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Effect of the variety of linseed and its form (rolled or extruded) in dairy cow diets on nutrient digestibility

Wpływ odmiany lnu i formy nasion lnu (gniecione lub ekstrudowane) w dawkach dla krów mlecznych na strawność składników pokarmowych

Summary. Digestibility studies were carried out on the influence of two linseed varieties: traditional (Szafir, high linolenic acid C18:3) and Amon variety (high linoleic acid C18:2) fed in 2 forms (rolled or extruded) on digestibility of the diet of cows fed in the dry and lactation periods. Linseed contained 3 or 6% of the diet dry matter in dry (3rd week previous to parturition) and lactation (10th week after calving) periods, respectively. The study was conducted on Polish Holstein-Friesian cows, 4 heads in each treatment. Apparent digestibility coefficients of diet nutrients, namely total organic matter, total protein, crude fiber, ether extract and nitrogen-free extract were determined. No influence of the investigated linseed varieties on the feed intake or diet digestibility, given both to the dry (3%) and lactating cows (6% diet dry matter), was noted. Also, the form of linseed (rolled or extruded) did not significantly influence the feed intake or digestibility of the organic matter. However, it had an impact on crude protein and crude fiber digestibility when 6% of linseed (lactation period) was fed. Linseed in the rolled form decreased ($p \leq 0.05$), whereas linseed extrudate increased ($p \leq 0.05$) digestibility coefficients of these nutrients

Key words: rolled linseed, linseed extrudate, variety, dairy cows, feed intake, digestibility

INTRODUCTION

Interest in the area of supplementing ruminant animal diets with various fat sources has increased over the past decades [Hess *et al.* 2008]. Initially, the primary aim of fat addition to the diets consumed by ruminants was to provide concentrated energy. Presently, the increase interest in fat utilization in ruminant nutrition is mainly a possibility to modify fatty acid composition of animal origin food products (milk, meat). Especially increased interest in feeding traditional varieties of linseed in dairy cows is noted, be-

cause of high level of linolenic acid in its fatty acid (FA) profile. This fatty acid promotes increased n-3 fatty acids and conjugated linoleic acid (CLA) content in milk [Chilliard *et al.* 2007]. Introduction of fat supplement to the ruminant diets may, however, have a negative impact on fermentation process in the rumen, and finally it can influence the total tract digestibility of dietary nutrients [Jenkins 1993]. The impact depends on the amount of the inserted additive [Hess *et al.* 2008], its form, e.g. crude or processed (extruded, micronized) oilseeds [Gonthier *et al.* 2004, Doreau *et al.* 2009] and diet composition, mainly high roughage vs. high concentrate diets [Hess *et al.* 2008].

From among oilseeds, treated in Petit [2002] and Beauchemin *et al.* [2009] studies as feed additives, the strongest negative impact on the diet digestibility was noted for traditional varieties of linseed, characteristic for its high content (over 50% of total FA) of linolenic acid (C18:3). Especially lower digestibility of diet nutrients was observed when linseed was compared with a supplement of crushed canola seeds, high in C18:1 (near 60% of total FA) [Beauchemin *et al.* 2009]. Somewhat smaller differences were noted by Petit [2002], who compared linseed with micronized soybeans, rich in C18:2 (near 60% of total FA). There is lack of digestibility investigations on dairy cows fed linseed with modified fatty acid profile in comparison with traditional varieties, containing, like soybean, high level of linoleic acid.

The aim of the study was to determine the effect of two linseed varieties – a traditional one and a variety with high linoleic content, fed in rolled or extruded form in cow diets during dry and lactation period.

MATERIAL AND METHODS

This work constituted a part of investigations carried out on dairy cows and their calves on the influence of different varieties and forms of linseed on production and composition of obtained products (milk, veal).

