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Compositional Characteristics and Nutritional Quality of European Beaver (*Castor fiber* L.) Meat and its Utility for Sausage Production

Joanna ŻOCHOWSKA-KUJAWSKA[1], *Kazimierz LACHOWICZ*[1], *Małgorzata SOBCZAK*[1], *Grzegorz BIENKIEWICZ*[2], *Grzegorz TOKARCZYK*[3], *Marek KOTOWICZ*[1] *and Ewelina MACHCIŃSKA*[1]

[1]*Department of Meat Science,* [2]*Department of Food Quality and* [3]*Department of Food Science and Technology, West Pomeranian University of Technology in Szczecin, Szczecin, Poland*

Abstract

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The composition of European beaver (*Castor fiber* L.) meat and its utility for sausage production were investigated. Beaver meat has a high concentration of protein (21.44% wet weight) with the high content of available lysine (1.97 g/100 g) and tryptophan (0.29 g/100 g). The fat (5.08%) was characterised by a generally high proportion of polyunsaturated fatty acids (35%) and lower proportion of monounsaturated fatty acids (29%). Octadecenoic acid (C18:1) was a dominant monounsaturated fatty acid. Beaver muscles were characterised by generally small muscle fibres, thick *perimysium* and low amount of intramuscular fat, thus this raw material may be used in sausage production as an alternative to pork. The most positive effects of beaver meat addition on the texture and palatability of sausages were obtained when about 20–40% of this kind of meat was used.

Keywords: beaver meat; nutritional value; structure; texture; comminuted product

Meat from hunted animals that feed on natural food rich in herbs and plants that have a positive effect on the meat flavour, and its nutritional value, is characterised by a high level of proteins, vitamins, mineral salts and a lower content of fat and cholesterol compared to meat of domestic slaughter animals, as well as by a lower level of energy value (Berrisch-Hempen 1995). Besides using the meat of common game species, in some regions of the world there is a tradition of consuming beaver meat (Jankowska *et al.* 2005). After having been reduced to about 1200 animals by the beginning of the 20th century, populations of European beavers (*Castor fiber* L.) are now established in most countries in Europe, or even grow higher from year to year (Halley *et al.* 2012). Also in Poland, the beaver population has increased considerably up to now and needs to be controlled as it has become harmful to the environment (Korzeniowski *et al.* 2001). Formerly, the beaver meat was treated as a local raw material and used in traditional European cuisine. Now this kind of meat has replaced the more frequently consumed meat of farm animals. The current limited consumption of beaver meat may be partly due to the lack of public knowledge of its nutritional quality. A few papers have reported the chemical composition of beaver meat (Kakela *et al.* 1996; Jankowska *et al.* 2005; Razmaitè *et al.* 2011). However, there is a lack of information about the use of this raw material in meat production. The objective of this study was to analyse the compositional characteristics, and to evaluate the nutritional quality of European beaver (*Castor fiber*) meat and its utility for sausage production.

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MATERIAL AND METHODS

Animals and location. Seventeen sexually mature (> 1.5-year old) males of European beavers were used in the experiment. All these samples were obtained from hunters within a 24-h period after the animal entrapment. In Poland, beaver hunting is allowed from October 1 until the middle of March (Regulation of the Minister of Environment of October 6, 2014). Thus the beaver was represented by individuals hunted during the winter hunting period (January to February) in the Western Pomeranian district in Poland.

Sample collection and measurements. The culled animals were skinned and eviscerated. Carcasses were cooled to 4°C, longitudinally divided into halves and then five elements, namely thigh, flank, loin, shoulder, and tail, were cut out. Each element was further separated into meat, bones, and fat. The contents of chemical components and structure were determined in the meat obtained from those elements, treated as one attempt. Data shown in this study are the means of the values obtained for each animal.

