseed-based feeds have been highly appreciated, but in more recent times a range of negative factors such as antinutritional compounds and the poor amino acid composition of linseed products have been reported (Olsson et al. 1988, van Kempen and Jansman 1994).

Apart from the interest in utilizing by-products of linseed oil production for feeding dairy cows, consumers are becoming increasingly aware of the health aspects of food and foods promoting health, i.e. functional foods. If milk fatty acid composition could be manipulated by feeding cows linseed oil, it might be possible to create special milk products with health-promoting effects. Rumen microbes are known to biohydrogenate dietary unsaturated fatty acids. Milk fatty acid composition can, however, be changed by feeding linseed oil to dairy cows (McDonald and Scott 1977, Kennelly 1996). Studies of typical Finnish dairy cow diets based on grass silage supplemented with locally produced linseed cake are, however, lacking.

The objective of this study, then, was to compare the production potential of linseed cake with that of rapeseed cake in milk production. Special attention was paid to the feasibility of altering milk fatty acid composition by feeding cows linseed cake.

Material and methods

Animals and basal care

Eight autumn-calving Finncattle cows, of which five were in their first lactation and three in their second lactation, were used. The cows had calved 70 (s.e. 8) days before the start of the experiment and their average live weight during the experiment was 468 kg (s.e. 17). They were fed and housed in individual stalls in the dairy barn at Koivikko Agricultural College. Grass silage was given twice daily *ad libitum* and concentrate feeds were offered as two equal meals at 06.30 and 14.30. The cows had free access to water, and a commercial mineral mixture was included according to their requirements.

Experimental design

The experiment was conducted as two replicated 4×4 Latin squares with periods of 21 days. The Latin squares were balanced for carry-over effects, within a square each treatment being once first and once preceeded by all other treatments. Experimental diets were formed by gradually replacing rapeseed cake (RC) with linseed cake (LC) as the protein supplement. The proportion of LC was 0, 1/3, 2/3 and 1 in the four treatments. The total amount of protein supplementation was 1.5 kg of air dry feeds per animal/day.

Feeds

The linseed cake was produced by Elixi Oil Ltd. and had been cold-pressed from oil linseed, variety Norlin. The rapeseed cake was a commercial heat-moisture -treated (Öpex®) product. The cows were also given a mixture of 4.5 kg (on air dry basis) of rolled barley and oats (1:1). Grass silage was produced from timothy-meadow fescue (4:1). It was ensiled in clamp silos with a formic acid-based additive (AIV 2) at a rate of 4 litres of formic acid per tonne of fresh grass.

Measurements and sampling

Data from the last week of each period were used to calculate concentrate intake. Silage intake was

Vol. 6 (1997): 161–172.

measured over the last 3 days only, a relatively short period due to practical reasons. Representative feed samples were collected over each period of intake measurements. Fresh silage samples were stored at –20°C before analysis. Samples of concentrate feeds were bulked over all periods, but silage samples were analysed separately for each period. Milk production was recorded during the last week of each period. Milk samples, in proportion to yield, were taken on the last four consecutive milkings of each period, and analysed for fat, protein and lactose using an infra-red milk analyser and for urea with an enzymatic UV test (Valio Ltd.). For milk fatty acid (FA) analyses, samples of two replicate animals were bulked.