Two experiments on multiparous Polish Holstein-Friesian cows, during late pregnancy and in lactation, were conducted. Experiment 1 was carried out on 56 cows, divided by analogues into 3 groups: control and two experimental ones (RLS and RLA) receiving in their diets a rolled linseed of different varieties, Szafir or Amon, respectively. Szafir variety is characteristic for its high level of linolenic acid, whereas Amon contains high content of linoleic acid. Experiment 2 comprised of 36 cows, divided analogically into 3 groups: control and two experimental ones (ELS and ELA), fed extrudates of linseed of the same varieties used in experiment 1.

The animals were fed according to IZ-PIB INRA [2009] norms. The basal rations of all groups in both experiment based on maize silage, grass haylage, and meadow hay mix, at 69 : 19 : 12 ratio (DM basis), during dry period and at 71 : 21 : 8 portion in lactation, given *ad libitum*. Linseed of both varieties and forms was introduced to the diets in amount of 3 and 6% (DM basis) in late dry period and lactation, respectively. The daily diet DM intake was estimated at the level of 12.8 and 20.2 kg DM for dry and lactation period, respectively. Both linseed varieties and forms were inserted in a proper concentrate mixture, whereas control groups received a standard mixture (Table 1). Supplementation of these mixtures began 6 weeks prior to expecting parturition and full dose of them (2.2 kg DM per head/ day) was fed 4 weeks before expecting parturition. Similar

quantity of the proper experimental mixtures (Table 1) were applied in both experiments during lactation. These contributed 1,2 kg linseed DM per head per day. These mixtures were fed in the morning and evening meals. Besides, after calving the animals of all treatments in both experiments received an appropriate quantity of standard concentrate mixture (Table 1), to meet their nutritional requirements (0.4 kg concentrate per 1 kg milk over 20 milk yield). Average roughage: concentrate ratio in dry period was around 83 : 17 and 56 : 44 in lactation time.

Table 1. Dry matter content, chemical composition and nutritive value of 1 kg feeds DM
Tabela 1. Zawartość suchej masy oraz skład chemiczny i wartość pokarmowa 1 kg suchej masy skarmianych pasz

Nutrient Składnik	Maize silage Kiszonka z kukurydzy	Meadow hay Siano łąkowe	Standard concentrate mixture Mieszanka treściwa standardowa	Linseed Nasiona lnu		Linseed extrudate Ekstrudat lnu	
				Szafir variety dmiana Szafir	Amon variety odmiana Amon	Szafir variety odmiana Szafir	Amon variety odmiana Amon
Dry matter, % Sucha masa, %	30,5	92,33	87,7	94,58	93,65	90,28	89,39
In 1 kg DM (g) W 1 kg suchej masy paszy (g)							
Crude fiber, g Włókno surowe, g	207	357,8	73	80,0	74,3	46,4	43,1
Crude protein, g Białko ogólne, g	83	94,7	228	218,4	238,7	185,4	202,5
Ether extract, g Tłuszcz surowy, g	31	15,4	27,8	419,2	425,6	248,5	239,0
NFE BAW	622	456,1	603,2	239,3	218,2	492,3	487,9
UFL JPM	0,9	0,71	1,09	1,58	1,52	1,38	1,31
PDIN, g BTJN, g	52	58,59	162	141	152	121	138
PDIE, g BTJE, g	66	73,85	134	87	84	98	93
LFU JWK	1,13	1,11	–	–	–	–	–

NFE – nitrogen-free extract, UFL – feed unit for milk production, LFU – fill units for cows, PDI – protein truly digestible in the small intestine (PDIE – when energy limits microbial protein synthesis, PDIN – when N limits microbial protein synthesis)
BAW – związki bezazotowe wyciągowe, JPM – jednostka paszowa produkcji mleka, JWK – jednostka wypełnieniowa dla krów, BTJ – białko rzeczywiście trawione w jelicie cienkim (BTJN – obliczone na podstawie dostępnego w żwaczu azotu paszy, BTJE – obliczone na podstawie dostępnej w żwaczu energii paszy)

Cows were housed in tie stalls and during trial were fed individually. Apparent total tract digestibilities of the diets' nutrients were determined 2 times in both experiments – during dry period (3rd week previous to the expected calving) and lactation (10^{th} week after calving). Digestibility investigations were carried out on 4 cows in group, chosen randomly from each treatment, using silica as a marker. Daily feed intake, composition and nutritive value of feeds as well as composition of feces samples (6 day collection) were determined. Contents of basic nutrients: dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), crude ash (CA) in roughages, concentrate mixtures and in feces were analyzed according to AOAC [2005] standards. The chromic oxide was determined according to Suzuki and Early [1991] method.