Sausage formulation and processing. Investigations have been done on sausages produced from beaver meat trimmings obtained as mentioned above and pork TB (*Triceps brachii*) muscles from the Mas-AR Food Industry and Experimental Production Plant, Szczecin, Poland. Beaver and pork meat was ground separately with a sieve of 3 mm mesh diameter. Minced meat was cured with a curing mixture (99.6% NaCl, 0.4% $NaNO_2$) until a 2.2% weight increase was obtained and kept in a cold room at 4°C for 24 hours. Three separate replicates of each batch were prepared on different days. A total of 10 kg of sausages per treatment were produced in each replicate. Six different formulations of sausages were processed in a Meat Science Department plant. The following batters were prepared: the control (100% pork meat and with no addition of beaver meat) and samples prepared from pork and beaver meat which replaced pork meat in an amount of 20, 40, 60, 80, and 100%. Each time the meat mixed as described above (about 1.5 kg) with 20% addition of ice and 10% addition of pork fat (relatively to the total mass of meat) was chopped with an FGC-E cutter under the following conditions: 1400 rpm axe speed, 12 rpm revolving bowl speed, until the batter was heated to 12°C. Sausage batters were stuffed in collagen casings of 20 mm diameter and subjected to cooking in water heated to 75 ± 1°C, until the temperature inside the sample reached 68 ± 1°C. The cooked samples were cooled under tap water to about 12°C and cold stored for 12 hours.

Methods

Moisture content was determined in triplicate by the AOAC (1995) method, and expressed as a percentage of the sample weight.

pH determination was measured directly in the minced meat using a digital pH-meter (N15170E; Teleko, Wrocław, Poland).

Fat content was determined according to the AOAC (1995) procedure.

Ash content was determined according to the AOAC (1995) procedure.

Total nitrogen was determined by the Kjeldahl method (AOAC 1995) with a Kjeltec System 1026 (Tecator, Sweden) instrument.

Protein content was determined by the Kjeldahl method (Total N × 6.25).

Determination of tyrosine was done by the modified Lowry method (Kołakowski 2005).

Determination of tryptophan by the *p*-dimethylaminobenzaldehyde method (Horn & Jones 1945).

Determination of available lysine (AL) using the fluorodinitrobenzene (FDNB) procedure of Carpenter (1960) with the modification proposed by Booth (1971).

Fatty acid (FAME – Fatty acid methyl esters) determination was prepared according to the AOCS (2004) method. GC analysis of FAME was carried out in an Agilent 7890A instrument (Agilent Technologies, Santa Clara, USA). The quantification of FAME was done according to AOCS (2004). C19:0 was used as an internal standard.

Structure. Mean fibre cross-sectional area (CSA), *perimysium* and *endomysium* thickness, and the area of intramuscular fatty tissue (IMF) were measured on beaver and pork meat cuts according to Burck (1975) procedure. The Multi Scan Base, Version 13 computer image analysis software (Computer Scanning System, Warsaw, Poland) was used to measure the meat structure (Lachowicz *et al.* 2004)

Texture parameter measurement. Muscle texture (hardness, cohesiveness, springiness, gumminess) was assayed following the Texture Profile Analysis (TPA) procedures (Bourne 1982), with an Instron 1140 device (Instron, Ltd., Bucks, UK) (deformation 80% of the sample original height, a crosshead speed of 50 mm/min and a load cell of 50 N).

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Thermal drip losses. Thermal drip loss (%) was calculated from the difference in sausage weight before and after thermal treatment.

Sensory parameter evaluation. The sensory evaluation of the sausages was done by a trained expert panel of 5 members with, in general, minimally four-year experience in the texture analysis of meat and meat products using a 7-point scale as follows: 1 point – the least tender, greasy, and samples with low juiciness and palatability; 7 points – the most tender, greasy, juicy, and with the highest palatability.

Statistical analyses. Obtained samples were statistically analysed (Statistica software, Version 7.0; StatSoft, Cracow, Poland), calculating mean values and SD for each sample. RIR-Tukey test with $\alpha = 0.05$ was applied to analyse the relevance of differences in every examined parameter between samples.

RESULTS AND DISCUSSION

The approximate composition of beaver (*Castor fiber* L.) meat is shown in Table 1. The meat from all the analysed carcasses had a high protein (above 21%) and water content which is comparable to results obtained for other wild animal species (Hoffman & Cawthorn 2013). As shown, beaver meat had the mean pH above 6.0, which is more than the expected range for normal venison carcasses (5.5–5.7) reported by Stevenson-Barry *et al.* (1999).

Table 1. Approximate composition (% of total wet weight) and pH value of beaver meat

Component	Mean	SD
Water (%)	71.18	0.30
Protein (%)	21.44	0.12
Fat (%)	5.08	0.23
Ash (%)	1.08	0.01
pH	6.12	0.01

Based on the fat content, the beaver raw material is generally an average-fat meat although the crude fat content presented in our study and published by Jankowska *et al.* (2005) was higher than the amount found in Lithuanian beaver (Razmaitė *et al.* 2011). The differences could be connected with different time of harvest or different environmental conditions between Polish and Lithuanian beaver (Simonavičiūtė & Ulevičius 2007; Razmaitė *et al.* 2011).

