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A COMPARISON OF SELECTED BIOCHEMICAL CHARACTERISTICS OF MEAT FROM NUTRIAS (*MYOCASTOR COYPUS* MOL.) AND RABBITS (*ORYCTOLAGUS CUNICULUS*)*

Łukasz Migdał[1♦], Bogusław Barabasz[1], Piotr Niedbała[1], Stanisław Łapiński[1], Henryk Pustkowiak[2], Branislav Živković[3], Władysław Migdał[4]

[1]Department of Poultry and Fur Animal Breeding and Animal Hygiene, University of Agriculture in Krakow, Al. Mickiewicza 24/28, 30-059 Kraków, Poland
[2]Department of Cattle Breeding, University of Agriculture in Krakow, Al. Mickiewicza 24/28, 30-059 Kraków, Poland
[3]Institute for Animal Husbandry, Autoput 16, 11080 Zemun, Republic of Serbia
[4]Department of Animal Product Technology, Faculty of Food Technology, University of Agriculture in Krakow, Balicka 122, 31-149 Kraków, Poland
♦Corresponding author: lmigdal@ar.krakow.pl

Abstract

The aim of this study was to compare major biochemical properties of nutria meat with relevant composition and texture data of rabbit carcasses. The meat from nutria *m. semimembranosus* (MS; thigh muscle) contained 29.54% dry matter (DM), 20.05% total protein (TP), 7.83% total fat (TF) and 1.23% total ash (TA). The ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA) was lower in nutria than in rabbit meat (0.55–0.58 and 0.93–0.94, respectively). The *n-6/n-3* PUFA ratio was 15.3 (MS) and 11.22 (*m. longissimus dorsi*, MLD; loin) in nutria meat and 7.55 and 8.08 respectively in rabbit meat, which appeared more beneficial for the consumer. Among the most important texture parameters, hardness ranged from 66 for MS to 73 N for MLD, and overall chewiness was 23 N. The collagen content was between 0.68 and 0.72%. The results show that in comparison with rabbit meat, nutria meat has valuable properties and is recommended for the human diet.

Key words: nutria, rabbit, meat, chemical composition, amino acids, fatty acids, texture parameters

The nutria (*Myocastor coypus* Mol.) is indigenous to South America but has been brought to North America and Europe. Nutrias are a major ecological problem in the southern United States, where they have devoured large areas of marshland (Tulley

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et al., 2000), but in Europe this fur species had significant economic value (Barabasz et al., 2007). East European countries (former East Germany, Poland, former Czechoslovakia and former Soviet Union) were the largest producers of nutria pelts, well known for their good quality, durability and softness. Nutria meat was always considered a by-product and its economic value was never as important as that of fur. Nevertheless, the consumption of nutria meat was popular in the western part of Poland (Głogowski, 2008), where most herds were kept.

Today they are limited to a genetic conservation programme following the decline in nutria breeding (Barabasz et al., 2007). The meat chemical composition and fatty acid content in the meat from intensively reared nutria were previously described by Faverin et al. (2002), Saadoun et al. (2006), and Saadoun and Cabrera (2008). Similar analyses of meat from feral nutrias were reported by Tulley et al. (2000).

In Europe, the meat from intensively fed nutria was described by Sperber et al. (1982), Cholewa et al. (2000), Kuźniewicz and Filistowicz (2006). Recently, the properties of meat from nutrias reared in extensive systems (fed crop products such as beet roots, steamed potatoes and clover) were evaluated by Mertin et al. (2003), Głogowski (2008), Głogowski and Panas (2009), and Głogowski et al. (2010). Moreover, Mertin et al. (2003) reported high value of edible viscera such as the heart, kidneys and liver.

Modern consumers look for valuable, soft and tender meat, rich in nutrients and vitamins, with a positive influence on human health (McMichael and Bambrick, 2005). It appears likely that nutria meat may represent the most preferred type from the consumer point of view. The main assumption of this experiment was that nutria meat could have similar nutrition value to rabbit meat. Therefore, the aim of this study was to analyse chemical composition, texture, collagen, pH, fatty acid profile and the amino acid content of nutria meat, and compare them with the relevant parameters of rabbit meat.

Material and methods

Animals and diets

The study was carried out on 11 Standard nutria females at the age of 6 months and 10 New Zealand White rabbit females at the age of 12 weeks. The animals originated from the research station of the Department of Poultry and Fur Animal Breeding and Animal Hygiene. Nutrias were kept in individual indoor pens without pools with unlimited access to water. Rabbits were housed in wire cages with unlimited access to water. Nutria and rabbits were fed *ad libitum* with commercial pelleted diet (15.80% protein, 3.20% fat, 6.90% crude fibre, 5.60% ash, 0.77% lysine, 0.52% phosphorus, 6 000 IE/kg vitamin A, 1200 IE/kg vitamin D_3, 34 ppm of vitamin E (DL-α tocopherol), 12 ppm of copper sulphate). The commercial pellet consisted of cereal grains, cereal dehulling residues, by-products of bakery, oil and noodle processing. Chopped beetroots and steamed potatoes were additionally distributed solely for nutrias.

