Compositional Characteristics and Nutritional Quality of Eurasian Beaver (*Castor fiber*) Meat

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Abstract

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The meat of Eurasian beaver (*Castor fiber*) as obtained in Lithuania contained 21.4% crude protein with high amounts of glutamic acid (152.6 mg/g), aspartic acid (87.6 mg/g), lysine (81.8 mg/g), leucine (75.7 mg/g), arginine (60.4 mg/g), and isoleucine (60.1 mg/g). This meat could be a high quality protein source because of its well-balanced essential amino acid composition. Polyunsaturated fatty acids were predominant with a percentage of 41.58% in thighs and of 42.12% in the fat depot of tails. Hexadecanoic acid (C16:0) was the dominant fatty acid in thigh muscles, followed by octadecadienoic (C18:2n-6), octadecenoic (C18:1), and octadecatrienoic (C18:3n-3) acids with the percentages 23.05, 22.66, 22.28, and 12.40, respectively. In the tail lipids, the dominant fatty acid was C18:1, followed by C18:3n-3 and C18:2n-6, and C16:0 with the percentages 31.72, 21.87, 18.53, and 12.96, respectively. With predominant polyunsaturated fatty acids and an n-6/n-3 PUFA value 2.1, beaver meat could be n-3 PUFA-rich food in human diets.

Keywords: beaver; meat; lipid; amino acid; fatty acid

The studies carried out in the early and mid-twentieth century of the few remaining hunter-gatherer societies showed them to be generally free of the signs and symptoms of cardiovascular disease (CVD) and other so-called diseases of civilisation. The high reliance upon animal-based foods and fat intake (28–58% of energy) would have been similar to or higher than those found in western diets, and thus it is likely that important qualitative differences in fat intake, including relatively high levels of MUFA and PUFA and a lower n-6/n-3 fatty acid ratio, would have served to inhibit the development of CVD (Cordain *et al*. 2002). Scientific evidence is accumulating that meat itself is not a risk factor in view of the incidence of western lifestyle diseases, the risk rather stemming from excessive fat and, particularly saturated fat associated with the meat of modern domesticated animals (Mann 2000; Li *et al.* 2005). For a long time, evolutionary selection has been in action, adapting our genetic make up and hence our physiological features to the diet high in lean wild game meat (Mann 2000; Cordain *et al.* 2002; Li *et al*. 2005). At present, however, wild mammals represent only 2% of the herbivore biomass (Gorman & Raffaelli 2008).

The archaeological excavations and geomorphological investigations have revealed that beaver bones represent from 5.50% to 66% of all animals found in different settlements of the Baltic region and are considered as refuse coming from human activity, in particular related to the food consumption during the Late Neolithic (Balodis *et al.* 1999; Stančikaitė *et al.* 2009). The exploitation led to almost complete extirpation of beavers in many countries. The decline in the size of the beaver population also resulted in the change of the consumption habits that led to almost complete forgetfulness of the beaver meat utilisation in the cuisine. In Lithuania, beaver population has increased considerably up to now and needs to be controlled as it has become harmful to the environment. The current limited consumption of beaver meat may be partly due to the lack of public knowledge of its nutritional quality. Therefore, a more extensive evaluation of beaver meat could increase the interest in wider consumption and sustainable hunting of the beaver. Several papers have reported the compositions of fatty acids of beaver (Käkelä & Hyvärinen 1996; Käkelä *et al*. 1996; Zalewski *et al*. 2009). However, most of them were related to the fatty acids compositions of the adipose tissues in the extremities and metabolic lipids of the liver of beavers in comparison with the muskrat, badger, and racoon dogs, and were aimed at clarifying the effects on peripheral heterothermy, diet, a fatty acid metabolism. The objective of this study was to analyse the compositional characteristics, and to evaluate the nutritional quality of Eurasian beaver (*Castor fiber*) meat.

MATERIAL AND METHODS

Sampling. Seventeen beavers (*Castor fiber*) were used in the experiment. The muscle samples excised from thigh muscles and the lipid samples excised from the base of tail, one of the main lipid depots in beaver, were collected from each beaver carcass used in the study. The thigh muscle samples were assigned to approximate composition determination and amino acid and fatty acid analyses. The lipid samples from the tail lipid depot were assigned to fatty acid analysis. All these samples were obtained from the hunters within during 24 h period after the animals entrapment. In Lithuania, beaver hunting is allowed from the first of August until the middle of April. The beaver was represented by individuals hunted during late autumn and winter hunting period (November to January) in the central parts of Lithuania in the latitude of 55°30'–55°43'N and in the longitude of 22°59'–23°42'E.