Chemical analyses

The dry matter (DM) content of feed samples was determined by oven drying at 103°C. Silage DM was corrected for loss of volatile substances [lactate, volatile fatty acids (VFA), ethanol and ammonia] according to Huida et al. (1986). The ash content of samples was obtained by ignition in a muffle furnace at 550°C for 6 h. Concentrate feeds were analysed for nitrogen (N) by the method of Sweeney (1989) on a Leco FP 428 nitrogen analyser, and fresh silage samples by the Kjeldahl method (EEC 1993). The crude protein (CP) content was obtained by multiplying the N content by 6.25. Silages were analysed for water soluble carbohydrates (Somogyi 1945), lactate (Barker and Summerson 1941), VFA (Huida 1973), ethanol (Huida 1982) and ammonia N (McCullough 1967). Crude fibre (EEC 1992) and ether extract (EEC 1984; method A) analyses were conducted according to the official procedure for feed analysis. For concentrate feeds, the samples were treated with HCl before ether extraction (EEC 1984; method B with ethyl-ether). Neutral detergent fibre (NDF) was determined according to Van Soest et al. (1991). Silage D-value was estimated *in vitro* with cellulase-based digestion (Friedel 1990).

To quantify individual milk FAs, milk fat was separated using the International Dairy Federation standard method and methylated as given in Antila and Kankare (1983). The methylated FAs were separated on an HP-Innowax (cross-linked PEG) column (30 m × 0.32 mm, film thickness 0.5 µm) in a gas chromatograph Hewlett Packard 5890 fitted with a flame-ionization detector and an automatic injector (Hewlett Packard 7673). The carrier gas used was helium and the split ratio was 50:1. The injector and detector temperatures were 250 and 275°C, respectively. The column temperature, which was 90°C at the start, was first raised to 105°C at a rate of 5°C/min, then to 225°C at a rate of 40°C/min, and finally to 250°C at a rate of 2°C/min. Individual FAs and their mass fractions were identified using the milk fat standard CRM 164 (Pocklington et al. 1993).

Feed values

The metabolizable energy (ME) content of concentrate feeds was calculated from the chemical composition and the reported digestibility values (Tuori et al. 1996). Effective protein degradability (EPD) in the rumen was calculated for both protein supplements from nylon bag incubations of 0, 2, 4, 8, 16, 24, 48 and 72 h in the rumen of three fistulated cows. Rapeseed cake was incubated as fed and LC was ground through a 6 mm sieve before incubation. After incubation the bags were washed in a household washing machine, dried at 60°C and analysed for N. The values of amino acids absorbed from the small intestine (AAT) and the protein balance in the rumen (PBV) for the feeds were calculated according to Tuori et al. (1996) but the measured EPD values were used for RC and LC.

Statistical analyses

Data were analysed with the GLM procedure of

Table 1. Chemical composition and feed values of the feeds.

	Barley and oats mixture	Linseed cake	Rapeseed cake	Grass silage
Dry matter (DM), g/kg	854	913	908	278
In DM, g/kg				
Ash	25	59	64	77
Crude protein	137	359	342	164
Ether extract	51[1)]	160[1)]	117[1)]	43[2)]
Neutral detergent fibre	250	213	279	520
Feed values, g/kg DM				
Metabolisable energy, MJ/kg DM	13.0	14.1	12.8	10.9
AAT[3)]	100	95	149	84
PBV[4)]	–25	207	115	20

[1)] With HCl hydrolysis
[2)] Without HCl hydrolysis
[3)] Amino acids absorbed from the small intestine
[4)] Protein balance in the rumen

the Statistical Analyses System (SAS Institute Inc. 1989) using the following model:

$$y_{ijkl} = \mu + S_i + S(C)_j + P_k + T_l + (S\times P)_{ik} + (S\times T)_{il} + e_{ijkl},$$

where S is a square, S(C) is a cow within a square, P is the period, T is the dietary treatment and S×P and S×T the subsequent interactions. The sums of squares for treatment effects were further separated, using orthogonal contrasts, into single degree of freedom comparisons of linear, quadratic and cubic effects of dietary LC increases. Quadratic and cubic effects were non-significant in virtually all cases. Consequently only linear effects are included in the tables.