Slaughter and sample collection

Before slaughter, animals were fasted for 12 h. All animals were stunned with electrical impulse (230V) and immediately bled, pelted and eviscerated. Following evisceration, carcasses without tail, head, front paws and hind feet with internal organs were weighed following the method of Cabrera et al. (2007). For further chemical analysis, samples from loin (*m. longissimus dorsi* – MLD) and thigh muscles (*m. semimembranosus* – MS) were collected and stored in liquid nitrogen until analysis.

The meat samples were chemically analysed to determine dry matter, protein, fat and ash content. Samples were ground twice in a mincer and a thoroughly mixed tissue was placed in a tight vessel, completely filled with the sample, from which deliberately weighed portions were taken for each analysis. The tests were commenced immediately after sample preparation. The water content was determined using the drying method in accordance with PN-ISO-1442 standard, protein content (%) using the method of Kjeldahl in accordance with PN-A-04018:1975, fat content (%) using the method of Soxhlet in accordance with PN-ISO-1444, and total ash content in accordance with PN-ISO-936. Total cholesterol was determined according to Rhee et al., (1982)

Amino acid content

Amino acid (AA) content was determined by the ninhydrin method using amino acid analyser AAA 400 (INGOS, Czech Republic). The standard contained 25 nmol of each component except for ammonia. Operating parameters are given according to AAA 400 analyser (2002).

Collagen content

The total collagen content was estimated according to Polish Standard PN-ISO 3496. The absorbance of samples was measured with Novasina spectrophotometer at 558 nm. The hydroxyproline content was read from calibration curve. The total collagen content was calculated from hydroxyproline amount using the coefficient 7.25 and with dilution factors included. The soluble collagen was calculated as the difference between total collagen and insoluble collagen. The amount of insoluble collagen was estimated according to the method of Liu et al. (1994) with our modifications. The hydroxyproline content was read from the spectrophotometric curve. Insoluble collagen content was calculated using the coefficient 7.25. The amount of soluble collagen was calculated and expressed as percentage of total collagen.

Fatty acid profile

Samples were extracted with chloroform-methanol (2:1, v/v) according to the method of Folch et al. (1957). Then 1 g of meat samples was mixed with 15 mL chloroform–methanol mixture and homogenized for 10 min at 5000 rpm, and after 5 min pause – 5 min at 1000 rpm using homogeniser MPW-120 (Mechanika Precyzyjna, Waszawa, Poland). The mixture was then filtered through filter paper to the regular cylinder and completed with extraction mixture up to 15 mL. Next, 3 mL of 0.74% KCl solution was added to 15 mL of filtrate. The alcohol–water phase was removed, and the chloroform phase was washed 3 times using 2 mL solution

of chloroform:methanol: 0.74% KCl (3:48:47, v/v/v). Subsequently the chloroform phase was recovered, dehydrated with anhydrous sodium sulphate (Na_2SO_4) and dried using nitrogen at 45ºC. To the sample (about 10 mg) were added 0.5 ml 0.5 N KOH in methanol and heated at 85ºC. Next 1 ml 12% BF_3 in methanol were added and the sample was again heated at 85ºC. After cooling in room temperature 1 ml hexane and 5 ml saturated solution of NaCl were added. Fatty acid methyl esters profile in one µl samples at the split ratio of 10:1 were separated by gas chromatography on a TRACE GC ULTRA gas chromatograph, equipped with 30 m capillary column SUPELCOWAX 10 of 0.25mm inner diameter and coating thickness of 0.25 µm (30 m × 0.25 mm × 0.25 um). Operating conditions were as follows: helium was used as a carrier gas, flow 1 ml/min, split flow 10 ml/min, injector temperature 220ºC, detector temperature 250ºC, initial column temperature 160ºC.

Meat colour

Lightness [L*], redness [a*] and yellowness [b*] of meat were determined using a Konica Minolta CM – 600d spectrophotometer. Values of [a*] and [b*] were used to calculate the saturation value – chroma [C*].

pH values

Changes in meat pH were determined from slaughter until 24 hours after slaughter using penetrating electrode Benchtop Electrochemistry Meter (Belgium). pH changes were monitored right after pelting (time 0), 15 and 45 minutes after pelting and later, every hour until 24 hours after pelting. Absolute and relative drop of pH according to Blasco and Piles (1990) was calculated.

Instrumental measurement of shear force

Cylinder-shaped samples (14 mm in diameter and 15 mm in height) were cut from the meat and roasted in oven at 180ºC until internal temperature of 78ºC. Shear force was measured using a TA-XT2 Texture Analyser (Stable Micro Systems) with a Warner-Bratzler attachment and a triangular notch in the blade. The blade speed during the test was 1.5 mm/s. Results were presented as force per area (kG/cm^2).