Approximate composition determination. Moisture content was determined by drying the sample in an oven at 105°C to constant weight (method No. 950.46B; AOAC 1990). Crude protein content was determined by the Kjeldahl method using the Kjeltec system 1002 apparatus (Foss-Tecator AB), the conversion factor of 6.25 having been used to convert total nitrogen to crude protein (method No. 981.10; AOAC 1990). Intramuscular fat was determined by the Soxhlet extraction method (method No. 960.39; AOAC 1990). Ash was determined by incineration in a muffle furnace at 550°C for 24 h (method No. 920.153; AOAC 1990). The approximate composition was expressed in the weight percentages in wet muscle tissue. The samples were analysed at least in duplicates for all analytes.

Amino acid analyses. The samples of thigh muscles were hydrolysed with 6N HCl in sealed glass tubes at 105°C for 24 hours. Amino acid analysis was performed by ion exchange chromatography using glass column Ostion LGANB (Lachema, Brno, Czech Republic) on AAA 339 amino acid analyser (Mikrotechna, Prague, Czech Republic). The identity and quantitative analysis of the amino acids were assessed by comparison with the retention times and peak areas of the standard amino acid mixture. Norleucine was used as the internal standard.

The essential amino acid score was calculated with respect to the WHO/FAO amino acid pattern of adults (WHO/FAO/UNU 2007) using the following formula:

$$\text{Amino acid score} = [\text{Sample amino acid (mg/g)}/\text{Reference amino acid (mg/g)}] \times 100$$

Fatty acid analysis. The extraction of lipids for fatty acid analysis was performed with chloroform/methanol (2:1 v/v) as described by Folch *et al*. (1957). Fatty acid methyl esters (FAME) were prepared using the procedure of Christopherson and Glass (1969). The FAMEs were analysed using a gas liquid chromatograph (GC-2010 Shimadzu) fitted with a flame ionisation detector. The separation of methyl esters of fatty acids was performed on an Alltech capillary column AT Silar, 30 m × 0.32 mm × 0.25 μm, by temperature programming from 100°C to 240°C. The column was tempered at 100°C for 4 min, then the temperature was increased to 240°C at 3°C/min and held for 10 minutes. The temperatures of the injector and detector were held, respectively, at 225°C and 250°C. The flow rate of carrier gas (nitrogen) through the column was 0.33 ml/minute. The peaks were identified by comparison with the retention times of the standard fatty acids methyl

Table 1. Approximate composition of beaver thigh muscle (% of total wet weight)

	Dry matter (%)	Crude protein (%)	Crude fat (%)	Crude ash (%)
Mean	23.5	21.6	0.51	1.09
SD	0.23	0.12	0.08	0.01

esters FAME Mix (Supelco, Bellefonte, USA). The relative proportion of each fatty acid was expressed as the relative percentage in the sum of the total fatty acids.

Statistical analysis. The data were subjected to one-way analysis of variance (ANOVA) with Tukey's tests to determine the significance of differences of means between the groups using MINITAB 15 software package. The differences were considered significant when $P < 0.05$.

RESULTS AND DISCUSSION

The approximate composition of Lithuanian beaver (*Castor fiber*) thigh muscles is shown in Table 1. Based on the fat contents, the beaver muscles are low-fat meat. Although the crude fat content was lower than the amount found in Polish beaver (Jankowska *et al.* 2005), the Polish authors did not report the time of harvest. It is known that the nutrition basis of the Eurasian beaver is composed of about 200 plant species (Simonavičiūtė & Ulevičius 2007) and the composition of the diet is dependent on the availability of the food resources in their living habitat and season. The amino acid composition of beaver thigh muscles is shown in Table 2. Beaver protein contained a high amount of glutamic acid, followed by aspartic acid, lysine, leucine, arginine, isoleucine, alanine, histidine, glycine, valine, threonine, serine, phenylalanine, and methionine in decreasing amounts. Glutamic acid is the most abundant amino acid in antelope and rabbit meat (Mostert & Hoffman 2007; Pogány Simonová *et al.* 2010), fish (Zhao *et al.* 2010), and crab tissues (Chen *et al.* 2007; Vilasoa-Martínez *et al.* 2007). Moreover, the sequence of other amino acids is similar to the sequence of amino acids in other meats. The essential amino acid composition is one of the most important nutritional qualities of proteins. The amounts of essential amino acids in beaver

Table 2. Amino acid composition of beaver thigh muscle

Amino acid	Mean content (g/kg wet meat)	SD	Content (mg/g crude protein)
Aspartic acid	18.9	0.09	87.5
Serine	9.0	0.27	41.4
Glutamic acid	33.0	0.33	152.8
Proline	7.5	0.09	34.7
Glycine	10.1	0.07	46.9
Alanine	12.9	0.06	59.7
Tyrosine	7.0	0.22	32.4
Threonine	9.0	0.23	41.7
Valine	9.1	0.18	42.1
Methionine	7.8	0.09	36.1
Isoleucine	13.0	0.07	60.2
Leucine	16.4	0.27	75.9
Phenylalanine	8.7	0.18	40.3
Histidine	11.0	0.05	50.9
Lysine	17.7	0.18	81.9
Arginine	13.1	0.32	60.6

