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Comparison of nutritive value of new commercial linseed oily cultivars for ruminants

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ABSTRACT

The chemical composition, fatty acid profile, content of amino acids, minerals, and gross energy of seeds of some commercial linseed oily cultivars: brown-seed (Flanders, Opal and brown-seed mixture) and yellow-seed (Hungarian Gold, Linola™947, Linola™989, Hungarian ecotype) were determined. The nutritive value of seeds for ruminants was also assessed according to the Polish IZ-INRA (1997) standards. Lysine was the main limiting AA for all cultivars. There were significant differences between cultivars in the contents of unsaturated fatty acids, $C_{18:2}$, $C_{18:3}$. In the Linola™947 and Linola™989 cultivars, the level of linolenic acid ($C_{18:3}$) was very low (about 2%), but the level of linoleic acid ($C_{18:2}$) was over 72% of total acids. There were differences between cultivars in PDIN and PDIE.

KEY WORDS: linseed oily cultivars, chemical composition, nutritive value, fatty acids, amino acids

INTRODUCTION

The new linseed (*Linum usitatissimum* L.) oily cultivars (LOC) are one of the most interesting alternative crops planted and distributed in some European countries, including Poland (Wałkowski et al., 1998). Linseed oil is used in the chemical, food, pharmaceutical, and cosmetic industries. The linseeds of oily cultivars are used in the bakery industry (Gambuś et al., 1999 a) and animal feeding (Brzóska et al., 1999; Barowicz, 2000; Stasiniewicz et al., 2000; Trevino et al., 2000).

The high nutritive and dietetic value of LOCs are the main reasons for the growing interest in using them for animals. Depending on the cultivars, LOC may contain 20-30 % crude protein of a desirable amino acid (AA) composition, and 38-47 % crude fat of which more than half is unsaturated fatty acids (Rowland et al., 1990 a,b; Kulasek and Bartnikowska, 1994; Sahi and Leitch, 1994; Dribnenki et al., 1999; Barowicz, 2000). However, the variation in chemical composition and nutritive value of different LOCs still needs to be evaluated. LOC also contain many mineral components (Brzóska et al., 1999) as well as pectins (which create a slime that can stimulate mucosa in the gastrointestinal tract) and lignans (with anticarcinogenic properties) (Cunnane et al., 1993).

So far, for breeding and planting objectives, the yield, morphological features of a plant, resistance to diseases and storage have been the main criteria for LOC evaluation (Rowland et al., 1990 a,b; Wałkowski et al., 1998; Dribnenki et al., 1999). However, the usefulness of LOC in animal nutrition should be evaluated on the basis of nutritive value. High energy and protein content may encourage more intensive use of LOC in high-yielding dairy cow or fattening cattle.

The aim of the study was to compare different linseed oily cultivars in order to find the effect of seed colour on chemical composition, AA composition, fatty acid profiles and nutritive value for ruminants.

MATERIAL AND METHODS

Two types of seeds of linseed oily cultivars were compared: brown-seed (Flanders, Opal) and yellow-seed (Hungarian Gold, Linola™947, Linola™989, Hungarian ecotype) and a brown-seed mixture used by the feed industry (CSM). The seeds were obtained from experimental plots of the Department of Plant Production of the Agricultural University of Cracow or from the Institute of Natural Fibres (Poznań, Poland).

The chemical composition was determined according to AOAC (1990), whereas NDF, ADF, ADL, according to the Goering and Van Soest (1970) methods. Phosphorus was analysed by the colorimetric method described by Skulmowski (1974), Ca, K, Na, Mg by atomic absorption spectroscopy (AAS-1, CARL-ZEISS, Jena, Germany). Gross energy was measured by a calorimetric bomb KL 10 (PRECYZJA, Bydgoszcz, Poland). The fatty acid profile was determined by gas chromatography using a Varian 3400 CX (VARIAN ASSOCIATES, Palo Alto, USA) GC with FID detector (argon; DB–23 column of 30 m x 0.53 mm i.d.; column and detector temperature was 100–205°C and 240°C, respectively). Amino acids were determined using a Carlo–Erba 3A–29 analyser (CARLO-ERBA, Italy) after hydrolysis with 6N HCl (110°C, 20 h). Sulphur-containing amino acids were assayed after oxidation with perchloric acid.

The results of chemical analyses were used in the estimation of nutritive value for ruminants, according to the Polish IZ-INRA (1997) standards, using Winwar software (version 1.3; DJ GROUP, Cracow, Poland). In the calculation of PDIN (protein truly digestible in the intestine, calculated when N is not limiting in the rumen), PDIE (protein truly digestible in the intestine, calculated when energy is not limiting in the rumen) and PDIA (dietary protein undegraded in the rumen but digested in the intestine), the coefficients of N degradability in the rumen and intestinal digestibility of rumen-undegraded protein were 0.80 and 0.60, respectively, according to INRA (1989).