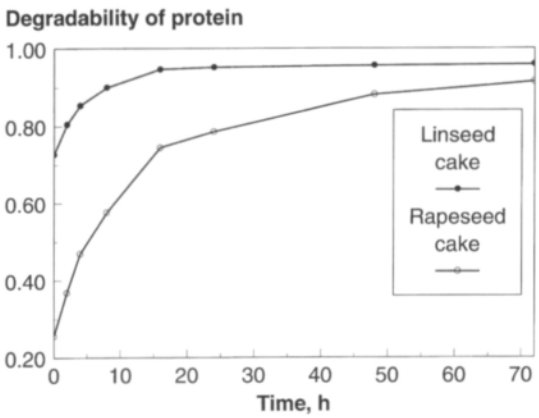

Fig. 1. Degradability of linseed cake and rapeseed cake protein incubated in nylon bags in the rumen of three replicate cows as a function of time.

Results

The composition of the feeds used in the present experiment is given in Table 1. The higher ether extract content of LC explains why its ME content was higher than that of RC. LC contained slightly more CP and clearly less NDF than RC. There was a marked difference in the protein values of the two supplements despite the small differences in CP content. This was due to the clearly higher EPD of LC than of RC (0.88 *vs* 0.61). Protein degradation curves for both supplements are presented in Figure 1. The silage clamp was changed in the middle of the experiment. The values describing the fermentation

Vol. 6 (1997): 161–172.

Table 2. Effects of gradual replacement of rapeseed cake with linseed cake on feed and nutrient intake.

	Proportion of linseed cake					Statistical
	0	1/3	2/3	1	SEM	significance
Feed intake, kg DM/d						
Silage	9.06	9.33	8.71	9.17	0.288	ns
Barley and oats mixture	3.83	3.83	3.76	3.62	–	
Rapeseed cake	1.37	0.91	0.45	0.00	–	
Linseed cake	0.00	0.46	0.89	1.29	–	
Total	14.26	14.53	13.81	14.08	0.343	ns
Nutrient intake, g/d						
Organic matter, kg/d	13.38	13.63	12.97	13.21	0.318	ns
Crude protein	2461	2530	2418	2445	55.2	ns
Ether extract						
Total	743	769	759	786	17.7	ns
From rapeseed cake	160	107	52	0	–	
From linseed cake	0	73	143	207	–	
AAT[1)]	1349	1343	1260	1258	30.2	*
PBV[2)]	223	292	316	335	8.9	***
Metabolisable energy (ME), MJ/d	166.4	168.9	162.0	165.9	4.02	ns

SEM = Standard error of the mean; Statistical significance: *** (P<0.001), * (P<0.05)

[1)] Amino acids absorbed from the small intestine

[2)] Protein balance in the rumen

quality of silage in the first and second halves of the experiment were: DM 229 and 328 g/kg, pH 4.78 and 4.14, water soluble carbohydrates 9 and 93 g/kg DM, lactate 44 and 29 g/kg DM, acetic acid 33 and 11 g/kg DM, butyric acid 2 and 0 g/kg DM, ammonium N 79 and 29 g/kg N and soluble N 525 and 645 g/kg N. Values indicate that the first batch of silage was extensively fermented, with a rather high pH, whereas the second batch was fermented to a restricted extent.

Dietary treatments had no effect on daily feed intake, but there were slightly more concentrate refusals when cows were fed high proportions of LC (Table 2). Organic matter, ME and CP intakes remained the same for all diets. Ether extract intake showed a slight numerical increase when more LC was fed, owing to an increase of 3.6 g/kg (P<0.001) in the ether extract content of the total diet. As a result of the difference in protein degradability characteristics between supplements, AAT intake was smaller (P<0.05) and PBV intake greater (P<0.001) on high LC diets.

Milk production (P<0.01) and energy corrected milk (ECM) production (P<0.05) declined with an increasing proportion of LC in the diet (Table 3). The decrease was smaller for ECM than for milk (5.6% *vs* 8.2%) because LC increased the milk fat content (P<0.05). The milk protein content tended to decrease (P<0.10) and the milk urea content increased (P<0.01) in high LC diets. The daily output of milk protein (P<0.001) and lactose (P<0.01) was clearly decreased by the gradual inclusion of LC but milk fat output was not significantly affected. The efficiency of dietary CP utilisation for milk protein was impaired (P<0.01) by a gradual increase of LC in the diet but feed conversion in terms of AAT, DM or ME into ECM was not affected by diet.