Instrumental measurement of texture parameters

Cylinder-shaped samples (14 mm in diameter and 15 mm in height) were cut from the meat roasted as described above. The texture was analysed using a TA-XT2 Texture Analyser (Stable Micro Systems) with an attachment in the form of a cylinder 50 mm in diameter. The samples were subjected to a double pressing test using a force of 10 g to 70% of their height. The cylinder speed was 2 mm/s, and the interval between pressures was 3 s.

Statistical analyses

Results are presented as means (x) with standard deviations (s), calculated using Statistica for Windows v. 8.0 software. t-Student test was used to determine the significance of observed differences.

Results

Table 1 presents the chemical composition of meat from nutrias and rabbits. Results show that the TF content in nutria muscles differs significantly. Moreover, rabbit meat is significantly leaner compared to nutria meat. Total cholesterol content was also higher in nutrias.

Table 1. Chemical composition of nutria and rabbit meat (%)

		Water	DM	TP	TF	TA	Total cholesterol (mg/100 g of fresh tissue)
MS	Nutria	70.46±2.57	29.54±2.57 a	20.05±0.65 A	7.83±1.09 A	1.23±0.18	68.16±2.89 A
	Rabbit	72.31±1.48	27.69±1.19 b	24.41±0.76 B	1.41±0.20 B	1.27±0.13	42.05±3.04 B
MLD	Nutria	74.57±1.71	25.43±1.72	20.89±0.74 r	3.12±0.75 R	1.22±0.15	64.42±1.84 R
	Rabbit	74.40±1.28	25.60±1.27	23.20±0.91 s	0.70±0.21 S	1.21±0.11	38.49±2.96 S

Values in the same columns with different letters differ significantly (MS – a, b – P≤0.05, A, B – P≤0.01; MLD – r, s – P≤0.05, R, S – P≤0.01); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi*, DM – dry matter, TP – total protein, TF – total fat, TA – total ash.

Table 2. Amino acid content in nutria and rabbit meat (mg/g of fresh tissue)

Amino acids	MS		MLD	
	nutria	rabbit	nutria	rabbit
Essential amino acids				
Threonine	8.42±0.08	8.86±0.06	9.65±0.10	9.53±0.07
Valine	10.26±0.09	10.98±0.09	11.24±0.10	11.30±0.08
Isoleucine	9.08±0.11	9.54±0.10	10.23±0.09	10.02±0.10
Leucine	16.16±0.11	16.52±0.12	17.58±0.11	16.75±0.13
Phenylalanine	8.09±0.08	8.24±0.09	8.74±0.09	8.16±0.09
Lysine	17.37±0.14	17.21±0.12	19.15±0.14	18.60±0.13
Arginine	14.29±0.12	14.59±0.10	15.78±0.12	15.01±0.11
Methionine	4.26±0.08	4.17±0.07	4.72±0.09	4.64±0.07
Histidine	7.45±0.09	7.71±0.08	8.48±0.09	8.96±0.10
Tyrosine	6.17±0.10	6.24±0.06	6.95±0.11	6.42±0.08
ΣEAA	101.55	104.06	112.52	109.39
Nonessential amino acids				
Cysteine	1.82±0.02	1.94±0.03	1.87±0.02	2.11±0.04
Aspartic acid	19.87±0.13	20.02±0.08	21.98±0.10	21.27±0.12
Serine	7.60±0.09	7.36±0.06	8.57±0.06	7.94±0.10
Glutamic acid	30.14±0.18	29.42±0.15	32.60±0.16 r	30.50±0.11 s
Proline	8.85±0.11	8.49±0.08	9.29±0.14	8.27±0.11
Glycine	9.08±0.14	9.01±0.06	9.56±0.12	9.13±0.08
Alanine	10.78±0.15	10.48±0.09	11.73±0.16	11.16±0.08
ΣNEAA	88.14	86.72	95.6	90.38

Values in the same columns with different letters differ significantly (MLD – r, s – P≤0.05); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi.*

Table 2 shows amino acids (AA) content in nutria and rabbit meat. MS muscles in nutrias and rabbits had similar AA content. Only nutria MLD had significantly higher level of glutamic acid than that in rabbits. However, MS in rabbits contained more essential and semi-essential AA (by 2.44 mg/g of fresh tissue) compared to nutria meat, and MLD in rabbits contained less essential and semi-essential amino acids (by 2.6 mg/g fresh tissue) compared to the same muscle in nutria.

Table 3. Collagen content in raw nutria meat (%)

		Total collagen	Soluble collagen	Soluble collagen (% of total collagen)
MS	Nutria	0.72±0.13 a	0.050±0.04	6.94±0.09
	Rabbit	0.58±0.07 b	0.039±0.03	6.72±0.08
MLD	Nutria	0.38±0.06 r	0.023±0.02	6.18±0.07
	Rabbit	0.25±0.04 s	0.015±0.02	6.28±0.08

Values in the same columns with different letters differ significantly (MS – a, b – P≤0.05; MLD – r, s – P≤0.05); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi*.

