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FATTY ACID CONCENTRATIONS IN THE INTRAMUSCULAR FAT OF NUTRIAS (*MYOCASTOR COYPUS MOL.*) FED DIETS SUPPLEMENTED WITH LINSEED AND APPLE SEED OILS

Łukasz Migdał[1], Anna Migdał[2], Piotr Niedbała[3], Stanisław Łapiński[3], Henryk Pustkowiak[4], Marek Pieszka[5], Robert Głogowski[6], Władysław Migdał[7]

[1] *Department of Genetic and Animal Breeding, University of Agriculture in Krakow, Poland*
[2] *Department of Animal Reproduction and Anatomy, University of Agriculture in Krakow, Poland*
[3] *Department of Poultry and Fur Animal Breeding and Animal Hygiene, University of Agriculture in Krakow, Poland*
[4] *Department of Cattle Breeding, University of Agriculture in Krakow, Poland*
[5] *National Research Institute of Animal Production, Poland*
[6] *Department of Animal Breeding, Warsaw University of Life Sciences, Poland*
[7] *Department of Animal Product Technology, Faculty of Food Technology, University of Agriculture in Krakow, Poland*

ABSTRACT

As reported previously, meat from nutria fed diets rich in protein is characterised by an unfavourable fatty acid profile. In the present study we tried to improve health-promoting properties of nutria meat by modifying the fatty acid concentrations with dietary supplementation of 1% of linseed oil or 1% of apple seed oil. The intramuscular fat of nutrias fed the diet with apple seed oil was characterized by a higher level of polyunsaturated (PUFA) and essential fatty acids (EFA) but not monounsaturated fatty acids (MUFA). n-6:n-3 PUFA ratio in meat of nutrias fed apple seed oil was most favourable for consumers, despite the similar content of C18:3 n-3 in ether extract in feed mixtures for nutria.

Key words: nutria, linseed oil, apple seed oil, meat, fatty acids.

INTRODUCTION

Nutria were brought to Europe from South America in the beginning of the 20th century as a valued source of fur and meat [1, 28].

In Europe, nutria initially were reared as fur animals. Their meat was generally considered as slaughter by-product. Although commonly consumed, it was never considered as important as nutria fur coats. Nowadays, the demand for nutria pelts is scarce, which significantly decreased the number of farms. In effect, nutrias were included in the genetic conservation programme in Poland [1]. A chance to save the population of nutria in Poland rests with meat, which is very popular and commonly consumed in South America [7, 22, 23].

An increasing interest in the meat and edible viscera of nutria can be observed in Europe [10, 12, 16]. Hoffman and Wilkund [13] suggest that the meat of nutria is an alternative to commonly consumed meats due to its low level of fat and cholesterol. Also consumers are paying more attention to functional food which lead to fortify meat with a high content of n-3 polyunsaturated fatty acids (n-3 PUFA), conjugated linoleic acid (CLA) and vitamins in meats [15, 19, 20].

The content of unsaturated fatty acids (UFA) (mainly essential fatty acids, EFA) and their ratio to saturated fatty acids (SFA)

are regarded as quality indicators. A lot of attention is paid to linoleic (C18:2 n-6) and linolenic acids (C18:3 n-6), which are not synthesised by the body, are involved in synthesis of eicosapentaenoic (EPA) and docosahexaenoic acids (DHA), and are precursors in synthesis of prostaglandins and prostacyclins [5].

Moreover, it has been found that the ratio of n-6:n-3 polyunsaturated fatty acids is also a risk factor in cancers and coronary heart disease, especially the formation of blood clots leading to a heart attack [25, 26, 30].

The addition of vegetable oils rich in n-3 PUFA to commercial diets should solve theproblem of favourable fatty acid profile in intramuscular fat. The vegetable oils with a favourable fatty acid profile seem to be linseed oil as well as apple seed oil, which is becoming increasingly popular.

Assuming that the addition of vegetable oil to a commercial diet will improve the functional traits of meat and increase consumer interest in nutria meat, we carried out an experiment to evaluate the influence of linseed and apple seed oil supplementation in a commercial complete diet for nutrias on fatty acid profile in intramuscular fat.