Gradual replacement of RC by LC had little effect on the milk short and medium chain (C4:0

Table 3. Effects of gradual replacement of rapeseed cake with linseed cake on milk production and milk composition and feed conversion.

	Proportion of linseed cake					Statistical
	0	1/3	2/3	1	SEM	significance
Milk produktion, kg/d						
Milk	18.5	18.2	17.2	17.1	0.38	**
ECM[1)]	20.7	20.6	19.7	19.6	0.43	*
Milk composition, g/kg						
Protein	33.5	33.8	33.1	32.5	0.43	o
Fat	43.6	44.8	46.4	47.0	0.85	*
Lactose	49.1	48.5	49.0	49.0	0.20	ns
Milk urea, mmol/l	6.08	6.32	6.83	6.70	0.153	**
Output in milk, g/d						
Protein	617	617	558	549	15.9	***
Fat	808	824	787	798	25.3	ns
Lactose	906	888	827	829	25.7	*
Efficiency of feed conversion						
Protein output/CP intake	0.252	0.245	0.232	0.226	0.0063	**
g AAT[2)]/kg ECM	49.2	50.0	48.0	47.6	1.62	ns
ECM/DM intake	1.46	1.42	1.44	1.41	0.034	ns
ME, MJ/kg ECM	5.55	5.81	5.73	5.89	0.212	ns

SEM = Standard error of the mean; Statistical significance: *** (P<0.001), ** (P<0.01), * (P<0.05), o (P<0.10)

[1)] Energy corrected milk calculated with the formula of Sjaunja et al. (1990)

[2)] Amino acids absorbed from the small intestine

to C16:0) FA composition other than a tendency (P<0.10) for the C14:1 proportion to decrease (Table 4). In contrast, C16:1 and C20:0 decreased (P<0.001 and P<0.01, respectively) while C18:0 and C18:3 increased (P<0.01 and P<0.05, respectively). At high LC levels, the proportion of C18:1 tended to decrease (P<0.10). Furthermore LC increased the degree of milk FA saturation (P<0.05).

Discussion

Milk production

Gradual replacement of RC with LC led to a significant decrease in the milk production of the cows. When cereal-based (usually a mixture of rolled barley and oats) concentrates have been replaced, by weight, with rapeseed feeds in Finnish feeding experiments, the production responses have, on average, been 1.07 kg milk or 39.9 g milk protein per kg DM replaced (Ahvenjärvi et al. 1995). Here, the response to replacement of LC with RC resulted in 1.03 kg milk, 0.81 kg ECM and 50 g milk protein output per day per kg DM replaced. These figures reveal that the production potential of LC is basically the same as that of cereal-based concentrates.

In a Swedish experiment using similar feeds, milk production was impaired to a similar extent. Replacement of RC with LC resulted in 0.57 kg less milk and 26 g less milk protein per kg DM replaced (Bertilsson et al. 1994). Kennelly (1996) reported two Canadian experiments investigating full fat linseed. In the first experiment, in which the whole linseed content of the diet was gradually increased (0, 50, 100 and 150

Vol. 6 (1997): 161–172.

Table 4. Effects of gradual replacement of rapeseed cake with linseed cake on milk fatty acid composition (g/kg).