Table 4. Fatty acid profile of intramuscular fat from nutrias and rabbits (%)

Fatty acid	MS		MLD	
	nutria	rabbit	nutria	rabbit
1	2	3	4	5
C10:0	0.04±0.004	-	0.03±0.006	-
C12:0	0.13±0.03	0.52±0.08	0.13±0.01	0.82±0.14
C14:0	3.94±1.51	2.96±0.62	3.94±0.36	3.04±0.59
C14:1 cis *n-9*	0.80±0.48	0.23±0.18	0.64±0.13	0.12±0.07
C15:0	0.38±0.13	0.54±0.09	0.33±0.04	0.58±0.06
C16:0	25.93±2.42	26.94±4.51	26.96±1.82	26.86±1.72
C16:1 cis *n-9*	0.76±0.07	-	0.68±0.14	-
C16:1 cis *n-7*	18.43±5.64 A	3.23±0.51 B	17.26±0.15 R	3.00±0.89 S
C17:0	0.20±0.01 a	0.50±0.04 b	0.21±0.01 r	0.53±0.06 s
C17:1 cis *n-9*	0.38±0.05	0.33±0.03	0.33±0.01	0.22±0.04
C18:0	4.66±1.69	5.89±0.74	5.24±0.44	5.76±0.81
C18:1 cis *n-9*	17.94±2.93	21.84±1.61	18.38±0.74	21.61±1.71
C18:1 cis *n*-7	5.22±0.07 a	1.64±0.14 b	4.86±0.48 r	1.46±0.18 s
C18:2 *n-6*	14.93±2.70 a	26.08±1.68 b	14.51±0.87 r	26.86±1.76 s
C18:3 *n-6*	0.07±0.01	0.08±0.01	0.06±0.01	0.09±0.02
C18:3 *n-3*	0.57±0.09 A	2.96±0.19 B	0.66±0.20 R	2.85±0.32 S
CLA	-	0.07±0.01	-	0.05±0.01
C20:0	0.03±0.02	0.09±0.02	0.03±0.01	0.10±0.01
C20:1 cis *n-9*	0.10±0.01 a	0.22±0.04 b	0.15±0.02	0.23±0.05
C20:2 *n-6*	0.09±0.02	0.21±0.03	0.09±0.01	0.23±0.05
C20:3 *n-6*	0.10±0.08	0.31±0.09	0.09±0.02	0.27±0.10
C20:4 *n-6*	3.65±1.23	3.20±0.89	3.44±0.42	3.36±2.10
C20:5 *n-3*	0.07±0.04 a	0.16±0.05 b	0.06±0.01	0.08±0.03
C22:4 *n-6*	0.40±0.11	0.71±0.08	0.33±0.06	0.69±0.30
C22:5 *n-3*	0.36±0.10	0.80±0.15	0.56±0.11	0.86±0.20
C22:6 *n-3*	0.28±0.14	0.13±0.05	0.36±0.02	0.11±0.06
Other	0.54±0.51	0.36±0.16	0,67±0.32	0.22±0.09

Table 4 – contd.

1	2	3	4	5
SFA	35.31±2.46	37.44±1.81	36.87±1.28	37.69±1.92
UFA	64.15±2.72	62.20±1.93	62.47±1.29	62.09±2.11
MUFA	43.63±7.22 A	27.49±1.54 B	42.31±0.43 R	26.64±1.71 S
PUFA	20.52±4.49 A	34.71±1.79 B	20.16±1.02 R	35.45±1.92 S
EFA	15.57±3.73 A	29.12±1.70 B	15.23±0.87 R	29.80±1.77 S
PUFA *n-6*	19.24±4.10 A	30.59±1.61 B	18.52±1.13 R	31.50±1.77 S
PUFA *n-3*	1.28±0.37 A	4.05±0.27 B	1.65±0.30 R	3.90±0.29 S
n-6/n-3	15.03±3.28 A	7.55±1.91 B	11.22±3.02 r	8.08±1.85 s
OFA	29.87±0.87	29.90±1.13	30.90±1.51	29.90±1.21
DFA	68.81±0.78	68.09±0.93	67.71±1.45	67.85±1.18
DFA/OFA	2.30±0.09	2.28±0.10	2.19±0.16	2.27±0.11
MUFA/SFA	1.24±0.32 a	0.73±0.09 b	1.15±0.05r	0.71±0.06 s
UFA/SFA	1.82±0.18	1.66±0.11	1.69±0.10	1.65±0.08
PUFA/MUFA	0.47±0.04 A	1.26±0.07 B	0.48±0.02 R	1.33±0.09 S
PUFA/SFA	0.58±0.16 a	0.93±0.06 b	0.55±0.05 R	0.94±0.07 S
A-SFA	30.00±0.86	30.42±0.94	31.03±1.50	30.72±1.15
AI index	0.65±0.05	0.63±0.07	0.56±0.09	0.56±0.08
T-SFA	34.53±2.31	35.79±1.79	36.14±1.31	35.66±1.20
TI index	0.98±0.07	0.87±0.06	1.02±0.03	0.87±0.06
Δ9-desaturase index	0,53±0.06	0.41±0.03	0.50±0.01	0.41±0.02
Thioesterase index	6.58±1.23	9.10±1.47	6.84±0.81	8.84±1.34
Elongase index	0.18±0.025	0.22±0.028	0.19±0.018	0.21±0.021