MATERIAL AND METHODS

Animals, slaughter and sample collection

The study was carried out on 18 young standard nutria females (±6 months old; 5.4±1.7 kg BW) chosen from the population on the research farm of the Department of Poultry and Fur Animal Breeding and Animal Hygiene of the Agricultural University of Krakow.

Animals were randomly divided into three groups (6 animals in each group) that were fed *ad libitum* and twice a day the fed was supplemented with mixtures. The control group (C) was fed with dry feed (15.8% crude protein, 3.20% crude fat, 6.90% crude fibre, 5.60% ash, 0.77% lysine, 0.52% phosphorus), the second group (L) was fed the same commercial pelleted diet with addition of 1% (DM) linseed oil, and the third group (A) was supplemented with 1% of apple seed oil (Table 2).

All groups were kept in indoor pens without pools and had unlimited access to drinking water. After 2 weeks of adaptation, animals received this feed for the next 30 days. Animals were slaughter at the age of 7,5 months (6,6± 0.54 kg BW). Before slaughter animals were fasted for 12h, stunned by using an electrical impulse (230V) and bled in an abattoir on the farm. *M. longissimus dorsi thoracis* and *m. semimembranosus* were dissected from carcasses. Approximately 60g of muscle tissue were collected and stored at -20°C until further analysis.

Apple seed oil and linseed oil

Oil from apple seeds originated from Mega-Sort Company (Poland), which specializes in the drying and packaging of fruit pomace produced after extraction of fruit and vegetable juices. Pomace with about 55% moisture content, originating from Hortex Company (Poland), was dried on drum driers to reduce the moisture below 10%. Dried fruit pomace was then cut and ground, and the seeds were separated. The production line (Scorpion, Poland) included a chopper, a separator and a pneumatic tunnel, in which the seeds were separated from the other parts. Oils were obtained from the seeds on a standard technological line used for cold-pressing of oilseeds (Farmet, Czech Republic) and equipped with a UNO screw press, a sedimentation tank, and board and candle filters. Seeds were subjected to a press head temperature of 55°C for 20 s. The pressed and filtered oils seeds were placed in dark glass containers with added N2, tightly closed and refrigerated at 4°C until further analyses. Linseed oil is one of the richest sources of α-linolenic acid, the average content of which in commercial oil is 57.3%, as confirmed by Choo et al. [4]. Composition of oils used in this study is showed in Table 1

Fatty acid content analysis

Lipids were extracted from muscle samples with chloroform-methanol (2:1) mixture, according to the method of Folch et al. [8]. The so prepared fatty acid methyl esters (FAME) were separated by gas chromatography on a TRACE GC ULTRA (Thermo Electron Corporation) equipped with 30 m capillary column (SUPELCOWAX, Bellefonte, USA) with 0.25 mm inner diameter and coating thickness of 0.25 mm (30 m x 0.25 mm x 0.25 μm).

Operating conditions were as follows: helium was used as a carrier gas with the flow of 1 ml/min. Split flow was set at 10 ml/min, injector temperature was 220°C, detector temperature was 250°C. Column temperature were initially 160°C for 3 min and then increased at 3°C/min up to 210°C and held for 25 min.

Statistical analyses

Arithmetic mean (x) and standard deviation (s) were calculated using Statistica for Windows 8.0. The effect of oils supplementation on meat was tested by the Analysis of Variance (ANOVA) with one-factor: oil (control, linseed oil, apple seed oil). Differences among treatments means were verified for significance with Duncan test.

RESULTS AND DISCUSSION

The results the fatty acid profile of intramuscular fat in nutria *m. semimembranosus* are presented in Table 4 and the fatty acid profile of intramuscular fat in nutria *m. longissimus dorsi* in Table 5. Apple seed oil is a rich source of n-6 PUFA, especially linoleic acid, while linseed oil contains large amounts of linolenic acid of the n-3 PUFA family (Table 1). The addition of linseed and apple seed oils modified the content of fatty acids in diets offered to nutria in our study (Table 2). As compared to control, apple oil supplemented pellets contained elevated amounts of unsaturated fatty acids (UFA) at the expense of saturated fatty acids (SFA), which is consistent with the results of Yukui et al. [33]. The composition of fatty acids in the oils from apple seeds

was characterised by a high content of unsaturated fatty acids (86.9%). Apple seed oil had a high content of oleic acid C18:1 (29.4%), which is in agreement with the findings of Yukui et al. [33]. In the apple seed oil, the level of α-linolenic acid did not exceed 1%. The analysed apple seed oil was characterized by increased peroxide values (within the normal range) of 10.59 mq O2/kg [21]. Lower concentrations of tocols (143.6 mg/100 g) were identified in the analysed apple seed oil. The dominant tocopherol isomer in apple was ß isomer (62.7) followed by α, δ and γ isomers (41.7, 21.2 and 13.6 mg/100 g, respectively). The tocopherol content in oil is considerably affected by the refining process, which removes about 40% of tocopherol.

