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Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

The effect of feeding linseed cake on milk yield and milk fatty acid profile in goats

Artur Jóźwik[1]*, Nina Strzałkowska[1], Emilia Bagnicka[1], Zbigniew Łagodziński[2], Bożena Pyzel[1], Wojciech Chyliński[1], Agnieszka Czajkowska[1], Weronika Grzybek[1], Danuta Słoniewska[1], Józef Krzyżewski[1], Jarosław Olav Horbańczuk[1]

[1] Polish Academy of Sciences Institute of Genetics and Animal Breeding, Jastrzębiec, 05-552 Wólka Kosowska, Poland

[2] Abbott Laboratories Poland, Postępu 21B, 02-676 Warsaw

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The study aimed at determining the effect of supplementation the diet with linseed on milk yield and milk fatty acids profile in the middle stage of lactation of goats. Used were 16 Polish Fawn Improved goats divided into two groups: (1) fed the standard diet without supplementation (control) and (2) fed the diet supplemented with linseed cake (19.9% of diets' total dry matter). Both diets were balanced according to INRA feeding standards and offered from week 12 to 17 of goats' lactation. Milk samples were taken twice: two weeks after the beginning and then at the end of supplementing the diet with linseed cake. The linseed cake led to increase in milk yield and to favourable changes in fatty acids profile (the share of MUFA increased and of SFA decreased). Moreover, CLA content of milk significantly increased (ca. 10-fold) after linseed cake supplementation, whereas the concentration of undesirable SFA (especially C12 to C16) dropped significantly (almost 2-fold).

KEY WORDS: goat / fatty acids / linseed cake / milk

Milk, is an important source of protein and fat in human diet [e.g. Strzałkowska *et al*. 2009ab]. Milk produced in suitable feeding and maintenance system may also be an important source of unsaturated fatty acids, especially conjugated linoleic acid

*Corresponding author: aa.jozwik@ighz.pl

(CLA) isomers, principally cis-9, trans-11 and trans-10, cis-12 that have functional properties affecting the consumers health positively [Nudda *et al*. 2006]. The *c9t11*CLA is considered to have anti-carcinogenic properties [Piperova *et al*. 2004] whereas the *c10t12*CLA, actively participating in lipid metabolism leads to a decrease in the fat content of cow milk [Baumgard *et al*. 2000]. One of the main factors affecting the milk fatty acid profile including CLA isomer content is the type of dietary fat and feed offered [Nudda *et al*. 2006]. In the last decade a considerable interest in the supplementation of ruminants' diet with different types of fat is shown, including plant oils and whole seeds in order to obtain milk with a higher concentration of desired fatty acids [Reklewska *et al*. 2002, Secchiari *et al*. 2003, Potkański *et al*. 2009]. However, there is insufficient information about supplementation the goat diet with linseed cake. Therefore, the aim of this study was to determine the effect of introducing linseed cake, as a by-product of "cold-pressed oil" extraction, to the goat's diet on milk yield, milk fat yield and milk fatty acids profile.

Material and methods

Animals, feeding, sampling

The study was carried out on 16 Polish Fawn Improved female goats in their second and third lactation, divided into two groups (eight animals per group). The animals were maintained at the Experimental Farm of the Institute of Genetics and Animal Breeding, Jastrzębiec, Poland. Goats were machine-milked twice daily and fed diets formulated according to the Institut National de la Recherche Agronomique

Table 1. Ingredients, chemical composition and nutritive value of the diets for goats

Item	Diet	
	control	experimental
Ingredients (% in DM)		
corn silage	29.7	30.7
meadow hay	29.2	30.1
oats (grain)	18.7	19.3
triticale (grain)	11.2	-
extracted rapeseed meal	11.2	-
linseed cake*/	-	19.9
Chemical composition and nutritive value (per kg DM)		
NEL (MJ)	6.29	6.25
crude protein (g)	142.4	147.5
PDI (g)	102.6	93.8
crude fibre (g)	184.4	216.2
NDF (g)	387.4	535.7
ADF (g)	213.7	290.8
ADL (g)	3.2	4.7
ether extract (g)	29.6	35.7

*Chemical composition (% of DM): crude protein 30.9; ether extract 9.2; crude fiber 7.8; crude ash 6.9; NFE 45.2.

