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Nutritive value of evening primrose (*Oenothera paradoxa*) cake for ruminants

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ABSTRACT

The nutritive value of evening primrose (*Oenothera paradoxa*) oil cake was estimated from chemical composition and nutrient digestibility. The cake contained on average (per kg): 210 g crude protein, 0.55 UFL, 0.44 UFV, 110 PDI (PDIE – PDIN = – 22 g), 92 g PDIA and 100 g of ether extract. The proportion of methionine and cystine in cake was relatively high (1.97 and 2.17 g/16 g N) but that of lysine was rather low (2.00 g/16 g N). Linoleic ($C_{18:2\ n\ 6}$) – 73.1%, γ-linolenic ($C_{18:3\ n\ 6}$) – 9,0% and oleic ($C_{18:1\ n\ 9}$) – 6.4% acids dominated in total fatty acid content. Rumen degradability and intestinal digestion coefficients of protein of evening primrose oil cake or seeds were 0.39 and 0.65, respectively.

KEY WORDS: evening primrose cake, nutritive value, ruminant

INTRODUCTION

Oil obtained from evening primrose (*Oenothera paradoxa*) seeds is used in therapeutics as a new source of essential polyunsaturated fatty acids, particularly γ-linolenic acid ($C_{18:3\ n\ 6}$) (Wolf et al., 1983; Hudson, 1984; Lammer-Zarawska, 1992; Lammer-Zarawska et al., 1992) which is involved in prostaglandin synthe-

sis as an intermediate metabolite of linoleic acid ($C_{18:2\ n\ 6}$) transformation (Horrobin, 1990).

Oil cake, a by-product obtained by squeezing the oil from evening primrose seeds in a cold pressing process, contains a relatively high level of fat and crude protein (Grela, 1995) and can be used as a feed for animals. In an experiment on rats Hanczakowski and Szymczyk (1993) found only limited suitability of this product as a feed for monogastric animals because of the low protein digestibility due to antinutritional factors present in it. Dixon and Hosking (1992) reported that rumen fermentation could modify antinutritional compounds to less harmful compounds for ruminants.

The aim of the present study was to estimate the nutritive value of evening primrose cake and as a source of polyunsaturated fatty acids for ruminants.

MATERIAL AND METHODS

Evening primrose (*Oenothera paradoxa*) oil cake was obtained by a cold pressing process from Agropharm mill (Poland). Proximate analysis, coefficients of crude protein degradation in the rumen *in situ* and intestinal digestibility of rumen undegraded protein of evening primrose cake (mobile bag technique) were determined. Individual fatty acids in fat, amino acids, minerals, trypsin inhibitor, carotenoids, xantophyll and glucosinolates were also determined. Soyabean oilmeal containing 45.7% crude protein was the reference sample for rumen degradability, intestinal digestibility and amino acid composition of feed protein. Rape seeds were used as the reference feed for fatty acid content. Evening primrose seeds were analyzed only for nutrient content, rumen protein degradability and intestinal digestibility.

Digestibility experiment

Digestibility coefficients of nutrients of evening primrose oil cake were determined on 6 bulls of 430±30 kg body weight (BW) by the difference method in two 35-day periods: 30 days of adaptation and 5 days of faeces collection. In the first period the animals were individually fed basic daily rations in two portions consisting of 1 kg of meadow hay and 6 kg of concentrate containing 14% crude protein (10% evening primrose cake and 90% ground barley) supplemented with 150 g of mineral mixture. In the second period the daily ration was decreased to 70% of the basic ration and supplemented with 2.5 kg of evening primrose oil cake mixed carefully with the concentrate.

Protein degradability

Protein degradability was determined according to Michalet-Doreau et al. (1997) *in sacco* using 3 bulls of 500±30 kg BW with rumen cannulas. Animals were fed at 8.00 and 16.00 a daily ration of 8.7 kg DM consisting of (%) meadow hay, 60 and concentrate, 40. The concentrate contained 15% crude protein and consisted of (%): ground barley, 50; ground wheat, 10; soyabean meal, 10; wheat bran, 28; and mineral mixture, 2. Samples of cake were ground to a particle size of 0.75 mm and placed (3 g) in polyamide bags (7.5x10 cm) with a pore size of 42 μm and then inserted into the rumen for 2, 4, 8, 16, 24 and 48 h. Effective degradability coefficients were calculated at a rumen outflow rate of 0.06 h^{-1}.