Table 1. Composition of fatty acids in linseed and apple-seed oils (% of ΣFA)

Fatty acid	Linseed oil	Apple-seed oil
C14:0	0.20	nd
C16:0	4.12	9.50
C16:1n7	0.15	nd
C18:0	5.23	1.82
C18:1n9	18.97	29.36
C18:2n6	16.95	55.54
C18:3n6	nd	0.34
C18:3n3	51.98	0.85
C20:0	0.18	1.56
C20:1	0.12	0.57
C 20:2n6	nd	0.09
C22:0	0.15	0.18
C22:1	0.01	0.07
C22:5n3	nd	0.11
C22:6n3	nd	0.01
nd – not detected		

Table 2. Fatty acid composition of diets (% of ΣFA)

Fatty acid	C	L	A
C10:0	0.065	0.074	0.042
C12:0	0.492	0.913	0.323
C14:0	0.919	0.869	0.586
C14:1n9	0.076	0.053	0.043
C15:0	0.148	0.119	0.107
C16:0	20.278	16.742	16.638
C16:1n9	0.213	0.203	0.182
C16:1n7	0.978	0.741	0.668
C17:0	0.286	0.213	0.194
C17:1n9	0.103	0.116	0.090
C18:0	5.506	4.583	3.961
C18:1n9	25.815	23.602	25.536
C18:1n7	3.229	2.879	2.844
C18:2n6	36.750	34.324	43.844
C18:3n6	0.026	0.019	0.021
C18:3n3	3.823	13.905	3.842
C20:0	0.236	0.204	0.430
C20:1n9	0.430	0.374	0.448
SFA	27.930	23.717	22.281
UFA	71.443	76.216	77.518
MUFA	30.844	27.968	29.811
PUFA	40.599	48.248	47.707
n3PUFA	3.823	13.905	3.842
n6PUFA	36.776	34.343	43.865
n6:n3	9.620	2.469	11.417
OFA	21.197	17.611	17.224
DFA	76.949	80.799	81.479
A-SFA	21.689	18.524	17.547
T-SFA	26.703	22.194	21.185

AI	0.342	0.277	0.249
TI	0.588	0.303	0.437
CI	3.823	3.905	3.842
Δ9-desaturase index	0.496	0.520	0.551
EFA	40.599	48.248	47.707
DFA/OFA	3.630	4.588	4.731
MUFA/SFA	1.104	1.179	1.338
UFA/SFA	2.558	3.214	3.479
PUFA/MUFA	1.316	1.725	1.600
PUFA/SFA	1.454	2.034	2.141

The comparison of nutria intramuscular fat content in the loin and thigh muscle samples presented in Table 3 shows that the diets offered in the current study resulted in relatively high fatness of meat compared to the findings of other authors. In animals fed fresh forage, the fat content of loin is slightly lower than in rabbits analysed for comparative reasons [10, 15]. Surprisingly, the differences are more pronounced in thigh muscles. The level of fat is about threefold higher in nutria supplemented with a high-protein apple oil diet than in intensively fed nutrias [23]. However, it seems likely that dietary addition of oil from apple seeds decreases intramuscular fat content in thigh muscles to the level similar to that found in extensively fed nutrias [3, 10].