	Proportion of linseed cake					Statistical
	0	1/3	2/3	1	SEM	significance
C4:0	33.3	34.6	33.9	34.5	0.62	ns
C6:0	23.4	23.3	23.3	24.0	0.39	ns
C8:0	13.6	13.2	13.2	13.6	0.37	ns
C10:0	29.0	28.0	28.2	28.3	0.92	ns
C10:1	2.2	4.2	1.3	1.7	0.95	ns
C12:0	32.0	30.7	30.8	30.7	1.08	ns
C12:1	0.3	0.6	0.4	0.4	0.15	ns
C13:0	1.5	1.5	1.3	1.4	0.11	ns
C14:0	109.8	107.6	109.0	108.0	1.65	ns
C14:1	10.2	9.9	9.4	9.3	0.29	o
C15:0	14.6	14.2	14.1	14.3	0.36	ns
C16:0	299.3	298.6	301.9	304.0	3.86	ns
C16:1	17.3	16.7	15.8	15.9	0.16	***
C17:0	10.3	10.7	10.6	10.5	0.19	ns
C17:1	2.6	2.5	2.5	2.4	0.07	o
C18:0	115.6	120.8	128.0	128.0	1.93	**
C18:1	239.6	243.1	236.5	232.4	2.77	o
C18:2	27.0	27.3	27.3	27.4	1.05	ns
C18:3	4.8	5.7	5.7	6.0	0.23	*
Saturated total	685.6	686.4	697.2	700.4	4.16	*
C16:0/C18 total	0.769	0.753	0.755	0.770	0.0174	ns

SEM = Standard error of the mean; Statistical significance: *** (P<0.001), ** (P<0.01), * (P<0.05), o(P<0.10)

g/kg DM), milk production and milk fat content were unaffected but the milk protein content decreased linearly. Thus little benefit was derived from feeding linseed with high protein and high energy contents in preference to other protein supplements which generally elicit rather high production responses. In the second experiment, a diet with no supplemental fat was compared with one including 100 g/kg of whole linseeds, rolled linseeds or a mixture of rolled linseeds and rapeseeds. There were virtually no differences in the production results of the last two diets, which are comparable to those fed in the current experiment. Milk yield was similar in both these diets and the control diet, but feeding whole linseeds significantly lowered milk production. In another Canadian experiment (Khorasani et al. 1994), linseed meal feeding maintained the same milk production as rapeseed meal, but the experimental feeds and basal diet were not comparable to those in our experiment, as the oilseed products were solvent extracted and fed in a whole crop oat silage-based total mixed ration.

In the present experiment, there are several potential causes for the reduced production potential of LC compared with RC: the slightly higher ether extract content of LC, which may have resulted in decreased diet digestibility; differences in FA composition; more extensive ruminal degradability of LC; differences in the amino acid profile; and, possibly, antinutritional factors contained in linseeds.

The linseed cake used here had a higher ether extract content than had RC. This particular rapeseed product was chosen as the reference feed, because it had the highest ether extract content of the domestic rapeseed products commercially available. The detrimental effects of high fat diets on rumen fermentation are well document-

ed. Decreased cellulolytic activity in the rumen would be highly detrimental in diets based extensively on silage, such as in the present experiment, in which 0.64 of diet DM derived from silage, which is high in potentially digestible fibre. A high dietary fibre content may, conversely, diminish the detrimental effects of FA feeding (Jenkins 1993).

Assuming that decreased digestibility on the LC diet was the reason for reduced milk output and that the efficiency of energy utilisation for milk production remained the same, OM digestibility should have declined by 25 g/kg DM. The level of ether extract supplementation was rather low in our experiment and the increase with an increasing proportion of LC was negligible, 47 g/day or from 52.3 g/kg diet DM on an all-RC diet to 55.9 g/kg DM on an all-LC diet. Studies reporting negative effects of fat have generally used higher levels of fat feeding (Palmquist 1984, Tesfa 1992, Wu and Huber 1994), while Palmquist (1976) suggested a 50 g/kg safety limit in dairy cow rations.