Intestinal digestibility

Digestibility coefficients of evening primrose cake protein undegraded in the rumen was carried out using the mobile bag technique according to Peyraud et al. (1988) on 3 bulls of 400±30 kg BW with cannulas inserted into the duodenum about 10 cm after the abomasal pylorus, and 3 bulls with rumen cannulas used in the previous experiment for degradability determination. The animals were fed as in the degradability experiment. Samples of feed were previously digested in the rumens of bulls for 16 h (15 bags of each feed) and subsequently digested for 2.5 h with pepsin solution (300-600 U/l) at pH 2 and 38.5°C (30 bags per 1 l of solution). Afterwards the bags were introduced 2.5 h after feeding animals, into the duodenum (5 at each 1.5 h). The bags were retrieved from the faeces but these which were excreted later than 24 h since introducing into duodenum were rejected.

Chemical analysis

Proximate analysis of feeds and faeces was carried out according to AOAC (1990) methods. Gross energy was determined using a KL-10 automatic calorimeter. Fatty acids were extracted from cake according to Bligh and Dyer (1959) and after transformation into methyl ester derivatives, determined with a Philips PU 4500 GLC using a 2 m long column filled with 10% EGSS-X on Chromosorb P, 100-200 mesh and argon as the carrier gas. The temperature of the column, detector and evaporator was 160, 250 and 219°C, respectively. Amino acids were analyzed with a Carlo-Erba 3A29 automatic analyzer. Mineral components were determined using atomic absorption equipment. Glucosinolates (ITC and VTO) were estimated according to Wetter (1955,1957), trypsin inhibitor activity using the method of Kakade et al. (1969), tannins with the vanillin method after extraction with a 1% solution of HCl in CH3OH (Price et al.,

1978), carotenoids according to Polish Standard Methods (1977) and xanthophyll according EEC (1984).

The nutritional value of feeds was estimated according to the INRA system (IZ, 1993) using INWAR ver. 1.0 (1993) software.

RESULTS

Analysis of evening primrose cake indicated a high content of crude protein, crude fibre and ether extract but rather low N-free extractives (Table 1). The cakes contained 20% more crude protein and 23% crude fibre but 68% less ether extract than unprocessed seeds.

TABLE 1

Content and digestibility of nutrients, rumen degradability and intestinal digestibility of feeds

Item	Dry matter	Organic matter	Crude protein	Crude fibre	Ether extract	Ash	N-free extactives	Gross energy Mcal
Evening primrose cake:								
chemical composition,%	88.91	81.35	21.31	22.73	7.69	7.56	29.62	4.17
digestibility *in vivo*,%	48±9.8	51±10.1	57±4.0	38±5.9	76±3.8	–	28±2.5	49.4
degradability			0.52					
intestinal digestibility			0.62					
Evening primrose seeds:								
chemical composition,%	91.90	85.99	17.74	18.43	23.76	5.91	26.06	5.15
degradability			0.23					
intestinal digestibility			0.67					

The highest digestibility coefficients were found for fat and the lowest for N-free extractives and crude fibre. Degradability of protein determined *in situ* was low and reached 23 for seeds and 52% for cake. Intestinal digestibility of rumen undegraded protein was similar for both seeds, 67%, and oil cakes, 62%. Degradability in the rumen and digestibility in the small intestine of soyabean oilmeal protein as a reference source of protein were 42 and 95%, respectively (Table 1).

Protein of evening primrose cake contained three times less lysine but markedly more methionine and cystine than soyabean protein (Table 2). The content of oleic acid ($C_{18:1\,n9}$) and α-linolenic acid ($C_{18:3\,n3}$) was markedly lower but linoleic acid ($C_{18:2\,n6}$) and γ-linolenic acid ($C_{18:3\,n6}$) higher in evening primrose cake than in rape seeds. Evening primrose cake abounded in minerals (Table 2) and was characterized by antitrypsin activity (9845 UIT/g protein), high level of tannins (116