Apparent digestibility coefficients (ADC) were calculated using the following equation:

$$ADC = 100 - (100 \times \frac{a \times b}{c \times d}) \quad (\%)$$

where:
a – the chromium content in feed (%),
b – the nutrient content in digesta or faeces (%),
c – the chromium content in digesta or faeces (%),
d – the nutrient content in feed (%).

The data obtained were analyzed statistically using a general linear model (GLM) of analysis of variance one-way ANOVA by means of SAS [SAS 2008], according to model:

$$Y_i = \mu + a_i + e_i$$

μ – overall mean,
a_i – influence of the dietary additives.
e_i – random error.

Tukey's test was applied for the multiple comparisons among means, considering $p \leq 0.05$ as significant. The tables illustrate the means and the levels of significance.

RESULTS AND DISCUSSION

The content of nutrients in the feeds and their nutritive values, calculated on the basis of chemical composition, show that all the feeds were typical in regard to the norms [IZ-PIB INRA 2009].

Neither supplement of traditional variety (Szafir) linseed nor its high linoleic acid variety (Amon) had any influence on feed intake or total tract digestibility of nutrients of the diets fed in dry period. Linseed extrudate of both varieties did not have any impact on these parameters, either, with exception of higher ($p \leq 0.05$) in comparison with control, crude protein digestibility. It should be noted, that linseed was added to the dry cow roughage-based diets in rather small amount of 3 % of the diet (DM basis) and the intro-

duced fat constituted about 1.3 % of diet DM. Similarly in the study carried out by Doreau *et al.* [2009] on dry cows, receiving the roughage- rich diets enriched with 2.5 times higher amount (7.5 %) of linseed (DM basis) fed as rolled or extruded seeds, both feed intake as well as DM digestibility were not changed in comparison with control.

Table 2. Intake of diet' dry matter (kg/day/head)
Tabela 2. Pobranie suchej masy dawki (kg/szt./dzień)

Week with reference to calving Tydzień w odniesieniu do wycielenia	Treatment Grupa			*SEM*
	Experiment 1/Doświadczenie 1			
	Control	RLS	RLA	
- 3	13,6	12,9	13,3	1,39
10	19,2^{ab}	20,4^{a}	18,8^{b}	1,65
Experiment 2/Doświadczenie 2				
	Control	ELS	ELA	
- 3	12,5	12,9	12,2	1,12
10	19,8^{ab}	20,3^{a}	19,1^{b}	1,83

$^{a, b}$ – values in the rows with different letters differ significantly ($p \leq 0,05$)
$^{a, b}$ – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy ($p \leq 0.05$)

Table 3. Apparent total tract nutrient digestibility coefficients (in %) of diets with rolled linseed of different variety (experiment 1)
Tabela 3. Współczynniki strawności pozornej składników pokarmowych dawek z lnem gniecionym różnych odmian (doświadczenie 1)

Nutrient Składnik	Week with reference to calving Tydzień w odniesieniu do wycielenia	Treatment Grupa			
		control kontrola	RLS	RLA	*SEM*
Organic matter	-3	75,9	76,6	76,4	6,12
Masa organiczna	10	77,6	75,8	75,3	5,07
Crude protein	-3	73,4	73,5	73,0	7,03
Białko ogólne	10	72,9^{a}	70,1^{b}	71,4^{ab}	4,22
Crude fiber	-3	62,8	63,2	62,9	4,11
Włókno surowe	10	64,9^{a}	60,4^{b}	59,7^{b}	3,24
Ether extract	-3	71,2	71,6	71,0	3,98
Tłuszcz surowy	10	71,9^{b}	76,9^{a}	75,2^{a}	4,87
NFE	-3	82,2	83,6	84,2	5,90
BAW	10	85,4	85,7	85,9	6,19