The FA composition of the two oilseeds also differs. Rapeseed oil contains high levels of oleic acid (C18:1), but linseed oil is high in linolenic acid (C18:3). In Sweden, the contents of oleic and linolenic acids in RC were 561 and 97 g/kg, and in LC 155 and 551 g/kg, respectively (Bertilsson et al. 1994). Finnish rapeseed oil contained 411 g/kg oleic acid and 73 g/kg linolenic acid (Tesfa 1992), the respective values for Finnish linseed oil being 172 and 619 g/kg (Elixi Oil Ltd., personal communication). On the basis of Finnish reference values, the LC diet resulted in 30 g lower C18:1 intake but 116 g higher C18:3 intake per day. Rumen protozoa are especially vulnerable to the presence of free FAs, and Doreau and Ferlay (1995) suggested, that linseed oil has a more negative effect than other sources of lipid on rumen protozoal number, possibly due to the higher C18:3 content of linseed oil than of other fat sources. The claim has, however, yet to be substantiated.

If the protozoal population had been decreased by LC feeding, it would still be difficult to reconcile the current results. The role of protozoa in digestion is not fully understood, as pointed out by Itabashi et al. (1990). Defaunation may improve the nutritional status of the host animal on a low protein diet but usually protozoa are considered useful to the ruminant. The proportion of butyric acid has been observed to decrease concomitantly with a decline in the protozoal population (Ikwuegbu and Sutton 1982, Sutton et al. 1983, Itabashi et al. 1990, Broudiscou and Lassalas 1991) and butyric acid generally promotes milk fat synthesis. Here, LC feeding resulted in a significant increase in milk fat content, which does not support the speculation of low butyrate production in the rumen as a result of potentially decreased rumen protozoal numbers.

The non-ammonia-nitrogen flow to the duodenum increased in sheep fed 43 g (Ikwuegbu and Sutton 1982), 77 g (Sutton et al. (1983) or 60 g (Broudiscou et al. 1994) of linseed oil in diet DM. The smaller protozoal population probably contributed, a suggestion supported by data of Broudiscou et al. (1994), who used defaunated sheep as a reference. Broudiscou and Lassalas (1991) reported that use of rumen fluid from sheep given linseed oil at a rate of 60 g/kg diet DM reduced the degradability of amino acids *in vitro*. Doreau and Ferlay (1995) argued that lipids have not been shown to decrease total bacterial populations nor non-cellulolytic strains in the rumen, so the above finding does not necessarily apply *in vivo*. The level of linseed oil supplementation in the present experiment was lower than in the studies mentioned earlier, being only 15 g/kg diet DM at the highest inclusion level.

Differences in diet DM ether extract (both amount and FA composition) may have partly accounted for the impaired milk production, but it seems unlikely that these differences could be of major importance.

Both oilseed cakes were almost identical in terms of CP content, but the rumen degradability of CP differed markedly. Linseed protein has been found to degrade rapidly in the rumen (Bertilsson et al. 1994, Moss and Givens 1994), a conclusion we also reached. The heat-moisture treatment of RC used may have further impaired

Vol. 6 (1997): 161–172.

the rumen degradability of its protein, but such treatment has not been shown to improve the production potential of the feed compared with that of untreated rapeseed products (Tuori 1992, Huhtanen and Heikkilä 1996). It is, however, possible that the higher EPD of LC refers to a certain feature in the feed owing to which its production potential is lower than that of RC. Calculated AAT balance (supply/requirement) was adequate in all diets (1.03, 1.04, 1.01 and 1.01 as proportion of LC increased). Moreover, all diets gave the cows sufficient N, as indicated by an average diet DM CP content of 174 g/kg DM and a high milk urea content averaging 6.48 mmol/l.

The amino acid composition of linseed protein is poorer than that of rapeseed protein in terms of the essential amino acids, lysine, methionine, threonine and histidine (Bertilsson et al. 1994, van Kempen and Jansman 1994, Tuori et al. 1996). Susmel et al. (1994) reported a relatively low amino acid content of LC protein (693 g/kg) and also a rather low biological value of LC protein as measured in hamsters (70).