RESULTS AND DISCUSSION

The chemical composition of LOC is presented in Table 1. The average protein content in all cultivars was 228 g kg^{-1} DM. These results are similar to values given in IZ-INRA (1997; 251 g kg^{-1} DM), Wałkowski et al. (1998), Brzóska et al. (1999) and Trevino et al. (2000), but lower than the 325 g kg^{-1} DM reported by Rowland et al. (1990 a,b). There were considerable differences between cultivars in the concentration of crude protein, with the highest contents in the Opal (brown-seed)

TABLE 1

Chemical composition of some linseed oily cultivars, in g kg^{-1} dry matter

Item	Brown seed cultivars			Yellow seed cultivars			
	Flanders	Opal	CSM[1]	Hungarian Gold	Hungarian ecotype	Linola™947	Linola™989
Dry matter, g kg^{-1}	924.7	934.3	926.4	955.8	924.7	941.2	936.5
Ash	38.5	41.6	36.3	44.3	41.7	32.6	32.2
Organic matter	961.5	958.4	963.7	955.7	958.3	967.4	967.8
Crude protein	222.3	273.1	217.3	231.5	241.3	202.5	208.2
Ether extract	459.9	430.6	470.5	429.3	467.3	451.4	445.5
Crude fibre	97.8	84.9	116.1	129.9	94.9	110.2	126.1
N-free extractives	181.5	169.8	159.8	165.0	154.8	203.3	188.0
NDF	413.4	463.6	387.7	353.8	410.5	331.7	339.8
ADF	187.9	157.0	246.5	200.4	144.0	148.7	173.1
ADL	56.0	41.3	66.9	29.3	29.8	27.2	28.9
Ca	2.1	2.0	1.7	1.2	2.1	2.2	2.1
P	7.1	7.9	6.7	5.8	7.4	5.7	5.8
Mg	3.4	3.7	3.6	3.1	3.6	3.2	3.0
K	6.0	6.1	6.4	6.4	6.1	5.5	5.6
Na	0.5	0.4	0.4	0.8	0.4	0.4	0.5

[1] CSM – commercial seed mixture

and Hungarian ecotype (yellow-seed) cultivars. The protein level in brown-seed cultivars was on average about 8 % higher than in yellow ones.

The average ether extract content in all cultivars was 451 g kg^{-1} DM. The differences between cultivars were not as big as in protein content, however, brown-seed cultivars contained more fat than yellow ones. This low variation between cultivars may have resulted from the fact that fatty acid content and profile have been the main traits in the breeding programme of linseed improvement (Sahi and Leitch, 1994; Grant et al., 1999; Saeidi and Rowland, 1999).

Similarly to protein content, the contents of crude fibre (average 109 g kg^{-1} DM) and fibre fractions (NDF, ADF, ADL) also depended on the cultivars. There was more crude fibre in the yellow- than in the brown-seed ones. On the other hand, average NDF, ADF, ADL contents in brown-seed cultivars were slightly higher than in yellow ones.

There were no differences among cultivars in the contents of macroelements, except for Ca. The Hungarian Gold and CSM contained less Ca than others, but this might have resulted from some unknown agronomy factors. The mineral contents of the studied cultivars were similar to those published in Ziołecka et al. (1987).

There were differences among LOC in AA composition (Table 2), particularly in aspartic acid, glutamic acid, leucine, tyrosine, phenylalanine, arginine, lysine and cystine. Compared with other cultivars, the Linola ones had lower concentrations of almost all AA (g kg^{-1} DM), however, this reflects the lower concentration of total AA in Linola cultivars.

The calculated essential AA index (EAAI; by the Oser method) averaged 68 (Table 2). Brown seeds had slightly higher EAAI than yellow ones, but the variation was higher among brown cultivars. Lysine was the main limiting AA in all cultivars, methionine in 5 cultivars, cystine in 4, isoleucine in 1 (Linola™947) and threonine in 1 (Linola™989). Nevertheless, the results show that LOC may be a good source of essential AA for farm animals, particularly for dairy cows.