TABLE 2

Content of fatty acids, amino acids and minerals in feeds

Fatty acids, %			Amino acid, g/16gN			Minerals in cake	
	ev. primrose			ev.primrose soyabean		element	
Acid	cake	rape seeds	amino acid	cake	oilmeal	g/kg	
C_{10}	0.06	–	Asp	7.23	10.28	Ca	23.66
C_{12}	0.05	0.01	Thr	3.00	3.83	P	4.62
$C_{12:1}$	0.05	–	Ser	4.36	3.72	Na	0.06
C_{14}	0.08	0.08	Glu	15.16	17.68	Mg	4.65
$C_{14:1}$	0.06	–	Pro	2.67	4.00	K	9.61
C_{15}	0.09	0.02	Gly	5.52	3.94		
iso-C_{16}	0.06	0.02	Ala	3.11	3.20		
						mg/kg	
C_{16}	5.47	4.36	Val	3.93	4.51	Fe	170.5
$C_{16:1}$	0.18	0.32	Ile	2.81	4.29	Mn	122
C_{17}	0.20	0.05	Leu	5.94	7.69	Zn	80.9
iso-C_{18}	0.28	0.05	Tyr	2.89	2.83	Cu	12.2
C_{18}	1.89	1.49	Phe	4.76	3.66	Pb	1.4
$C_{18:1}$	6.35	58.65	His	2.65	3.64	Cd	0.2
C_{19}	0.13	–	Lys	2.00	6.68		
$C_{18:2\ n6}$	73.10	20.50	Arg	10.82	9.39		
$C_{18:3\ n6}$	9.01	0.66	Cys	2.17	0.87		
$C_{18:3\ n3}$	0.45	10.85	Met	1.97	1.46		
C_{21}	0.12	–					
$C_{20:2}$	0.15	–					
$C_{20:4\ n6}$	0.56	–					
$C_{20:5\ n3}$	0.76	–					
C_{22}	0.44	0.16					
$C_{22:1}$	–	2.24					
$C_{22:4}$	0.13	0.13					
C_{24}	0.33	0.11					

mg/g) and contained carotenoids (0.6 μg/g) and xanthophyll (0.2 μg/g), but the presence of glucosinolates was not detected.

The nutritive value of the evening primrose cake and unprocessed seeds estimated according to the INRA system (IZ, 1993) revealed a high level of PDIA and similar level of PDIN and PDIE. Both feeds were rather low in nutritive value (FU/kg of feed) and their energetic values for meat production (UFV) were by about 20% lower than for lactation (UFL) (Table 3).

TABLE 3

Nutritive value of feeds according to INRA system, in 1 kg of feed [1]

Feed	UFL	UFV	PDIA	PDIN	PDIE
Evening primrose cake	0.55	0.44	92	132	110
Evening primrose seeds	0.68	0.55	101	116	108

[1] INWAR wer. 1.0 (1993) accepting the same digestibility coefficients for cake and seeds

DISCUSSION

The fat content in evening primrose cake was rather low (8.6% in DM) whereas a similar product obtained from the same mill but of different batch had a 60% higher fat content. Szymczak and Drzewicka (1992) and Hanczakowski and Szymczyk (1993) also found that the content of ether extract in DM of primrose cake is variable and ranges from 6.1 to 17.0%. The differing ether extract content in various batches of evening primrose cake found in our laboraty (8.6 and 13.9% in DM) suggests that parameters of pressing were different for batches. Variable fat content in the cake can influence digestibility of nutrients (Kowalczyk et al., 1976). The level of the remaining nutrients was comparable if recalculated for samples of cake as content in fat-free matter.

The nutrient content in evening primrose cake and digestibility in total digestive tract were within the limits given by Nehring et al. (1972) for other cakes. The low digestibility of crude fibre in bulls could probably be explained by small particles of cake enhancing faster passage of fibre along the digestive tract (Strzetelski et al., 1987a) and with relatively high level of fat in the diet which decreases digestion of fibre (Kowalczyk et al., 1977). Low digestibility of protein, crude fibre and N-free extractives resulted in a low level of organic matter digestion and thereby digestible energy and UFL and UFV values (INRA-PAN, 1993). The low value of the ratio of N-free extractives to crude fibre content (1.2) could be the reason why the UFV value of the cake was smaller than UFL.