Table 3. Comparison of the content of fat in loin and thigh muscles of young nutrias fed different diets and rabbits fed diet supplemented with linseed (%)

	Nutrias						Rabbits	
	this study[1]			Saadoun et al.[2]	Cholewa et al.[3]	Głogowski & Panas[4]	Kouba et al.[5]	
	C	L	A				Control	Linseed
Loin	3.13±0.26	4.05±0,45	2.68±0,73	–	–	0.8	1.2	1.3
Thigh	7.76±0,91	7.71±0,54	5.99±0,76	1.56	5.72	5.3	1.1	1.3

C – control group.
L – linseed supplemented group.
A – apple seed supplemented group.
[1] – concentrate (15.8% protein, 3.2% fat).
[2] – concentrate (16% protein, 3% fat).
[3] – 33% wheat/rye, 66% barley; beetroots or silage in winter; green forage in summer.
[4] – brewed cereals; wheat bran, beetroots and hay in winter; steamed potatoes and fresh grass or clover in summer.
[5] – concentrate (18% protein, 4.6% fat); Linseed group was supplemented with 60g/kg of Croquelin®.

The addition of linseed and apple seed oils influenced the fatty acid profile of nutria intramuscular fat. Sum of SFA tended to be greater in group A than in groups L and C.

The higher level of C18:2n-6 acid in diet caused the growth of that fat levels in meat fats (statistically significant in *m. longissimus dorsi),* whereas the higher level of C18:3n-3 acid in L diet caused the growth in meat fat (statistically significant in *m. longissimus dorsi)* of animals fed those dosages in diets. The interesting fact was the growth of C20 and C22n-3 fatty acids in nutria meat fats obtaining diet A supplemented with 1% of apple seed oil, characterised with high content of C18:2n-6 (43.84%) acid. The linoleic acid during the desaturation process forms the γ-linolic acid (C18:3n-6), which is elongated to dihomo-γ-linoleic acid (C20:3n-6). The last one is converted through Δ5-desaturase to arachidonic acid (C20:4n-6). In nutria meat obtaining the A diet supplemented with 1% of apple seed oil the highest amount of arachidonic acid (C20:4n-6) – up to 8.447% in *m. semimembranosus* and 4.16% in *m. longissimus dorsi.* The above mentioned enzymes cause the conversion of α- linolenic acid to eicosapentaenoic acid (C20:5n-3, EPA), of which the docosahexaenoic acid (C22:6n-3, DHA) is formed. In nutria meat, of animals obtaining diet L supplemented with 1% of linseed oil, characterised with high quantity of C18:3n3 up to 13.905%, the highest level of C18:3n3 acid was observed. Whereas there was not observed the growth in C20:5n-3 and C22:6n-3 acids levels. The higher amount of 18:3n-3 in the linseed group and the higher amount of 18:2n-6 in the apple seed group is not reflected in the fatty acid composition of the m. semimembranosus tissue. In both muscles, the proportion of C20 and C22 n-3 fatty acids is highest in the A treatment despite the highest levels of n-6 fatty acids in the diet. Above statements need to be verified through repetition of the experiment.

The fatty acids of n-6 and n-3 families compit for the same enzymes taking a part in linoleic acid and α-linolenic acid metabolites synthesis. In agreement with above the consumption of the diet containing meaningful amounts of linoleic acid causes inhibition of C20:5n-3 and C22:6n-3 acids synthesis from α-linolenic acid and the speeding in arachidonic acid synthesis. Similarly the big amounts of α-linolenic acid digested with the diet favour synthesis of C20:5n-3 and DHA and weaken the origin of arachidonic acid. According to Wood et al. [32] long-chain (C20-C22)n-3 PUFA are synthesized from 18:3 in the animal although docosahexaenoic acid (C22:6n-3) is not increased when diets are supplemented with 18:3.

Application for nutria animals the diets with apple seed oil or linseed oil additives caused lowering of n-6:n-3 acids ratio in meat fat. Supplementing pig diets with 18:3 to lower the n-6:n-3 ratio has been examined by several workers [32].

Apple seed oil addition significantly increased the sum of PUFA but decreased MUFA ($P<0.001$) in the loin (Table 5).

The increased intake of linoleic acid and an elevated ratio of omega-6 to omega-3 fatty acids is a major risk factor for western-type cancers, thrombotic diseases, apoplexy, allergic hyperreactivity, and diseases for which anti-inflammatory drugs are effective [18, 25]. According to FAO/WHO [6] the ratio of n-6:n-3 fatty acids in food for humans should be lower than 4, and the PUFA/SFA ratio should be above 0.4 [32].