Table 3. Amino acid score of protein from beaver

Essential amino acids	Content (mg/g crude protein)	Reference (mg/g crude protein)*	Score
Threonine	41.7	23	181
Valine	42.1	39	108
Methionine	36.1	16	226
Isoleucine	60.2	30	201
Leucine	75.9	59	129
Phenylalanine+Tyrosine	72.7	30	242
Histidine	50.9	15	339
Lysine	81.9	45	182

*Reference amino acid pattern of adults WHO/FAO/UNU (2007)

proteins, including arginine and histidine essential only in certain cases, were higher than those of non essential amino acids (the ratio of essential to non essential amino acids was 1.07). Nowadays, histidine is considered to be an essential amino acid because of the detrimental effects on haemoglobin concentrations (Report of a Joint WHO/FAO/UNU Expert Consultation; WHO/FAO/UNU 2007). The amino acid scores are shown in Table 3. When compared to the reference amino acid pattern of adults, all of the detected amino acid scores were > 100. Although tryptophan and cysteine were not detected, yet according to all of the detected amino acid scores the protein in beaver muscle is well-balanced in essential amino acid composition and is of high quality.

Both intramuscular and tail lipids of the beaver (*Castor fiber*) were (Table 4) characterised by the highest percentage of polyunsaturated fatty acids (PUFA) (41.58–42.12). Although we observed seasonal variation in fatty acid composition (unpublished data), high lipid unsaturation in the present study is consistent with the findings of Käkelä and Hyvärinen (1996) and Zalewski *et al.* (2009). In this study, the intramuscular lipids in the thigh muscles were also characterised by a higher percentage of saturated (SFA) (33.00) and a lower percentage of monounsaturated fatty acids (MUFA) (25.42). However, the lipids in the tails were characterised by a higher percentage of MUFA (38.65) and a lower percentage of SFA (19.23). It can be observed that saturated hexadecanoic (C16:0), monounsaturated octadecenoic (C18:1), and polyunsaturated octadecadienoic (C18:2n-6) and octadecatrienoic (C18:3n-3) acids represented 80.39% and 85.11% of all fatty acids in the thighs and tails, respectively. The presence of odd-chain

Table 4. Fatty acid composition (% of total fatty acids) in different sites of Lithuanian beaver (*Castor fiber*)

Fatty acids	Thigh	Tail
C14:0	0.83 ± 0.25	0.82 ± 0.14
C15:0	0.84^c ± 0.17	0.71^d ± 0.19
C16:0	23.05^a ± 3.81	12.96^b ± 3.28
C17:0	1.20 ± 0.66	0.90 ± 0.30
C18:0	6.77^a ± 1.08	3.02^b ± 1.49
C20:0	0.30^a ± 0.21	0.81^b ± 0.37
SFA	33.00^a ± 4.28	19.23^b ± 4.51
C16:1	2.62^a ± 0.98	6.07^b ± 1.67
C17:1	0.29 ± 0.25	0.54 ± 0.43
C18:1	22.28^a ± 8.12	31.72^b ± 6.20
C20:1	0.23^c ± 0.13	0.32^d ± 0.06
MUFA	25.42^a ± 8.84	38.65^b ± 6.45
C16:2	1.00 ± 0.81	0.76 ± 0.50
C18:2n-6	22.66 ± 6.16	18.56 ± 6.37
C18:3n-3	12.40^a ± 5.19	21.87^b ± 5.55
C20:3n-3	0.34^c ± 0.24	0.19^d ± 0.07
C20:4n-6	4.01^a ± 2.84	0.54^b ± 0.20
C22:6n-3	1.17^a ± 0.75	0.20^b ± 0.05
PUFA	41.58 ± 8.39	42.12 ± 9.31
P/S	1.28^a ± 0.32	2.37^b ± 0.87
18:2n-6/18:3n-3	2.11^a ± 0.98	0.88^b ± 0.39
n-6/n-3	2.12^a ± 0.93	0.89^b ± 0.38

Mean values in the same row having different superscripts indicate significant difference for Tukey test: $^{a–b}P < 0.001$; $^{c–d}P < 0.05$

SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids pentadecanoic (C15:0) and heptadecanoic (C17:0) fatty acids in the intramuscular fat and fat depots of the beaver in the study of Martysiak-Żurowska *et al*. (2009) were described as unusual, however, heptadecanoic (C17:0) fatty acid in lower proportions was found in the muscle and subcutaneous tissue of pigs and their wild boar hybrids (Razmaitė & Švirmickas 2010). Furthermore, the higher wild boar proportion in hybrids also increased the concentration of heptadecanoic fatty acid (Razmaitė *et al*. 2008).