$^{a, b}$ – values in the rows with different letters differ significantly ($p \leq 0,05$)
$^{a, b}$ – wartości w wierszach oznaczon różnymi literami różnią się istotnie przy ($p \leq 0.05$)

Table 4. Apparent total tract nutrient digestibility coefficients (in %) of diets with linseed extrudate of different variety (experiment 2)
Tabela 4. Współczynniki strawności pozornej składników pokarmowych dawek z ekstrudatem lnu różnych odmian (doświadczenie 2)

Nutrient Składnik	Tydzień w odniesieniu do wycielenia	Treatment Grupa			
		control kontrola	ELS	ELA	*SEM*
Organic matter	-3	76,4	77,1	77,5	7,81
Masa organiczna	10	77,2	78,3	79,2	6,11
Crude protein	-3	72,9[b]	74,4[a]	74,8[a]	5,49
Białko ogólne	10	71,7[b]	76,2[a]	77,1[a]	4,71
Crude fiber	-3	63,0	64,2	62,4	4,59
Włókno surowe	10	63,9[b]	65,1[a]	64,1[ab]	4,72
Ether extract	-3	72,4	71,9	73,1	5,23
Tłuszcz surowy	10	72,6[b]	73,8[ab]	74,5[a]	4,94
NFE	-3	85,0	84,9	85,3	4,97
BAW	10	85,7[b]	86,2[ab]	87,1[a]	5,98

[a, b] – values in the rows with different letters differ significantly ($p \leq 0,05$)
[a, b] – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy ($p \leq 0.05$)

Dry matter intake during lactation period of investigations was not significantly affected by linseed supplements, suggesting that feeding linseed up to 6% of dietary DM had no adverse effect on feed intake. Lack of negative influence of linseed on feed intake was observed in some other studies, among other in Gonthier *et al.* [2004], who fed the cows in late lactation a diet containing as much as twice more linseed in comparison with our experiment. On the other hand Kim *et al.* [2009] observed a reduced feed intake when fed linseed at levels above 10% of diet DM. They suggest as a reason a diminished palatability of the linseed diets.

Lack of a negative influence of linseed on feed intake was observed in some other studies [Petit 2002, Gonthier *et al.* 2004, Doreau *et al.* 2009, Gilbery *et al.* 2010], where linseed in various forms (raw or processed) was added in amount ranging from 7.5 % [Doreau *et al.* 2009] to 12.6 % [Gonthier *et al.* 2004] of diet DM. Contrary results were obtained by Martin *et al.* [2008], who supplemented cow diets with 12.4 % linseed in extrudate form. They noted a reduced feed intake of 16%.

In this experiment both varieties did not have any ($p \geq 0.05$) considerable influence on total tract digestibility coefficients of organic matter. Also the form of linseed (rolled or extruded) had not any significant impact on OM digestibility. However, in comparison with control, this parameter was somewhat lower in experiment 1 (rolled linseed), whereas in experiment 2 with linseed extrudate, OM digestibility was somewhat improved, although the differences were not statistically proved. According to Jenkins [1993], fats added to ruminant diets can disrupt fermentation in the rumen, causing reduced digestibility of nonlipid energy sources. In some digestibility investigations, however, linseed of traditional varieties added in different form, up to 12.4% diet DM, like in our experiments, either did not change or even increased DM digestibility [Ueda *et al.* 2003, Gonthier *et al.* 2004, Micek *et al.* 2004, Doreau 2009, Gilbery *et al.* 2010]. In the

contrary to the above findings, Martin *et al.* [2008] who supplemented the cow lactation diets with 12.4% of crude linseed or its extrudate noted a significantly decreased, by about 7–8 percentage points, digestibility of diet DM. In our investigations a different influence of linseed form on crude protein and crude fiber digestibility was noted. Rolled linseed decreased CP digestibility (statistically confirmed difference with regard to traditional – Szafir variety) and digestibility of crude fiber. Contrary to that, both varieties of linseed given in extrudate form, increased crude protein as well as crude fiber digestibilities. Similarly, in Gonthier *et al.* [2004] study, who supplemented the lactation cow diets with 12.6 % of linseed extrudate of traditional variety, a significant increase of protein digestibility was noted. Opposite to our results, however, a significant increase of diet CP digestibility was also observed, when linseed was added in crude form.