Values in the same columns with different letters differ significantly (MS – a, b – P≤0.05, A, B – P≤0.01); (MLD – r, s – P≤0.05, R, S – P≤0.01); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi*; 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 index – atherogenic index – (C12:0 +4xC14:0 + C16:0) / [(MUFA + ∑SPUFA (*n-6*) + (*n-3*)] (Ulbricht et al., 1991); A-SFA: the sum of C12:0, C14:0 and C16:0; T-SFA: the sum of C14:0, C16:0 and C18:0; TI – thrombogenic index – (C14:0+C16:0+C18:0)/0.5*MUFA+0.5*n-6-PUFA+3**n-3*PUFA + *n-3*PUFA/*n-6*PUFA) (Ulbricht et al.,1991).

Δ9-desaturase index = (C16:1+c9C18:1+c11C18:1)/(C16:1+c9C18:1+c11C18:1+C14:0+C16:0+C18:0) (Smith et al., 2002); Thioesterase index: C16:0/C14:0 (Zhang et al., 2007); Elongase index: C18:0/C16:0 (Zhang et al., 2007).

Table 3 presents collagen content in both species, with nutria muscles containing more total collagen compared to that in rabbit muscles. Rabbit and nutria MS muscles had higher total collagen content compared to MLD. In nutrias, digestible collagen content was between 6.18% (MLD) and 6.94% (MS) of total collagen, while in rabbits it was 6.72% and 6.28%, respectively. Nutria intramuscular fatty acid profile showed significantly higher level of C16:1*n-7*, C18:1*n-7* and significantly lower level of C17:0, C18:1*n-9*, C18:2*n-6*, C18:3*n-3*, C20:2*n-6*, C20:3*n-6*, C22:4*n-6*, C22:5*n-3* (Table 4). Higher level of monounsaturated (MUFA) and lower polyunsaturated (PUFA) with essential fatty acids (EFA) levels were found in the intramuscular fat of nutrias compared to those in rabbits. *n-6/n-3* PUFA ratio in nutria meat ranged between 11.22 (MLD) and 15.3 (MS) while in rabbits it was 7.55 and 8.08, respectively. In the present study, the PUFA/SFA ratio ranged from 0.55 to 0.58 in nutria meat and from 0.93 to 0.94 in rabbit meat.

Table 5 shows meat colour (L* a* b*) measurement results for rabbits and nutrias. Nutria meat is darker than that of rabbits (higher L* value), and can be considered red.

Table 5. The colour of nutria and rabbit meat

		L*	a*	B*	C*
MS	Nutria	34.56±6.31 a	8.52±4.25	10.07±2.53	13.19±4.31
	Rabbit	48.88± 4.08 b	10.70±3.95	9.45±1.68	14.27±5.34
MLD	Nutria	31.72±3.06 r	11.38±4.42 r	13.15±1.49 r	17.39±3.36 r
	Rabbit	46.39±4.04 s	4.46±1.39 s	7.24±1.12 s	8.50±2.28 s

Values in the same columns with different letters differ significantly (MS – a, b – P≤0.05; MLD – r, s – P≤0.05); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi*.

Table 6. Postmortem changes in pH of nutria and rabbit meat

Time after slaughter	MS		MLD	
	nutria	rabbit	nutria	rabbit
15 min.	6.81±0.14	6.69±0.28	6.78±0.17	6.72±0.27
1	6.57±0.23	6.12±0.36	6.43±0.13	6.24±0.23
2	6.46±0.19	5.97±0.29	6.28±0.18	6.10±0.22
3	6.25±0.22 a	5.56±0.21 b	6.10±0.15	5.67±0.22
4	6.19±0.05 a	5.54±0.11 b	6.06±0.16	5.59±0.24
5	6.26±0.12 a	5.58±0.15 b	6.20±0.07 r	5.46±0.01 s
6	6.18±0.15 a	5.64±0.11 b	6.12±0.11 r	5.51±0.05 s
7	6.09±0.11	5.72±0.07	6.16±0.07 r	5.55±0.03 s
8	6.03±0.06	5.64±0.03	6.11±0.02 r	5.55±0.02 s
9	6.03±0.12	5.60±0.05	6.05±0.04 r	5.50±0.03 s
10	5.92±0.07	5.54±0.04	5.95±0.12	5.44±0.01
11	5.95±0.08	5.57±0.03	6.00±0.09	5.51±0.01
12	6.01±0.05	5.59±0.01	6.08±0.06 r	5.47±0.02 s
18	6.06±0.09	5.85±0.11	6.13±0.06	5.65±0.02
24	6.13±0.05	5.74±0.02	6.26±0.10 r	5.70±0.03 s
absolute drop in pH	0.89±0.14	1.15±0.05	0.83±0.10 r	1.28±0,05 s
relative drop in pH	0.13±0.02	0.17±0,01	0.12±0.01	0.19±0,01