Another noticeable proportion, that of polyunsaturated to saturated fatty acids (PUFA:SFA) is widely regarded as an indicator of fat quality, but the favourable ratio of PUFA:SFA does not go hand in hand with favourable n-6:n-3 ratio, since the increase of PUFA results mainly in the increase of n-6 PUFA [27]. In the present study, the PUFA/SFA ratio in *m. longissimus dorsi* was between 0.55 (C) and 0.66 (A) (P=0.219) (Table 5) and in hind leg between 0.59 (L) and 0.88 (A) (P=0.002) (Table 4). PUFA:SFA ratio was 0.57–0.59. Saadoun et al. [23], who fed nutria *ad libitum* diet based on soybean and corn (diet provided 14.59 MJ/kg of metabolizable energy, 16% crude protein, 3% fat, 1.03% calcium and 0.55% total phosphorus) found the n-6:n-3 ratio to be 40–44 in *pectoralis* muscles, and 16.8 in male and 29 in female thigh muscles. Saadoun and Cabrera [22], when comparing the ratio of polyunsaturated fatty acids to saturated fatty acids in indigenous sources of meat in South America found the recommended ratio of these acids (0.4–1.0) in capybara and nutria meat.

Table 4. Fatty acid profile of intramuscular fat in m. semimembranosus (% of ΣFA)

Fatty acid	C	L	A	SEM	*P*
C10:0	0.154	0.024	0.035	0.032	0.231
C12:0	0.118	0.114	0.092	0.006	0.116
C14:0	3.182	3.947a	2.347b	0.319	0.086
C14:1n9	0.607	0.476	0.283	0.077	0.253
C15:0	0.318	0.261	0.200	0.025	0.174
C16:0	26.342	27.182	27.213	0.324	0.551
C16:1n9	0.740a	0.748a	0.603b	0.026	0.007
C16:1n7	14.939	14.713a	8.636b	1.366	0.077
C17:0	0.212a	0.211a	0.322b	0.018	<0.001
C17:1	0.318	0.287	0.234	0.020	0.255
C18:0	5.839a	4.844a	8.554b	0.616	0.008
C18:1n9	16.512a	20.680b	13.501c	1.050	<0.001
C18:1n7	5.174a	4.824a	4.164b	0.145	0.001
C18:2n6	16.798	15.726	20.045	0.818	0.044
C18:3n6	0.067	0.080	0.065	0.004	0.223
C18:3n3	0.621	0.781	0.737	0.040	0.311
C20:0	0.031	0.039	0.035	0.002	0.532
C20:1	0.115	0.122	0.103	0.006	0.466
C20:2	0.102	0.083a	0.118b	0.007	0.057
C20:3n6	0.141	0.077a	0.166b	0.018	0.074
C20:4n6	4.964a	3.106a	8.447b	0.809	0.001
C20:5n3	0.098a	0.043a	0.193b	0.023	0.002
C22:4n6	0.455a	0.277b	0.606c	0.050	0.002
C22:5n3	0.899a	0.477a	1.801b	0.221	0.011
C22:6n3	0.540	0.415	0.815	0.087	0.13
SFA	36.197a	36.622a	38.795b	0.503	0.053
UFA	63.091a	62.912a	60.514b	0.541	0.069
PUFA	24.685a	21.616a	34.202b	2.084	0.013
MUFA	38.406a	41.849a	27.523b	2.458	0.007
OFA	29.524a	31.129b	29.559a	0.331	0.027
DFA	68.930	67.756	69.067	0.291	0.009
EFA	16.865	15.806a	20.110b	0.816	0.113
n3 PUFA	2.158a	1.716a	3.545b	0.332	0.048
n6 PUFA	22.425a	19.265a	29.328b	1.661	0.103
n6:n3	12.622	11.258	8.282	0.876	0.048
DFA:OFA	2.337a	2.169b	2.340a	0.036	0.049
MUFA:SFA	1.075a	1.143a	0.710b	0.079	0.043
UFA:SFA	1.751a	1.718	1.561b	0.038	0.345
PUFA:MUFA	0.717a	0.518a	1.244b	0.117	0.104
PUFA:SFA	0.676a	0.591a	0.882b	0.049	0.002
AI	0.621	0.686	0.608	0.015	0.044
TI	0.959	1.005	0.973	0.013	0.054