The amino acid (AA) profile is important because some AA must be supplied by the diet. The selected AA composition of beaver meat is shown in Table 2. Beaver meat protein contained a high amount of available lysine and average content of tyrosine and tryptophan. The content of AA is connected with an animal species. Lower content of lysine and higher content of tyrosine compared to those found in this study were detected in eland meat (Bartoň *et al.* 2014). On the other hand, Hoffman *et al.* (2007), who compared the effect of age, gender, and production region of springbok, found a lower content of lysine but a higher content of tyrosine in comparison with data presented in our research. In turn, Strazdina *et al.* (2013), who compared the amount of essential AA in beaver, deer and wild boar meat samples, found that game meat, specifically beaver meat, is well-balanced in AA composition and the protein in beaver muscle is of high quality (Razmaitė *et al.* 2011).

Intramuscular lipids of beaver meat, shown in Table 3, were characterised by the 64% content of unsaturated fatty acids, including 35% of polyunsaturated fatty acids (PUFA), and 29% of monounsaturated fatty acids (MUFA) as well as by 36% of saturated fatty acids (SFA). As pointed out by Berrisch-Hempen (1995), a high level of unsaturated fatty acids is normal in the lipids of all herbivorous and ruminant animals; however, the level of PUFA in beaver fat is unusually high. Similarly to our findings, Razmaitė *et al.* (2011), who compared lipids of the tail and thigh of Lithuanian beaver, showed a slightly higher content of PUFA and a lower content of MUFA. The differences could be explained by seasonal variations in fatty acid composition (Razmaitė *et al.* 2011) or differences in breeding or feeding (Korzeniowski *et al.* 2001).

The recommended ratio of PUFA to SFA (P/S) in the human diets should be above 0.4 (Wood *et al.*

Table 2. Selected amino acid composition of beaver meat

Component	Mean content (g/100 g wet meat)	SD	Content (g/100 g crude protein)	SD
Tyrosine	0.0214	0.002	0.0942	0.0086
Lysine (available)	1.97	0.05	8.74	0.21
Tryptophan	0.29	0.01	1.31	0.034

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Table 3. Fatty acid composition of beaver meat

Component	Mean (mg/g crude fat)	SD
SFA	221.74	7.919
MUFA	180.95	6.503
C18:1	171.86	5.687
PUFA	214.05	7.693
PUFA/SFA	0.96	0.910
n-3	33.76	1.213
n-6	180.29	6.479
n-6/n-3	5.34	0.004

SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids

2003). In our study, beaver meat had a P/S ratio of around 0.9, thus this raw material may be more favourable compared with meat coming from some other farm and wild animals (Mostert & Hoffman 2007; Razmaitė *et al.* 2011). In turn, the recommended ratio between n-6 PUFA and n-3 PUFA should be lower than 4 (Wood *et al.* 2003). In this study, the n-6/n-3 ratio is about 5 and is higher than the reference pattern and data reported by Razmaitė *et al.* (2011). In recent years, the potential for reducing SFA in human nutrition through substitution with MUFA, especially with oleic acid as the most common MUFA, has increased (Williams 2000). As shown in Table 3, oleic acid (C18:1) represented 95% of MUFA in beaver meat. A lower percentage of this acid was presented by Razmaitė *et al.* (2011).

By this part of research, we pointed out that beaver meat could be a high quality protein source due to its well-balanced composition and predominant unsaturated fatty acids both in the diets and meat industry. Therefore, in the second part of this study, beaver meat was used as a substitute for pork, which is the most frequently used raw material in sausage production.

A comparison between the structure of beaver meat and pork meat (Table 4) showed that larger mean fibre cross-sectional area (CSA) and significantly thicker *endomysium* ($P \leq 0.01$) were typical of pork. In turn, beaver meat had a significantly thicker (by about 50%) *perimysium*. A comparison of intramuscular fat (IMF) amount showed that the pig muscle was characterised by a higher fat content ($P \leq 0.01$) than the beaver muscle. A higher amount of connective tissue, especially thicker *perimysium*, as well as larger CSA or fibre diameters in muscles of wild animals compared to pig meat were observed also by other researchers (Lachowicz *et al.* 2004).