New information on the role of individual amino acids in the metabolism of dairy cows fed grass silage-based diets has recently accumulated at our Institute. Histidine seems to be the first limiting amino acid in diets similar to those tested in the current experiment (Vanhatalo et al. 1997). If we assume that the histidine content of RC was 2.8 g/100 g CP and that of LC 2.1 g/100 g CP (Tuori et al. 1996) and further that the EPD of histidine is similar to that of CP, intestinal histidine supply would have been 3.9 g/day higher on the RC diet than on the LC diet. An increase in histidine supply to the mammary has led to an improvement in milk production and lower milk fat content (Vanhatalo et al. 1997), as was observed here, too, when the proportion of LC in the diet decreased. Inclusion of LC caused a decrease of 12.4% in milk protein yield, 1.3% in fat yield and 9.3% in lactose yield compared with RC-based diets. These figures suggest that mammary amino acid supply or balance may have been an important contributer to the results obtained.

Linseeds are known to contain certain poisonous or antinutritional factors such as the cyanogenic glucosides, linamarin, lotaustarin, linustatin and neolinustatin (see Olsson et al. 1988, van Kempen and Jansman 1994). Several rumen microbes are able to break down linamarin (Majak and Cheng 1987), which leads to the production of highly toxic hydrogen cyanide. Toxic compounds may affect either the microbes in the rumen or the host metabolism. In our experiment, we did not attempt to clarify the possible toxic effects of linseed feeding, and their contribution to the impaired production cannot be totally excluded.

Milk fatty acid composition

Milk FA composition is influenced by the profile of FAs circulating in the blood stream. Dietary effects of FA supplementation on milk FA composition depend on the extent to which dietary FAs escape rumen microbial hydrogenation (Grummer 1991). Here, the content of C18:1 tended to decrease and that of C18:3 increased with increasing LC feeding, reflecting the changes in dietary FA intake. These changes were, however, of minor impact. If we assume similar C18:3 intakes from the basal diet, the approximate intake of C18:3 on the all-LC diet was 116 g/day higher than on the RC diet. The difference in milk output of C18:3 was 0.8 g/day, leading to an extraction rate of only 0.07%. It is apparent that C18:3 was almost totally hydrogenated to C18:0 in the rumen. Subsequent intestinal and mammary desaturase activity resulted in high C18:1 outputs in milk, such as are generally observed when any FAs containing 18 carbon units (C18) are fed in dairy rations (Grummer 1991). The milk FA profile was very similar in all diets owing to the similar intakes of C18 FA. The ratio of C16:0 to C18 FA in milk has been used to describe the potency of milk to affect human blood cholesterol levels (Grummer 1991). We noted no differences. C18:1 was not analytically separated into different positional isomers, but it is possible that partial hydrogenation of C18:3

in the rumen led to a greater accumulation of *trans* isomers of C18:1 and C18:2 (Grummer 1991) in cows on LC diets than in those on RC diets.

Other researchers have been able to markedly affect milk FA composition when comparing diets with no additional lipid supplementation and those containing linseed oil. McDonald and Scott (1977) reported that feeding approximately 80 g/kg linseed oil protected from rumen microbes by formaldehyde-treated casein increased the milk C18:3 content dramatically from 10 to 220 g/kg. A gradual increase in whole full fat linseed from 0 to 150 g/kg DM raised the total C18 FA content from 316 to 476 g/kg and C18:3 from 8 to 12 g/kg (Kennelly 1996). Comparison of rolled linseed with a mixture of rolled linseed and rapeseed offered at a level of 100 g/kg DM resulted in a decrease in C18:0 (124 *vs* 143 g/kg), but both C18:2 (31 *vs* 24 g/kg) and C18:3 (10 *vs* 8 g/kg) were higher on the all-linseed diet (Kennelly 1996). Similarly, comparison of RC and LC led to negligible but significant increases in C18:3, from 7 to 9 g/kg (Bertilsson et al. 1994). In conclusion, the content of C18:0 and C18:1 in milk can be increased to a certain extent by feeding cowss unprotected linseed products, i. e. by increasing their total intake of any C18 FA, but if the content of C18:3 needs to be increased considerably, FAs need to be protected from biohydrogenation in the rumen. Note, however, that increased unsaturation of milk FAs increases the risk of oxidation and instability of milk and milk products and may impair their sensory quality.