The high level of tannins in evening primrose cake could negatively influence crude protein digestibility. Tannins forming insoluble complexes with the feed protect protein from rumen degradation and reduce intestinal digestibility of undegraded protein (Pisulewski and Ryś, 1974). Low values of protein degradability in the rumen and intestinal digestibility found in the present experiment confirm their statement. The influence of trypsin inhibitor present in the cake should be also taken into consideration in lowering digestibility as the inhibitor can pass into the intestine in active form and additionally restrict digestibility. In their study on the efficiency of protein extraction from evening primrose cake, Szymczak and Drzewicka (1992) found that such protein had a low solubility, limited digestibility and availability. Studies of Hanczakowski and Szymczyk (1993) on rats confirm the limited digestibility of evening primrose cake protein.

Biohydrogenation of polyunsaturated fatty acids in the rumen could be limited as an effect of oils being protected by the protein-tannin complex (Strzetelski et al., 1987b) since fat digestion could be partially displaced from the rumen into the intestine. This in turn would be advantageous in feeding ruminants considering improvement of fat composition and beef quality (Strzetelski et al., 1992, 1993) as fat in evening primrose seeds or cake contains a high proportion of unsaturated fatty acids, particularly linoleic, γ-linolenic and oleic acids. Including evening primrose seed oil or oil cake into the diet could also protect protein from rumen degradation (Szyszkowska et al., 1994). Nonetheless, it is possible that the level of fat in the feed affects protein degradability (Kowalczyk et al., 1977) since the respective coefficients of protein degradability in the rumen are lower for evening primrose seeds than for cake containing less fat.

The lower digestibility of crude fat of evening primrose cake compared with fat of soyabean cake (Nehring et al., 1972) could probably be explained by protection of fat by a protein-tannin complex.

Amino acid composition of evening primrose cake protein compared with that of soyabean oilmeal suggest that cake could be a good source of the sulphur-containing amino acids, cystine and methionine, but its lysine content is low. Szymczak and Drzewicka (1992) reported that the biological value of cake was similar to that of oat protein, but with a favourable cystine and methionine content.

The proportion of fatty acids in the fat of evening primrose oil cake was characterized by a high level of unsaturated fatty acids. A similar proportion of unsaturated fatty acids in evening primrose oil was found, in agreement with the findings of other authors (Manku, 1983; Sołtyhwo, 1992; Szymczak and Drzewicka, 1992; Zaderenowski et al., 1992). The high level of γ-linolenic acid in the cake in comparison with its content in rape seeds suggests that evening primrose cake could be used as a biologically active factor as well as a γ-linolenic acid source that improves animal product quality.

Mineral components in evening primrose cake were found in amounts similar to those reported by Szymczak and Drzewicka (1992). The level of Zn, Pb and Cd in cake exceeded Polish Standards and, according to Lammer-Zarawska and Hojden (1992), the level of heavy metals in evening primrose seeds should be controlled since it depends to a high degree on exposure to industrial and urban pollution.

It can be concluded that evening primrose cake can be a supplementing feed for balancing protein and energy in the case of feeds containing protein easy degradable in the rumen, considering the high PDIA content and low energy value (UFL and UFV/kg) of primrose cake. Oil cake could be a good complementary source of sulphur-containing amino acids and polyunsaturated fatty acids, particularly γ-linolenic acid as biologically active factors that favourable affect the quality of animal products. However, its use can be limited by low intestinal digestibility of rumen undegradable protein and its low lysine content.

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STRESZCZENIE

Wartość pokarmowa makuchu z wiesiołka (*Oenothera paradoxa*) dla przeżuwaczy

Wartość pokarmową makuchu z wiesiołka oznaczono na podstawie jego składu chemicznego oraz oznaczonych współczynników strawność składników pokarmowych. Makuch zawierał średnio, w kg: białka ogólnego 210g, UFL 0,55; UFV 0,44; PDI (PDIE – PDIN = – 22g) 110; PDIA 92 g i ekstraktu eterowego 100 g. Zawartość metioniny i cystyny w makuchu była stosunkowo wysoka (1,97 i 2,17 g/16 g N), lizyny niska (2,00 g/16 g N).

Kwasy linolowy ($C_{18:2\ n\ 6}$) – 73,1%; γ- linolenowy ($C_{18:3\ n\ 6}$) – 9,0% i olejowy ($_{C18:1\ n\ 9}$) – 6,4%, dominowały w sumie kwasów. Rozkład białka w żwaczu i jego strawność jelitowa makuchu i nasion wiesiołka wynosiły odpowiednio 0,39 i 0,65.