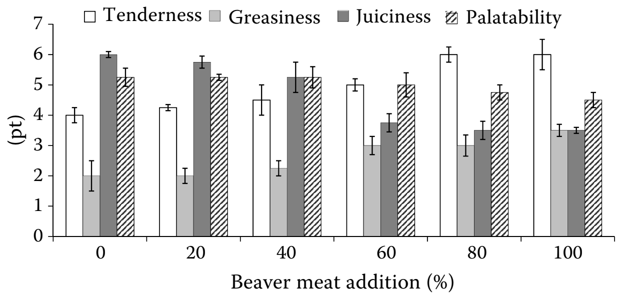

Figure 1. Selected sensory properties of pork sausages produced with different addition of beaver meat

A comparison of the textural parameters of pork sausages showed that the larger beaver meat proportion produced significantly higher ($P \leq 0.01$) values of hardness, cohesiveness, and gumminess as well as lower springiness. The greatest changes in textural parameters were observed in sausages made from 80–100% of beaver meat, compared to the control sample (100% of pork). The addition of beaver meat also affected higher thermal drip losses (Table 5).

The analysis of sensory properties showed that sausages became more tender, greasy, and less juicy as the addition of beaver meat increased (Figure 1). A higher proportion of beaver meat in the stuffing caused a decrease of palatability due to the appearance of undesirable taste.

The probable cause of changes in the sensory quality and texture of sausages while increasing the share of

Table 4. Structure of beaver and pork meat as a raw material for sausage production

Sample	Muscle fibre cross-section area (μm^2)		*Perimysium* thickness (μm)		*Endomysium* thickness (μm)		Intramuscular fat area (μm^2)	
	mean	SD	mean	SD	mean	SD	mean	SD
Beaver meat	1 436.58^a	124.65	29.87^a	3.39	1.92^a	0.14	12 661^a	6 457
Pork meat	1 651.52^a	95.57	14.82^b	2.45	2.16^b	0.21	197 124^b	24 587

Values in rows denoted with different letters are significantly different at $P \leq 0.01$

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Table 5. Texture and thermal drip losses of sausages depending on the variable proportion of beaver meat in the batter

Beaver meat (%)	Hardness (N)		Cohesiveness (–)		Springiness (cm)		Gumminess (N)		Thermal drip losses (%)	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
0	61.41[a]	2.15	0.173[a]	0.03	1.05[b]	0.03	10.63[a]	1.23	4.82[a]	2.21
20	63.50[a]	1.98	0.186[ab]	0.03	1.03[ab]	0.05	11.82[a]	0.98	4.97[a]	1.57
40	69.07[b]	2.39	0.194[ab]	0.03	1.03[ab]	0.06	13.38[ab]	1.76	7.01[ab]	2.18
60	74.82[c]	3.02	0.202[ab]	0.03	0.99[ab]	0.05	15.12[bc]	2.01	8.72[ab]	2.64
80	82.61[cd]	4.84	0.204[ab]	0.02	0.99[ab]	0.03	16.84[cd]	1.36	10.67[bc]	1.62
100	90.28[d]	3.71	0.215[b]	0.01	0.94[a]	0.04	19.42[d]	1.44	13.53[c]	1.77

Values in rows denoted with different letters are significantly different at $P \leq 0.01$

beaver meat in the stuffing was described previously as differences in the structure, especially the thicker *perimysium* and lower amount of intramuscular fat found in beaver meat compared to pork. A similar effect of the amount of both connective tissue and intramuscular fat on sausage texture and sensory properties was reported by Rywotycki and Dolata (1994). In turn, an increase in thermal drip losses together with higher addition of beaver meat may probably be connected with an increase in insoluble collagen content. As a consequence, an increase in connective tissue may cause higher thermal drip losses and poor water-binding capacity (Amrosiadis & Wirth 1984).

CONCLUSIONS

The presented results indicate that the beaver meat has a desirable chemical composition, high percentages of protein and lysine, average amount of fat but with a high concentration of PUFA. This kind of raw material that was characterised, compared to pig muscles, by smaller muscle fibres, thicker *perimysium*, and lower amount of IMF may be used as a substitute for pork in sausage production. The effects of beaver meat addition on palatability of sausages were positive when 20–40% of this kind of meat was used.

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Corresponding author:

Joanna Żochowska-Kujawska, Ph.D., West Pomeranian University of Technology in Szczecin, Department of Meat Science, K. Królewicza St 4, 71-550 Szczecin, Poland; E-mail: joanna.zochowska-kujawska@zut.edu.pl