CI	1.259	1.238	1.744	0.115	0.021
A-SFA	29.642a	31.243b	29.651a	0.333	0.075
T-SFA	35.363a	35.973a	38.113b	0.512	0.004
Δ9-desaturase index	0.340a	0.383a	0.277b	0.016	0.01

differences marked with various superscripts within a row are significant at $P<0.05$
SFA – saturated fatty acids
UFA – unsaturated fatty acids
PUFA – polyunsaturated fatty acids
MUFA – monounsaturated fatty acids
EFA – essential fatty acids (18:2 + C18:3)
OFA – hypercholesterolemic acids (C14:0 + C16:0)
DFA – neutral and hypocholesterolemic acids (C18:0 + UFA)
AI – atherogenic index (C12:0 +4xC14:0 + C16:0)/[(MUFA + ∑SPUFA (n6) + (n3)] [Ulbricht & Southgate, 1991]
TI – thrombogenic index (C14:0+C16:0+C18:0)/0.5*MUFA+0.5*n6PUFA+3*n3PUFA + n3PUFA/n6PUFA) [Ulbricht & Southgate, 1991]
A-SFA – (C12:0 + C14:0 + C16:0)
T-SFA – (C14:0 + C16:0 + C18:0)
Δ9-desaturase index – (C14:1n9+ C16:1n9+ C18:1n9)/(C14:1n9+ C18:1n9+ C18:1n9+ C14:0 + C16:0 + C18:0) [Smith et al., 2002]
CI – consumer index (C18:3 + C20:5 + C22:6) [Wood et al., 2004]

Table 5. Fatty acid profile of intramuscular fat in m. longissimus dorsi (% of ΣFA)

Fatty acid	C	L	A	SEM	*P*
C10:0	0.129	0.026	0.035	0.026	0.271
C12:0	0.133a	0.105b	0.111b	0.004	0.003
C14:0	3.942a	3.407b	3.050c	0.124	0.002
C14:1	0.640a	0.433b	0.279c	0.049	0.001
C15:0	0.326a	0.241b	0.273b	0.013	0.009
C16:0	26.955	28.393	29.256	0.518	0.228
C16:1n9	0.685	0.768a	0.607b	0.034	0.12
C16:1n7	17.260a	13.113b	9.686c	0.974	<0.001
C17:0	0.209a	0.226a	0.316b	0.017	0.002
C17:1	0.326a	0.256b	0.286	0.012	0.033
C18:0	5.237a	6.217	6.985b	0.278	0.022
C18:1n9	18.381	19.480	18.144	0.372	0.298
C18:1n7	4.864a	4.980a	4.008b	0.175	0.015
C18:2n6	14.506a	16.027a	18.777b	0.601	0.001
C18:3n6	0.064	0.061	0.215	0.054	0.432
C18:3n3	0.664a	1.026b	0.579a	0.071	0.002
C20:0	0.033a	0.030a	0.054b	0.004	0.012
C20:1	0.152a	0.119b	0.139a	0.005	0.015
C20:2	0.086a	0.084a	0.113b	0.005	0.002
C20:3n6	0.085	0.086	0.087	0.005	0.98
C20:4n6	3.440	3.372	4.160	0.188	0.149
C20:5n3	0.063a	0.051a	0.088b	0.006	0.013
C22:4n6	0.332	0.316	0.295	0.011	0.482
C22:5n3	0.565a	0.486a	0.977b	0.075	<0.001
C22:6n3	0.355a	0.300a	0.564b	0.038	<0.001
SFA	36.963	38.645	40.079	0.650	0.169
UFA	62.470	60.510	59.453	0.636	0.175
PUFA	20.162a	21.361a	26.303b	0.906	<0.001
MUFA	42.308a	39.148a	33.150b	1.285	<0.001
OFA	30.897	31.800	32.306	0.448	0.509
DFA	67.707	66.726	66.437	0.442	0.556
EFA	15.234a	17.114a	19.571b	0.624	0.001
n3PUFA	1.648a	1.863a	2.655b	0.184	<0.001