Conclusions

The results of the present experiment suggest that linseed cake is less suitable than rapeseed cake for dairy cow feeding. If linseed cultivation continues to expand and/or demand for milk produced by linseed feeding to increase, it may be necessary to evaluate the effects of linseed processing on milk production. Linseed products could benefit from decreased ruminal protein degradability, and antinutritional factors could probably be reduced in the process. To overcome the possible negative effects of linseed FAs on rumen microbes (Sutton et al. 1983) and to amplify changes in milk FA composition (McDonald and Scott 1977), it might be beneficial to protect linseed oil from rumen microbial interference.

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SELOSTUS

Rypsipuristeen asteittainen korvaaminen pellavapuristeella lypsylehmien säilörehuun perustuvassa ruokinnassa

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Maatalouden tutkimuskeskus ja Koivikon maatalousoppilaitos

Lypsylehmien ruokintatutkimuksessa rypsipuristetta korvattiin asteittain pellavapuristeella siten, että pellavapuristeen osuus oli 0, 1/3, 2/3 tai 1 valkuaisrehusta, jonka määrä oli yhteensä 1,5 kg ilmakuivaa rehua päivässä. Koerehujen lisäksi lehmille annettiin 4,5 kg/pv ohran ja kauran seosta ja vapaasti nurmisäilörehua. Kokeessa oli 8 Koivikon maatalousoppilaitoksen suomenkarjalehmää.

Koeruokinnat eivät vaikuttaneet rehujen syöntiin. Nailonpussiuitoin määritetty valkuaisen pötsihajoavuus oli pellavapuristeessa suurempi kuin rypsipuristeessa, mikä johti pienempään ohutsuolesta imeytyvien aminohappojen saantiin mutta suurempaan pötsin valkuaistaseeseen ruokinnoilla, joissa pellavapuristeen osuus oli suuri.

Maitotuotos pieneni suoraviivaisesti 18,5:stä 17,1 kg:aan/pv, kun pellavapuristeen osuus lisääntyi. Maidon rasvapitoisuus suureni 3,4 g/kg, mutta maidon valkuaispitoisuus pieneni lievästi pellavapuristeen lisääntyneen syötön myötä. Pellavapuristeen lisäys ei vaikuttanut päivittäiseen maitorasvan tuotantoon, mutta maitovalkuaisen tuotanto väheni 68 g/pv. Maidon ureapitoisuus lisääntyi pellavapuristeen lisäyksen myötä. Rypsi- ja pellavaöljyn rasvahappokoostumuksen selkeästä erosta huolimatta muutokset maidon rasvahappokoostumuksessa olivat erittäin pieniä.

Pellavapuristeen hieman suurempi rasvapitoisuus, rasvahappokoostumus, valkuaisen suuri pötsihajoavuus ja/tai heikko aminohappokoostumus sekä mahdolliset haitta-aineet ovat voineet vaikuttaa pellavapuristeen rypsipuristetta heikompaan tuotantovaikutukseen. Mikäli öljypellavan viljely lisääntyy entisestään tai pyritään tuottamaan terveysvaikutteisia maitotuotteita, joissa pellavaöljyn rasvahappoja halutaan siirtää maitoon, kannattaisi selvittää pellavapuristeen prosessoinnin vaikutuksia tuotantovaikutukseen ja rasvahappojen suojaamiseen pötsimikrobien muokkaukselta.