The fat level in the ruminants diet, especially in non-protected form, may influence rumen fermentation [Szumacher-Strabel *et al.* 2009]. Linseed of both varieties, added in our trials both in rolled and extrudate, form significantly elevated digestibility of ether extract. These findings could be explained in detail if the analysis of rumen fluid was performed. However, the studies show [Jalč *et al.* 2006, Szumacher-Strabel *et al.* 2009] that the addition of up to 5% in diet DM of oils rich in linoleic acid did not strongly influence rumen fermentation. Similar results, a significant increase in digestibility of this nutrient was also noted in Micek *et al.* [2004] investigations, who supplemented linseed of several varieties, among others with elevated linoleic acid content (Linola variety). They did not note any differences in other nutrients' digestibility regarding linseed variety.

CONCLUSIONS

1. Linseed of traditional (Szafir) variety (high linolenic acid content) or high linoleic acid variety (Amon) given in rolled or extruded form to the dry cows (high-roughage diet) in amount of 3 % of diet DM did not influence feed intake or apparent total tract nutrient digestibility coefficients.

2. Form (rolled or extruded) of both linseed varieties supplementing the lactating cow diets in portion of 6% diet DM did not have any significant impact on feed intake or digestibility of organic matter. However, it had different influence on crude fiber and crude protein digestibility (decreased with rolled and increased with extruded linseed of both varieties). Similarly to dry cow diets, linseed varieties of high or low linolenic acid did not have any impact on feed intake and digestibility.

3. The addition of linseed in rolled or extruded form, in amount 3% and 6% of roughage-based diets DM for dry and lactating cows, respectively, seems the appropriate amount without adverse effect on feed intake or nutrients digestibility.

REFERENCES

AOAC, 2005. Official methods of analysis. Association of Official Analytical Chemists. 18th Edition, Meryland, USA.

Beauchemin K.A., McGinn S.M., Benchaar C., Holtshausen L., 2009. Crushed sunflower, flax or conola seeds in lactating dairy cow diets: Effect on methane production, rumen fermentation, and milk production. J. Dairy Sci. 92, 2118–2127.

Chilliard Y.F., Glasser F., Ferlay A., Bernard L., Rouel J., Doreau M., 2007. Diet, rumen biohydrogenation and nutritional quality of cow and goat milk fat: A review. Eur. J. Lipid Sci. Technol. 109, 828–855.

Doreau M., Aurousseau E., Martin C., 2009. Effects of linseed lipids fed as rolled seeds, extruded seeds or oil on organic matter and crude protein digestion in cows. Anim. Feed Sci. Technol. 150, 187–196.

Gilbery T.C., Lardy G.P., Hagberg D.S., Bauer M.L., 2010. Effect of flax inclusion on rumen fermentation, digestion and microbial protein synthesis in growing and finishing diets for beef cattle. Anim. Feed Sci. Technol. 161, 1–8.

Gonthier C., Mustafa A.F., Berthiaume R., Petit H.V., Martineau R., Ouellet D.R., 2004. Effects of feeding micronized and extruded flaxseed on ruminal fermentation and nutrient utilization by dairy cows. J. Dairy Sci. 87, 1854–1863.

Hess B.W., Moss G.E., Rule D.C., 2008. A decade of development in the area of fat supplementation research with beef cattle and sheep. J. Anim. Sci. 86 (E. Suppl.), E 188–E 204.

IZ PIB–INRA, 2009. Normy żywienia bydła, owiec i kóz. Wartość pokarmowa pasz dla przeżuwaczy. Instytut Zootechniki – Państwowy Instytut Badawczy, Kraków.