n6PUFA	18.427a	19.862a	23.535b	0.768	0.003
n6:n3	11.556	10.661	8.864	0.981	0.036
DFA:OFA	2.196	2.109	2.041	0.044	0.424
MUFA:SFA	1.146a	1.020a	0.828b	0.047	0.005
UFA:SFA	1.692	1.576	1.484	0.043	0.165
PUFA:MUFA	0.476a	0.546a	0.799b	0.047	<0.001
PUFA:SFA	0.547a	0.556a	0.656b	0.021	0.219
AI	0.687	0.699	0.701	0.012	0.911
TI	1.021	1.080	1.079	0.033	0.002
CI	1.083a	0.930a	1.678b	0.111	<0.001
A-SFA	31.030	31.905	32.417	0.445	0.517
T-SFA	36.134	38.016	39.290	0.647	0.156
Δ9-desaturase index	0.357	0.358	0.330	0.008	0.219

differences marked with various superscripts within a row are significant at $P<0.05$
SFA – saturated fatty acids
UFA – unsaturated fatty acids
PUFA – polyunsaturated fatty acids
MUFA – monounsaturated fatty acids
EFA – essential fatty acids (18:2 + C18:3)
OFA – hypercholesterolemic acids (C14:0 + C16:0)
DFA – neutral and hypocholesterolemic acids (C18:0 + UFA)
AI – atherogenic index (C12:0 +4xC14:0 + C16:0)/[(MUFA + ∑SPUFA (n6) + (n3)] [Ulbricht & Southgate, 1991]
TI – thrombogenic index (C14:0 + C16:0 + C18:0)/0.5*MUFA + 0.5*n6PUFA + 3*n3PUFA + n3PUFA/n6PUFA) [Ulbricht & Southgate, 1991]
A-SFA – (C12:0 + C14:0 + C16:0)
T-SFA – (C14:0 + C16:0 + C18:0)
Δ9-desaturase index – (C14:1n9+ C16:1n9+ C18:1n9)/(C14:1n9+ C18:1n9+ C18:1n9+ C14:0 + C16:0 + C18:0) [Smith et al., 2002]
CI – consumer index (C18:3 + C20:5 + C22:6) [Wood et al., 2004]

n-6: n-3 PUFA ratio was between 11.56 (*m. longissimus dorsi)* and 12.62 in meat of nutria fed the control diet (hind leg), between 10.66 and 11.26 in meat of nutria fed the diet supplemented with linseed oil, and between 8.86 (P=0.036) and 8.28 (P=0.048) in meat of nutria fed with the addition ofapple seed oil (Table 4 and 5). n-6:n-3 PUFA ratio in group A was the most favourable for consumers. Głogowski et al. [12] reported the n-6:n-3 PUFA ratio in hind leg muscles to be 2.97 in females and 2.61 in males.

Ulbricht and Southgate [29] suggest another index of cardiovascular risk linked with fat quality, namely the atherogenicity index (AI). It defines the proportion of SFA (C14:0 myristic and C16:0 palmitic acid) to UFA (PUFA+MUFA), which indicates a significant, negative role of myristic acid, and a positive role of MUFA in human nutrition and should be as low as possible [5]. In the present study, this index was 0.608–0.686 for *m. semimembranosus* (P=0.044) (Table 4) and 0.608–0.701 for *m. longissimus dorsi* (P=0.91) (Table 5), whereas Głogowski et al. [11] reported the values of 0.584 and 0.608, respectively. Gašperlin et al. [9] considered the AI index of 0.60 in rabbit meat as quite favourable. This index was also lower than in sheep (1.00) and cattle (0.78) and similar to that in pigs (0.60) [29].

Another index suggested by Ulbricht and Southgate [29] is the thrombogenic index (TI), which in the present study was 0.96–1.01 for *m semimembranosus* (P=0.054) (Table 4) and 1.02–1.08 for *m. longissimus dorsi* (P=0.002) (Table 5), compared to 0.716 and 0.753 respectively in Głogowski et al. [11]. In rabbit meat this index was 0.81 according to Peiretti et al. [19] and 1.1 in bovine meat [24] and was stated as favourable.

Δ9-desaturase index in our study was 0.28–0.38 for *m semimembranosus* (P=0.01) (Table 4) and 0.33–0.36 for *m. longissimus dorsi* (P=0.219) (Table 5), compared to 0.524 and 0.568 respectively in Głogowski et al. [11].

Sum of the content of C18:3+C20:5+C22:6 acids in nutria meat ranged between 1.26–1.74 in hind leg (Table 4) and 0.93–1.68 (*m. longissimus dorsi*) (Table 5). In Głogowski et al. [11], the sum of C18:3+C20:5+C22:6 acids in the hind leg of extensively fed nutria ranged from 4.1 in females to 5.1 in males, while according to Saadoun et al. [23] thesum of these acids was only 0.2–0.3. Wood et al. [32] reported that thesum of these acids should not exceed 3% of total fatty acids. Oxidation of n-3 PUFA causes disagreeable fish odour [17], which should be avoided.