Values in the same rows with different letters differ significantly (MS – a, b – P≤0.05; MLD – r, s – P≤0.05); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi.*

Nutria meat was characterized by higher pH value compared to rabbit meat (Table 6). Both initial and final pH of nutria meat was higher compared to those in rabbits. But the absolute drop of pH in nutria meat (0.83–0.89) was lower than that in rabbits (1.15–1.28). The lowest pH value in nutria meat was observed 10 h after slaughter (5.92–5.95) compared to 4–5 h after slaughter in rabbit meat (5.46 in MLD, 5.54 in MS), with the second drop noted 10 h after slaughter (5.44–5.54). 24 h after slaughter the final pH of nutria meat was 6.13 for MS and 6.26 for MLD, and in rabbit meat it was 5.74 and 5.70, respectively.

Shear force of nutria meat was approximately 7.51 kG/cm^2 (73.65 N/cm^2) for MS and 7.93 kG/cm^2 (77.77 N/cm^2) for MLD, with the hardness ranging from 73.02 (MS) to 75.63 N (MLD) (Table 7).

Table 7. Comparison of shear force and texture parameters of roasted nutria and rabbit meat

		Shear force (kG/cm^2)	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)	Resilience
MS	Nutria	7.51±1.70 A	75.63±12.31	0.63±0.06 a	0.56±0.03 a	23.76±5.30 a	0.26±0.02 a
	Rabbit	3.31±0.83 B	66.71±10.50	0.49±0.08 b	0.37±0.05 b	13.52±4.16 b	0.12±0.03 b
MLD	Nutria	7.93±1.65 R	73.02±13.98	0.59±0.07	0.53±0.07 r	23.02±6.96 r	0.25±0.03
	Rabbit	3.12±0.94 S	65.84±11.05	0.50±0.06	0.41±0.03 s	14.73±3.11 s	0.18±0.03

Values in the same columns for the carcass part with different letters differ significantly (MS – a, b – P≤0.05, A, B – P≤0.01; MLD – r, s – P≤0.05, R, S – P≤0.01); MS – *m. semimembranosus*, MLD – *m. longissimus dorsi.*

Discussion

Chemical composition of meat

According to Głogowski and Panas (2009), the composition of nutria meat (especially fat content) is related to the age of animals. Highest fat content was found in 9-month-old nutrias (5.0 in MLD and 7.4% in MS) compared to 0.8 and 5.3% in 6-month-old nutrias and 1.1 and 4.0% respectively in nutrias aged 13 months. Moreover, those authors reported higher fat content in the meat of females compared to males. In the pectoral muscle of 5-month-old nutria, Saadoun et al. (2006) found from 22.05 (in females) to 22.34% (in males) protein and from 1.84 to 1.78% fat, respectively. In the hind leg, fat and protein content was lower than that in pectoral muscles, and fat and protein content in hind leg was higher in females than in males.

Tulley et al. (2000) found that feral nutria meat has lower fat content compared to that of farm-reared animals. Saadoun and Cabrera (2008), who compared the quality of meat from various South American species, stated that nutria meat had medium fat content and similarly to yacare (Caiman) meat, is the highest in cholesterol. Cabrera et al. (2007) reported the content of cholesterol to be from 69.9 to 71.8 mg per 100 g of fresh tissue. Similar cholesterol content was noted by Saadoun et al. (2006). The cholesterol content differs between feral (Tulley et al., 2000) and farm-reared nutrias. The lipid content of meat observed in our study was slightly higher than that in the feral population examined by Tulley et al. (2000). These differences may be likely attributed to either rearing or diet characteristics.

Cabrera et al. (2007), who analysed meat from 8-month-old nutria fed a pelleted diet with 16, 19 or 22% of TP, did not find a significant effect of sex and diet on nutria pectoral muscle protein and lipid content. Indeed, the protein content of MS, revealed in our study was lower than that in older females fed a diet with 16% of TP but moreover, lower than that in animals of similar age, fed extensive diets (Głogowski and Panas, 2009). One plausible explanation may be the housing conditions, as was previously demonstrated in rabbits (Lazzaroni et al., 2009).

The meat of rabbits in our study showed lower fat content than that of nutrias. The optimal fat content, preferred by consumers, should not exceed 3%, due to its beneficial influence on juiciness and tenderness of meat (Maj et al., 2008). High

fatness of nutria meat may be the consequence of elevated energy content in diet, limited animal mobility restricted by housing conditions and the age at slaughter (Głogowski and Panas, 2009).