(INRA) standards, which met all their individual nutritive requirements. The basic diet consisted of corn silage, hay, concentrate and mineral and vitamin premix, chalk and NaCl. The data on the composition of control and experimental diet are shown in Table 1.

Diet supplementation with linseed (group 2) started in week 12 and ended in week 17 of lactation (middle stage of lactation). Milk samples were obtained from each goat from the morning milking, twice during the experiment. The first milk samples were taken two weeks after introducing the cake, while the last at the end of supplementation. The milk yield was recorded and milk samples analysed for fat content. Fatty acid profile of milk was determined.

Fatty acids profile

Frozen milk samples were freeze-dried for 48 hours and then extracted with chloroform-methanol and water (4:2:1, v/v) mixtures. The lower layer was hydrolyzed and free fatty acids were extracted. The precipitate obtained was dissolved in a mixture of dibromoacetophenone and triethylamine, after which acetic acid was added to stop the derivatization reaction [Czauderna and Kowalczyk 2001]. The derivatizing procedure for standards was the same as that for biological samples. Derivatized samples were filtered through a 0.2 μm membrane filter (Whatman) and the solutions obtained were injected into chromatographic columns.

Analyses of the dibromoacetophenacyl ester of fatty acids were carried out on HPLC systems Series 200 PERKIN ELMER, USA. The development of the gradient elution system, collection and data integration were performed with the TURBOCHROM Workstation Ver. 6.1.2 software. The separation was performed on Spheri-5 RP-18, 5μm, 220 x 4.6 mm columns (PERKIN ELMER, USA). All solvents were degassed under vacuum and then flushed with 99.996 helium (PRAXAIR, Poland). The column temperature was maintained at 35°C and the eluted dibromoacetophenylacyl esters of fatty acids were detected at 242 nm. Elution was performed using a concentration of a mixture of methanol (MeOH) and acetonitryl-water (ACN-H_2O, 40-60, v/v). The elution of dibromoacetophenacyl ester of 4:0-20:5 fatty acids was completed within 40 min at a flow-rate of 2.6 ml/min.

Statistical

The statistical evaluation of results was performed with the GLM procedure of SAS Version 9.1 for Windows [SAS, SAS/STAT, 2002-2003], using the model including a fixed effect of time of milk collection and effect of diet interaction. Except for the milk yield, a fixed regression on fat yield was used.

Results and discussion

The effect of supplementation the diet with linseed cake on the analysed traits is shown in Table 2. The diet with linseed cake showed an impact on almost all traits,

Table 2. Significance of investigated effects on milk yield, milk fat yield, milk fat content and milk fatty acids profile

Trait	Effect		
	time of sample collection	diet	regression on fat yield
Milk yield	NS	**	-
Fat yield	NS	NS	-
Fat content	NS	NS	NS
C4:0	NS	**	*
C6:0	NS	**	*
C8:0	NS	NS	NS
C10:0	NS	**	NS
C12:1	NS	NS	NS
C12:0	**	**	NS
C14:1	*	**	NS
C14:0	NS	*	NS
C16:0	NS	**	*
C16:1	NS	*	NS
C17:0	NS	**	NS
C18:0	**	**	NS
C18:1 *cis*	NS	NS	NS
C18:1 *trans*	NS	*	NS
C18:2	NS	NS	NS
CLA total	NS	**	NS
C18:3	NS	*	NS
C20:3	NS	NS	NS
C20:4	NS	**	NS
C20:5	NS	**	NS
SFA	NS	**	*
MUFA	NS	*	NS
PUFA	NS	NS	NS
SCFA	NS	**	NS
MCFA	NS	**	*
LCFA	NS	**	NS

*P≤0.05; **P≤0.01.
SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids, SCFA – short-chain fatty acids; MCFA – medium-chain fatty acids; LCFA – long-chain fatty acids.

while the time of sample collection and regression on fat yield did not affect the profile of fatty acids. Goats supplemented with linseed cake produced more milk than controls fed extracted rapeseed meal (Tab. 3), but there was no difference between groups in fat yield and its concentration. Similar results were shown by Sanz Sampelayo *et al*. [2007]. The milk of goats fed with linseed cake was characterized by lower concentration of saturated fatty acids (SFA). This is in accordance with results obtained by Schmidely *et al*. [2005]. In turn, the concentration of short-chain