The ratio of hypercholesterolemic and hypocholesterolemic acids in nutria meat was similar: 2.041–2.196 for *m. longissimus dorsi* (Table 5) and 2.169–2.34 for *m. semimembranosus* (Table 4). It is believed that hypocholesterolemic acids reduce the absorption of dietary cholesterol and cholic acids and affect the synthesis of lipoproteins [20].

The presence of UFA in meat fat is beneficial due to its lower melting point. UFA are easily oxidized as they contain more double bonds than others acids. In addition to the absolute content of fatty acid groups with varying degrees of saturation, a very important indicator of the quality of fat is UFA/SFA ratio, which in the human diet should reach a value close to 2.

In the present research this ratio was 1.48–1.69 for *m. longissimus dorsi* (Table 5) and 1.56–1.75 for *m. semimembranosus* (Table 4). In nutria, Głogowski et al. [11] found this ratio to range from 1.81 (males) to 2.1 (females), and Saadoun et al. [23] from 1.34 (females) to 1.36 (males).

Stearic acid (C18:0 – SA) contributes significantly to meat tenderness and juiciness. The levels of stearic (C18:0) and linoleic acids (C18:2n-6) are strictly related to meat tenderness, firmness and juiciness. The above acids differ in melting temperature points (69.6 and -5°C, respectively), what has a significant effect on meat cohesion and firmness [5]. According to Wood et al. [32], when concentrations of α-linolenic acid (18:3n-3) approach 3% share of neutral lipids or phospholipids there are any adverse effects on meat quality, defined in terms of shelf life (lipid and myoglobin oxidation) and flavour [32]. A significantly higher content of SA was found in meat fat from group A compared to that from groups C and L, despite the lower content of SA in diet of group A. Reports of Wood et al. [31, 32] showed a positive correlation between the taste of meat and SFA and MUFA content and a negative correlation with PUFA.

CONCLUSION

The addition of apple seed oil to nutria diets influenced the FA profile of intramuscular fat more favourably than the addition of linseed oil.

The oil from apple seeds can be regarded as special oil (bio-oil), and due to itspossible nutrition effects in human it could find broader application, not only in the cosmetic industry but also in the animal feed and food industries.

It can find special application in the design and production of foods with specific health-promoting effects, rich in bioactive components and helpful in preventing metabolic diseases of modern civilization.

Compared with results from two different feeding systems (forage and other crop products; commercial dietary pellet only), results from this experiment showed that in current meat production the addition of vegetable oils is the easiest way to improve raw material quality and indexes related to human health

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Łukasz Migdał
Department of Genetic and Animal Breeding, University of Agriculture in Krakow, Poland
al. Mickiewicza 24/28
30-059 Krakow
Poland
email: lmigdal@ar.krakow.pl

Anna Migdał
Department of Animal Reproduction and Anatomy, University of Agriculture in Krakow, Poland
al. Mickiewicza 24/28
30-059 Krakow
Poland

Piotr Niedbała
Department of Poultry and Fur Animal Breeding and Animal Hygiene, University of Agriculture in Krakow, Poland
al. Mickiewicza 24/28
30-059 Krakow
Poland

Stanisław Łapiński
Department of Poultry and Fur Animal Breeding and Animal Hygiene, University of Agriculture in Krakow, Poland
al. Mickiewicza 24/28
30-059 Krakow
Poland

Henryk Pustkowiak
Department of Cattle Breeding, University of Agriculture in Krakow, Poland
al. Mickiewicza 24/28
30-059 Krakow
Poland

Marek Pieszka
National Research Institute of Animal Production, Poland
ul. Krakowska 1
32-083 Balice
Poland

Robert Głogowski
Department of Animal Breeding, Warsaw University of Life Sciences, Poland
ul. Ciszewskiego
02-786 Warsaw
Poland

Władysław Migdał
Department of Animal Product Technology, Faculty of Food Technology, University of Agriculture in Krakow, Poland
ul. Balicka 122
30-149 Kraków
Poland