Jensen (1993) reported that exogenous AA content in rabbit meat is about 2% higher than that in other slaughter animals. Significantly higher content of glutamic acid in MLD in nutrias can be considered valuable, and likely indicates naturally enhanced flavour (Jurado et al., 2007). In our experiment AA content was higher in nutria MLD for EAA and NEAA and in MS for EAA. Based on Jensen (1993) and results from our experiment, we can say that nutria meat (especially MLD) is rich in AA and can be recommended for the human diet (Table 2).

Dietary *n-3* PUFA apparently protect from tumour incidence (Simopoulos, 2001; Jelińska, 2005). 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 (Okuyama, 1997; Simopoulos, 1999). According to FAO/WHO (2003), the ratio of *n-6/n-3* in food for humans should be lower than 4, and PUFA/SFA higher than 0.4. The PUFA/SFA ratio is widely regarded as an indicator of fat quality in terms of human health, but the favourable value of this index does not go hand in hand with favourable *n-6/n-3*, since the dietary increase in PUFA promotes mainly isomers of the *n-6* family. Szkucik and Ziomek (2010) reported *n-6/n-3* PUFA ratio of 6.29 in French Lop meat and 2.66 in crossbred rabbits fed conventionally with forage and root crops with addition of crushed barley and hay, respectively. Cygan-Szczegielniak et al. (2010), who compared fatty acid profile in rabbits fed organic pellets and rabbits fed farm-produced feeds (forage and concentrate), found a beneficial *n-6/n-3* PUFA ratio and lower cholesterol content in meat from rabbits receiving farm-produced feed.

Głogowski et al. (2010) reported desired values of *n-6/n-3* PUFA (2.97 in females and 2.61 in males) in thigh muscles of nutrias, fed fresh green forage. On the other hand, a simple calculation of the data, presented by Saadoun et al. (2006) for intensively fed nutrias shows a substantially high value of *n-6/n-3* in thigh muscles (approximately 29.0). This may indicate that feeding nutrias with concentrate based diets may have detrimental effects on biochemical quality of their meat.

Ulbricht and Southgate (1991) reported other indicators of fat quality, including the atherogenicity index (AI), which likely reflects the risk of cardiovascular disease (CVD). It defines the proportion of SFA (myristic and palmitic acid) to UFA (PUFA + MUFA), indicating a significant, negative role of myristic acid, and an adverse effect of UFA in human nutrition. In our study, we found slightly higher AI values for MS than those reported by Głogowski et al. (2009) (0.65 versus 0.58, respectively). The same pattern was observed in thrombogenic index (TI). Compared to green forage diet, the meat from animals receiving dry pelleted feed had a higher content of prothrombogenic SFA (0.71 versus 0.98, respectively) (Table 4).

Meat colour

This rheological characteristic is influenced, among others, by the high concentration of haeme pigments such as metmyoglobin (MetMb) (Calkins and Hodgen,

2007). Nutria MS muscle tissue was lighter than MLD, which can be associated with higher intramuscular fat content (lighter colour of fat). a* value was higher for MLD, which indicates that this muscle is more red than hind leg muscles. An inverse relationship was found for rabbit meat, with a higher a* value found for MS. a* value depends on the muscle pigment myoglobin level and the relative proportions of myoglobin forms. b* value was higher in nutria meat than in rabbit meat. Saturation value C* was highest in nutria MLD (17.39) and lowest in the same muscle in rabbit (8.50). A similarly high value of this ratio in rabbit meat was reported by Łapa et al. (2008).

pH value

This indicates lower acidification of nutria meat compared with rabbit, caused probably by lower glycogen content and thus another process of *rigor mortis*. Cholewa et al. (2009) found that the estimation of pH value, electrical conduction and brightness in muscle homogenate were not representative of nutria meat quality.

Szkucik and Pyz-Łukasik (2006), when analysing pH of rabbit meat right after pelting (time 0), 15 and 60 min later and after 12, 24, 72 and 144 h of carcass cold storage, showed that rabbit meat pH underwent a progressive drop to 12 h (lowest postmortem acidification), remained stable until 24 h after slaughter and increased to neutral after 144 h. The authors cited above found significant differences in pH values in different parts of the carcass in the time period examined. Similar pH of rabbit meat to ours after 24 h at 4ºC was reported by Virág et al. (2008). According to Popek (1993), pH of good quality rabbit carcass should be between 5.7 and 5.9 (similar to that in our study) and that of medium quality carcass between 6.0 and 6.2, and pH 24 > 6.2 is commonly considered an indicator of poor meat quality. Acidity of muscle tissue had a strong influence on such meat parameters as water holding capacity, tenderness, flavour and colour. Good quality meat is characterized by pH of 6.1–6.8 (after slaughter) and measurements from our study fit this range. Lower pH reflects watery meat and poorer processing properties (Hulot and Ouhayoun, 1999). There are very few publications regarding pH changes in nutria meat. Results presented in this study describe changes of pH during the first 24 h after slaughter, which are very important for further technological processes.