The fatty acid profile (% of sum of fatty acids) of linseed fat was different among cultivars (Table 3), particularly in terms of unsaturated fatty acids. Myristic acid ($C_{14:0}$) was not found in Linola™947 and Linola™989. On the other hand, the content of stearic acid ($C_{18:0}$) was lower and palmitic acid ($C_{16:0}$) was higher in these cultivars in comparison with others. There were significant differences between cultivars in the contents of unsaturated fatty acids, particularly $C_{18:2}$ and $C_{18:3}$. In the Linola™947 and Linola™989 cultivars the level of linolenic acid ($C_{18:3}$ n-3) was very low (about 2%; the fat of other cultivars contained over 50 % of this acid); in contrast, the level of linoleic acid ($C_{18:2}$ n-6) was over 72% of total acids. These cultivars were developed in Canada, and the Canadian breeding programme for linseed has been aimed at increasing the content of $C_{18:2}$ at the cost of $C_{18:3}$ and $C_{18:1}$ (Dribnenki et al., 1999; Grant et al., 1999; Saeidi and Rowland,

TABLE 2

Amino acid content of linseed oily cultivars, in g kg^{-1} dry matter

Item	Brown seed cultivars			Yellow seed cultivars			
	Flanders	Opal	CSM	Hungarian Gold	Hungarian ecotype	Linola™947	Linola™989
Thr	6.56	7.26	6.07	6.40	7.02	6.01	5.53
Asp	21.77	25.10	20.82	22.54	24.11	18.38	20.28
Ser	9.72	10.82	9.63	10.24	11.04	7.90	9.22
Glu	40.84	48.39	40.71	43.73	46.63	32.89	37.18
Pro	6.89	7.78	6.90	7.18	8.08	6.71	6.84
Gly	13.02	14.97	12.65	13.17	14.26	10.63	11.88
Ala	10.16	11.74	9.71	10.29	11.15	8.19	9.19
Val	11.19	12.62	10.63	11.03	12.13	9.17	10.06
Ileu	9.82	11.41	9.09	9.79	10.50	7.70	8.63
Leu	13.38	14.99	12.49	13.22	14.04	10.68	11.92
Tyr	5.77	6.33	5.02	5.35	5.87	4.54	5.00
Phe	10.45	11.94	9.60	10.45	11.19	8.47	9.49
His	4.81	5.43	4.58	4.72	5.10	3.82	4.40
Lys	8.55	9.46	8.30	8.41	9.04	7.04	7.94
Arg	20.62	24.28	19.46	21.37	23.01	15.96	18.24
Cys	4.18	5.37	4.38	4.35	4.54	3.93	4.02
Met	3.70	4.26	4.18	3.89	4.32	3.76	3.80
Total AA	201.43	232.15	194.22	206.13	222.03	165.76	183.62
EAAI	69.61	64.57	71.34	66.74	68.83	64.73	67.60
Limiting AA	Met Lys	Lys Cys Met	Lys Cys Met	Lys Cys Met	Lys Cys Met	Lys Ileu	Lys Thr

1999; White et al., 1999). It should also be noted that the content of oleic acid ($C_{18:1}$) was also the lowest in the Linola™947 and Linola™989 cultivars. The composition of fatty acids in fat of other LOC was similar to the results shown by others (Rowland et al., 1990 a, b; Kulasek and Bartnikowska, 1994; White et al., 1999). The differences among cultivars in the fatty acid profile had only a slight effect on the proportion of saturated to unsaturated acids. However, this proportion was higher in brown seeds.

The quantity and proportion of fatty acids determines not only nutritive value but also the dietetic value of a dietary component. Since fatty acids take part in many biochemical reactions in the body, they influence the health, growth, development, production and reproduction of animals and humans (Cunnane et al., 1993; Bartnikowska and Kulasek, 1994). Among unsaturated fatty acids, one of the most important is linoleic acid ($C_{18:2}$, n-6), from which after desaturation and elongation dihomogamma-linolenic acid ($C_{20:3}$, n-6) and arachidonic acid ($C_{20:4}$, n-6)

TABLE 3

Fatty acid contents of linseed oily cultivars, % of total fatty acids

Acid	Brown seed cultivars			Yellow seed cultivars			
	Flanders	Opal	CSM	Hungarian Gold	Hungarian ecotype	Linola TM947	Linola TM989
$C_{14:0}$	0.06	0.04	0.02	0.16	0.03	-	-
$C_{16:0}$	5.88	6.32	5.25	6.90	5.90	7.64	7.60
$C_{18:0}$	4.04	3.25	3.79	3.81	4.32	2.88	3.13
$C_{18:1}$	18.57	22.55	17.16	24.67	20.10	14.41	14.12
$C_{18:2}$ (n-6)	15.19	15.95	15.83	13.29	14.04	72.10	72.85
$C_{18:3}$ (n-3)	55.44	51.50	57.18	50.46	54.71	2.02	1.82
$C_{20:0}$	0.15	0.11	0.15	0.15	0.15	0.21	0.14
$C_{20:1}$	0.17	0.20	0.17	0.05	0.12	0.32	0.23
Other unidentified acids	0.50	0.08	0.45	0.51	0.63	0.42	0.11
Sum of saturated acids	10.3	9.72	9.21	11.02	10.40	10.73	10.87
Sum of unsaturated acids	89.37	90.2	90.34	88.47	88.97	88.85	89.02
Saturated : unsaturated acid ratio	1:8.7	1:9.3	1:9.8	1:8.03	1:8.5	1:8.3	1:8.2
$C_{18:2}$ (n-6) / $C_{18:3}$ (n-3)	0.28:1	0.30:1	0.28:1	0.26:1	0.26:1	36:1	40:1