Jalč D., Potkański A., Szumacher-Strabel M., Kowalczyk J., Cieślak A., 2006. The effect of a high concentrate diet and different fat sources on rumen fermentation *in vitro*. J. Anim. Feed Sci. 15, Suppl. 1, 137–140.

Jenkins T.C., 1993. Symposium: advances in ruminant lipid metabolism. Lipid metabolism in the rumen. J. Dairy Sci. 76, 3851–3863.

Kim C.M., Kim J.H., Oh Y.K., Park E.K., Ahn G.C., Lee G.Y., Lee J.I., Park K.K., 2009. Effects of flaxseed diets on performance, carcass characteristics and fatty acid composition of Hanwoo steers. Asian Australas. J. Anim. Sci. 22, 8, 1151–1159.

Martin C., Rouel J., Jouany J.P., Doreau M., Chilliard Y., 2008. Methane output and diet digestibility in response to feeding dairy cows crude linseed, extruded linseed, or linseed oil. J. Anim. Sci. 86, 2642–2650.

Micek P., Borowiec F., Marciński M., 2004. Linseed-based diets for sheep. 1. Nutrient digestibility, N retention and rumen fermentation. J. Anim. Feed Sci. 13, 2, 15–18.

Petit H., 2002. Digestion, milk production, milk composition, and blood composition of dairy cows fed whole flaxseed. J. Dairy Sci. 85, 1482–1490.

SAS, 2008. SAS User's guide: Statistics. SAS for Windows. Release 9.2. SAS Institute Inc., Cary NC.

Suzuki E.Y., Early R.J., 1991. Analysis of chromic oxide in small samples of feds and feces using chlorine bleach. Can. J. Anim. Sci. 71, 931–934.

Szumacher-Strabel M., Cieślak A. Nowakowska A., 2009. Effect of oils rich in linoleic acid on in vitro rumen fermentation parameters of sheep, goats and dairy cows. J. Anim. Feed Sci. 18, 440–452.

Ueda K., Ferlay A., Chabrot J., Loor J.J., Chilliard Y., Doreau M., 2003. Effect of linseed oil supplementation on ruminal digestion in dairy cows fed diets with different forage: concentrate ratio. J. Dairy Sci. 86, 3999–4007.

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Streszczenie. Przeprowadzono badania strawnościowe nad wpływem dwóch odmian lnu – tradycyjnej (Szafir), o wysokim poziomie kwasu linolenowego (C18:3) i odmiany Amon, o wysokim poziomie kwasu linolowego (C18:2) – a także nad wpływem formy podawania tych nasion na strawność dawek pokarmowych u krów skarmianych w okresie zasuszenia i laktacji. Len stanowił 3 lub 6% suchej masy dawki, odpowiednio w okresie zasuszenia (3. tydzień poprzedzający poród) i laktacji (10. tydzień po wycieleniu). Badanie przeprowadzono na krowach rasy polskiej holsztyńsko-fryzyjskiej (8 krów w każdej kombinacji doświadczalnej). Określono współczynniki strawności pozornej: całkowitej dla masy organicznej, białka ogólnego, włókna surowego i związków bezazotowych wyciągowych (BAW). Nie stwierdzono wpływu żadnej z odmian na pobieranie paszy ani też na strawność składników pokarmowych dawek podawanych zarówno krowom zasuszonym (3%), jak i krowom w laktacji (6%). Również forma podawanego lnu (len gnieciony lub ekstrudowany) nie wpłynęła istotnie na pobranie paszy i strawność masy organicznej. Jednak po zastosowaniu 6-procentowego dodatku lnu (okres laktacji) zanotowano wpływ formy lnu na strawność białka ogólnego i włókna surowego. Len w formie gniecionej obniżył współczynnik strawności tych składników pokarmowych ($p \leq 0,05$), podczas gdy ekstrudat lnu go podwyższył ($p \leq 0,05$).

Słowa kluczowe: len gnieciony, ekstrudat lnu, odmiana, krowy mleczne, pobranie paszy, strawność