Although the total content of SFA ($P < 0.001$), including most of the saturated fatty acids detected in tail lipid tissues, was lower than that in the intramuscular lipids, the content of eicosanoic (C20:0) fatty acid was higher ($P < 0.001$) in the tail. The ratio of polyunsaturated fatty acids to saturated fatty acids (P/S) was higher ($P < 0.001$) in the lipids of the tail. The lipid tissue of the tails also had a higher total proportion ($P < 0.001$) of (C18:3n-3) fatty acid which resulted in an insignificantly higher total proportion of PUFA in comparison with the PUFA in intramuscular lipids in the thighs. However, the proportions of such polyunsaturated fatty acids as eicosatrienoic (C20:3n-3) ($P < 0.05$), eicosatetraenoic (C20:4n-6), and DHA (docosahexaenoic C22:6n-3) ($P < 0.001$) were higher in intramuscular lipids than in the lipid tissue of the tails. As a consequence, the ratio of C18:2n-6/C18:3n-3 and the ratio of n-6/n-3, including all n-6 and n-3 polyunsaturated fatty acids, were similar. However, these ratios were lower in the lipid tissue of the tail than in intramuscular fat ($P < 0.001$). The recommended ratio of polyunsaturated fatty acids to saturated fatty acids (P/S) in the human diets should be above 0.4. Since some meats (muscle and adipose tissue) naturally have a P/S ratio of around 0.1 (Wood *et al*. 2003), the meat of beaver, including fat, is more favourable compared with those coming from some other farm and wild animals (Mostert & Hoffman 2007; Razmaitė *et al*. 2008). More recently, nutritionists have focused on the type of PUFA and the balance in the diet between n-6 PUFA and n-3 PUFA (Givens *et al*. 2006; Wood *et al.* 2008). The recommended ratio is lower than 4. However, domestic animals produce an undesirably high n-6/n-3 ratio in meat (Wood *et al.* 2003). In this study, both C18:2n-6/C18:3n-3 and the total n-6/n-3 ratios both in the intramuscular and lipid tissue of the beaver were significantly lower than the reference n-6/n-3 ratio pattern. Moreover, it can be observed that n-6/n-3 ratio was more favourable than that of hooded and harp seals (Brunborg *et al*. 2006), and of equal value as with some species of fish and crabs (Chen *et al*. 2007; Jankowska *et al*. 2010). Although the beavers are monogastric animals Käkelä and Hyvärinen (1996) and Martysiak-Żurowska *et al*. (2009) reported on the presence of trans fatty acids with 3–4.5% of the main vaccenic acid (*trans*-11 18:1) in the beaver fat depot, in our study trans fatty acids were not detected. It has been recommended that the value of 2% of the total energy intake as trans fatty acids consumption level should not be exceeded (Léger *et al.* 2007) but, on the other hand, the evidence presented in the studies on human diet history shows that, for a very long period and until very recently, the humans had been regularly consuming ruminant fats contributing up to 5% trans fatty acids in the fats eaten by hunters and later in foods taken by most agricultural populations (Ackman 1997). Moreover, natural *trans* vaccenic acid can be metabolised into conjugated linoleic acid and, besides, vaccenic acid does not inhibit the metabolic conversion of linoleic to arachdonic acid (Kummerow 2009). Food and Drug Administration (FDA) assumed that some of *trans* acids might be derived from the natural vaccenic acid that has no harmful effects and suggested that approximately 2.6% of the total daily fat intake came from trans fat and 50% of the trans fatty acids might come from vaccenic acid. Therefore, the presence of vaccenic acid (*trans*-11 18:1) in the beaver fat, reported by Käkelä and Hyvärinen (1996) and Martysiak-Żurowska *et al.* (2009), should not be a limiting factor for the use of beaver meat. Different marine and land mammals (walrus, whale, seal, moose, caribou, and reindeer, mink, muskrat) intake, including, the beaver, maintain healthful blood lipid profiles in Eskimos (Mann *et al.* 1962; Nobmann *et al.* 1992; Cordain *et al*. 2002). Nowadays, the meat quality concept has become dynamic and includes eating and technological quality, nutritional value and safety, and thus meat diversification is considered as quality. It is likely that the consumption of beaver meat should suggest meat diversification and a better n-6/n-3 PUFA ratio in meat products for consumer health.

It can be concluded that, although the beaver (*Castor fiber*) was widely used in ancient times, beaver meat consumption is not common due to small populations in some countries or the lack of knowledge in others. However, wider consumption and sustainable hunting as a management tool for beaver population is highly demanded. By this study, lean beaver meat could be a high quality protein source due to its well-balanced essential amino acid composition. With predominant polyunsaturated fatty acids and the n-6/n-3 PUFA value of 2.1, it could be n-3 PUFA-rich food in the diets.

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