are synthesized. On the other hand, linolenic acid ($C_{18:3}$, n-3) is a precursor of EPA ($C_{20:5}$, n-3) and DHA ($C_{22:6}$, n-3). The proper ratio of $C_{18:2}$, n-6 to $C_{18:3}$, n-3 in the diets of humans and animals should be 4-10 to 1 (Bartnikowska and Kulasek, 1994). In this context the dietetic value of linseed oily cultivars of high linoleic acid (Linola™947 and Linola™989) contents might have been negatively classified (Table 4). However, in ruminants, the actual proportion of fatty acids that are absorbed in the intestine is highly influenced by the intensive processes of bacterial biohydrogenation of unsaturated fatty acids in the rumen (Tamminga and Doreau, 1991).

TABLE 4

Nutritive value for ruminants of linseed oily cultivars

Item	Brown seed cultivars			Yellow seed cultivars			
	Flanders	Opal	CSM	Hungarian Gold	Hungarian ecotype	Linola TM947	Linola TM989
Gross energy, MJ kg^{-1} DM	27.9	28.1	29.9	29.1	29.3	30.7	29.7
UFL, kg^{-1} DM	1.6	1.5	1.7	1.6	1.6	1.7	1.7
UFV, kg^{-1} DM	1.5	1.5	1.6	1.6	1.6	1.7	1.6
PDIN, g kg^{-1}DM	129	159	126	135	140	118	121
PDIE, g kg^{-1}DM	57	66	56	61	59	56	57
PDIA, g kg^{-1}DM	30	36	29	31	32	27	28

The studied seeds contained 27.9-30.7 MJ GE kg^{-1} DM (Table 4). According to the IZ-INRA (1997) standards, the linseed had high net energy value, e.g. 1.55-1.74 UFL (energy unit for milk production) and 1.50-1.69 UFV (energy unit for meat production). The average PDIN and PDIE contents for brown seeds were 138 and 128 g kg^{-1} DM, whereas for yellow seeds they were 59 and 58 g kg^{-1} DM, respectively. PDIA contents were 32 and 29 g kg^{-1} DM, respectively. These values are similar to those presented in IZ-INRA (1997) standards. The differences mainly reflect the variation in the crude protein content (Table 1).

CONCLUSIONS

The study showed variation between linseed oily cultivars in their chemical composition and nutritive value. The biological value of oily linseed protein is limited by lysine, cystine and methionine content. In Linola™989 and Linola™947 cultivars the level of linoleic acid was very high, whereas the level of linolenic acid was only about 2 %. Such a proportion of fatty acids was completely different from traditional cultivars that contained over 50 % of linolenic acid. There were differences between cultivars in PDIN and PDIE, but not in energy value for ruminants.

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STRESZCZENIE

Porównanie wartości pokarmowej różnych odmian nasion lnu dla przeżuwaczy

Oznaczono skład chemiczny i wartość pokarmową nasion różnych odmian lnu oleistego: Flanders, Opal i mieszanki nasion (odmiany brązowe) oraz Hungarian Gold, Linola™947, Linola™989 i ekotyp węgierski (odmiany żółtonasienne), w tym zawartość podstawowych składników, frakcje włókna (NDF, ADF, ADL), kwasy tłuszczowe, aminokwasy, składniki mineralne oraz energię brutto. Na podstawie przeprowadzonej analizy obliczono wartość biologiczną białka oraz wartość pokarmową dla przeżuwaczy według systemu IZ-INRA (1997), wyliczając zawartość BTJN, BTJE i BTJP oraz JPM i JPŻ.

Odmiany Linola™989 i Linola™947 zawierały dużo kwasu linolowego ($C_{18:2}$), a mało (około 2% sumy kwasów tłuszczowych) kwasu linolenowego ($C_{18:3}$). Proporcja udziału tych kwasów w sumie kwasów tłuszczowych była więc odwrotna niż w pozostałych odmianach. Głównymi aminokwasami ograniczającymi wartość biologiczną białka badanych nasion były lizyna, cystyna i metionina. Zwraca uwagę duża różnica w stosunku zawartości BTJN do BTJE. Różnice w składzie chemicznym i wartości pokarmowej nasion dwóch typów lnu oleistego (brązowonasiennych i żółtonasiennych) powinny być uwzględniane przy wykorzystaniu tych nasion w żywieniu zwierząt.