Table 3. Least squares means (LSM) and their standard errors (SE) for percentages of individual fatty acids and their groups in relation to the sum of fatty acids considered as 100

Trait	Diet		
	control group	experimental group	SE
	LSM	LSM	
Milk yield	1.61^{A}	2.05^{B}	0.10
C4:0	0.67^{A}	0.93^{B}	0.05
C6:0	0.40^{a}	0.78^{b}	0.10
C8:0	1.20^{a}	0.50^{b}	0.23
C10:0	8.17^{A}	4.47^{B}	0.49
C12:1	0.11^{NS}	0.12^{NS}	0.03
C12:0	3.96^{A}	2.61^{B}	0.18
C14:1	0.14^{A}	0.07^{B}	0.01
C14:0	7.68^{a}	6.04^{b}	0.47
C16:1	0.38^{a}	0.68^{b}	0.07
C16:0	21.54^{A}	12.37^{B}	1.14
C17:0	0.34^{A}	0.20^{B}	0.03
C18:0	5.70^{A}	11.65^{B}	0.59
C18:1 *cis*	12.00^{NS}	14.30^{NS}	1.25
C18:1 *trans*	1.37^{a}	2.86^{b}	0.42
C18:2	1.09^{NS}	1.05^{NS}	0.05
CLA total	0.03^{A}	0.28^{B}	0.05
C18:3	0.79^{a}	0.49^{b}	0.07
C20:3	0.22^{NS}	0.21^{NS}	0.01
C20:4	0.78^{A}	0.26^{B}	0.10
C20:5	0.18^{A}	0.08^{B}	0.02
SFA	49.67^{A}	39.60^{B}	1.95
MUFA	13.99^{a}	18.05^{b}	1.33
PUFA	3.15^{ns}	2.27^{ns}	0.29
SCFA	10.44^{A}	6.70^{B}	0.65
MCFA	34.15^{A}	22.15^{B}	1.52
LCFA	22.22^{A}	31.11^{B}	1.94

^{aA}Within rows means bearing different superscripts differ significantly at: small letters – $P \leq 0.05$; capitals – $P \leq 0.01$.
SFA- saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids
SCFA – short-chain fatty acids; MCFA – medium-chain fatty acids; LCFA – long-chain fatty acids.

fatty acids (SCFA) in the present study, *i.e.* C4:0 and C6:0 increased after linseed cake supplementation, while C8:0 and C10:0 dropped (Tab. 3). In studies reported by Nudda *et. al*. [2006] the addition of plant oil to the diet had no effect on the SCFA content of goat milk. It should be emphasized that the high concentration of SCFA intensifies the taste and flavour of milk.

Among medium-chain fatty acids (MCFA) only the concentration of C16:1 was higher, while those of other MCFA occurred lower in the experimental group as compared to the control animals (Tab. 3). Also Nudda *et al*. [2006] showed that addition of linseed cake results in decrease in MCFA concentration.

The experimental diet led to higher concentration of monounsaturated fatty acids (MUFA) of milk. The increase in MUFA concentration was observed despite the fact that, as shown by Strzałkowska *et al*. [2009c], the level of MUFA in the goat milk during the first half of lactation is comparatively low. The concentration of C18:1 *trans* considerably increased in group fed with linseed cake as compared to the control group. Similar results were obtained by Nudda *et al*. [2008] and Chilliard *et al*. [2003].

No significant differences were identified in the total concentration of PUFA in milk between examined groups. The results obtained in the present investigations differ from those reported by Sanz Sampelayo *et al*. [2007] and Chilliard *et al*. [2003]. However, there were observed significantly increasing content of CLA and decreased concentration of C18:3, C20:4 and C20:5. This is probably due to less interaction with rumen bacteria.

Summarizing**,** the milk yield was higher when goats were fed diet supplemented with linseed cake. The changes in the profile of fatty acids were recorded; CLA content increased ca. 10-fold after linseed cake introduction to the diet, while the SFA (especially C12 to C16) decreased (almost 2-fold). Thus, from the consumers point of view, the supplementation of goat diet with linseed cake resulted in favourable changes in the FA profile.

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