Meat texture

Meat texture can be easily described as a set of physical characteristics resulting from its composition and consistency. They are characterized by several factors affecting others. Meat from MLD is considered harder than in hind leg with substantially lower fat content. Łapa et al. (2008), who estimated texture parameters and shear force of meat from New Zealand White and California rabbits, stated that shear force of raw meat from MLD was between 12.13 N/cm^2 (California White) and 15.9 N/cm^2 (New Zealand White). Moreover, according to Larzul et al. (2005) there is no influence of sex on shear force of rabbit meat. The authors observed an influence of genotype (different genetic lines of rabbits) on shear force values (between 28.4 and 45.1 N). The results indicated that analysed meat can be classified as

of medium tenderness. According to Kołczak (2007) a shear force value of 4–5 kG/cm^2 (39.23–49.03 N/cm^2) is typical of tender roasted meats and values higher than 15 kG/cm^2 (147.1 N/cm^2) are considered typical of firm meat. Nutria meat can be classified as tender meat which is important for consumers preferring that kind of meat. Beneficial tenderness of rabbit meat is linked with the diameter of muscle fibre (30–41 μm). Elevated hardness is linked with lower fatness and higher collagen level in meat (Łapa et al., 2008). Nutria meat has a higher content of collagen compared with rabbit meat, which most likely resulted in significantly increased shear force regardless of the muscle, and explained differences in other physical properties of both species.

In conclusion, compared with rabbit meat, nutria meat is a nutritious and tender product that can be valuable for the human diet. The majority of meat characteristics estimated in our study showed differences between both species, nevertheless it needs to be emphasized that the consumption of nutria meat is safe and advantageous.

In the present study, fatty acid content of nutria meat appeared less favourable than that of other meats, in terms of the low concentration of PUFA and high *n-6/n-3* PUFA ratio. One plausible explanation is the composition of diet, which promoted MUFA accumulation. As previously demonstrated, the offering of green forage may increase the concentration of health-promoting fatty acids in the carcass of farmed nutrias (Głogowski et al., 2010). Nutria meat parameters can be also modified by addition of vegetable oils to the diet. The results shown above support the thesis that nutria meat can be a valuable product in the human diet. AA content and protein content have a beneficial influence on human health. Especially the extensive breeding system of these animals can be important now that consumers look for more products from the extensive system. Thus, it seems reasonable to regard nutrias as valuable animals for slaughter.

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ŁUKASZ MIGDAŁ, BOGUSŁAW BARABASZ, PIOTR NIEDBAŁA,
STANISŁAW ŁAPIŃSKI, HENRYK PUSTKOWIAK, BRANISLAV ŽIVKOVIĆ,
WŁADYSŁAW MIGDAŁ

Porównanie wskaźników biochemicznych mięsa nutrii (*Myocastor coypus* Mol.) i królików (*Oryctolagus cuniculus*)

STRESZCZENIE

Celem badań było porównanie wskaźników biochemicznych mięsa nutrii i królików. Mięso nutrii charakteryzowało się wyższą zawartością tłuszczu (od 3,12% *m. longissimus dorsi* do 7,83% *m. semimembranosus*) w porównaniu z mięsem króliczym (odpowiednio 0,7 i 1,41%). Stosunek wielonienasyconych do nasyconych kwasów tłuszczowych w mięsie nutrii wynosił 0,55–0,58, natomiast w mięsie króliczym 0,93–0,94. Stosunek wielonienasyconych kwasów tłuszczowych *n-6/n-3* w mięsie nutrii był mniej korzystny dla konsumenta i wynosił 15,3 (*m. semimembranosus*) i 11,22 (*m. longissimus dorsi*) w porównaniu z mięsem króliczym (odpowiednio 7,55 i 8,08). Mięso nutrii w porównaniu do mięsa króliczego charakteryzowało się mniejszą zawartością białka oraz większą zawartością kolagenu. Wyższa zawartość kolagenu spowodowała, że mięso nutrii było twardsze i wymagało większej siły cięcia. Jednocześnie mięso nutrii było ciemniejsze (L* od 31,72 do 34,56) w porównaniu z mięsem króliczym (L* od 46,39 do 48,88). Mięśnie nutrii charakteryzują się wyższym wskaźnikiem pH w porównaniu z mięśniami królików i różnią się przebiegiem stężenia pośmiertnego *rigor mortis*. Najniższą wartość pH w mięśniach nutrii stwierdzono w 10. godzinie po uboju, natomiast w mięśniach królików już w 5. godzinie po uboju. Wysokie pH mięsa nutriowego może sprzyjać szybszemu psuciu się tego mięsa. Dobre parametry mięsa nutriowego wskazują, że jest to mięso delikatne, nadające się zarówno do przetwórstwa (produkcja kiełbas i pasztetów), jak i jako mięso kulinarne do pieczenia i smażenia. Może być mięsem alternatywnym dla innych gatunków, co pozwoli zachować nutrie jako gatunek hodowlany i zwierzęta rzeźne w polskiej hodowli.