https://doi.org/10.17221/112/2024-CJFS

Comparative study on quality parameters of dry-cured beaver (*Castor fiber*) and nutria (*Myocastor coypus*) sausages

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Citation: Slováček J., Nedomová Š., Janík Piechowiczová M., Mikulka O., Jůzl M. (2024): Comparative study on quality parameters of dry-cured beaver (*Castor fiber*) and nutria (*Myocastor coypus*) sausages. Czech J. Food Sci., 42: 382–389.

Abstract: The aim of the study was to define and compare the quality properties of dry-cured heat-treated meat products from the meat of free-living semi-aquatic wildlife species. Eurasian beaver (*Castor fiber*) and nutria (*Myocastor coypus*) are wild animals whose presence in the countryside is regulated in the Czech Republic. Basic chemical, microbiological, sensory analyses, and instrumental measurements of the colour and texture of dry-cured sausages (pork, as a control group with 51% lean pork and experimental groups with 51% lean beaver and nutria meat in fresh state) were performed. There were no statistically significant differences ($P > 0.05$) in microbiological counts per gram between the sausage groups according to the meat used after 3 weeks of storage. In the sensory analysis, beaver sausages were rated as the darkest and least attractive ($P < 0.05$). The data obtained using the Meullenet-Owens Razor Shear (MORS) test did not show a statistically significant difference ($P > 0.05$). However, a significant difference ($P < 0.05$) was measured between the beaver product and the pork and nutria variants using the compression method.

Keywords: game; colour; texture; sensory analysis; microorganisms

The life of wild animals is considered natural. Game meat is perceived as a locally available raw material. In terms of the environmental impact, hunting for wild game is comparable with organic livestock production (Tomasevic et al. 2018). Hunting and harvesting of game meat is based on traditional principles. Meat from farmed animals tends to be very consistent in hygienic and microbiological quality (Tůmová et al. 2021). This is not easy to achieve in the case of wild game and its products. The ability to monitor the welfare of individual animals is very limited. Neither is it possible to influence all the factors that

Supported by the Internal Grant Agency of Mendel University in Brno No. AF-IGA2022-IP-030 'Quality parameters of meat of nutria (*Myocastor coypus*) and its technological evaluation in meat products'.

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https://doi.org/10.17221/112/2024-CJFS

affect the quality of game (Neethling et al. 2016). Despite some problematic aspects related to the health safety or processing of game meat, it is a regionally available raw material with high nutritional value due to its low-fat content and favourable composition of selected nutrients (Kudrnáčová et al. 2018; Corradini et al. 2022).

From an ecological point of view, there is also an abundance of wildlife in many areas. Control of overabundant species is a necessity in many countries to prevent damage to fields and forests. To some extent, game meat is a nutritionally valuable by-product of wildlife management, where the main objective is to control potential damage (Barrios-Garcia and Ballari 2012). More than 70% of our planet is covered by water, and many species have evolved adaptations for aquatic or semi-aquatic specialisation (Riggsbee et al. 2013). Semi-aquatic species include the largest rodents in the world. These are the North American beaver (*Castor canadensis*) and the Eurasian beaver (*Castor fiber*), which is protected in many countries (Ziomek et al. 2021). According to Razmaitė et al. (2011), a significant increase in beaver populations in Central and Eastern Europe has led to the need to control and regulate their populations. Giżejewska et al. (2015) stated that regulation is necessary mainly because of the significant economic losses associated with tree felling, gnawing of rare trees, flooding of grasslands, damage to arable land, and losses in fisheries production. Sustainable hunting is the best way to manage beaver populations. In areas where beaver can be legally hunted, the meat of these animals is offered for consumption, as food or dishes made from beaver meat have always been highly valued for their unique taste (Domaradzki et al. 2019). Many species artificially introduced into European ecosystems are very rapid colonisers and invaders. In several European countries, this is particularly true of the nutria (*Myocastor coypus*). These animals have been imported into Europe for breeding purposes or deliberately released into the wild for farming purposes and are often considered to be very problematic in the wild. In European countries, nutria is classified as an invasive species that has a negative impact on native flora and fauna. In regions where these semi-aquatic rodents are overbred, there are opportunities to use their meat as a food source for human populations. The use of multiple preservation techniques for the reduction of biological risk in food production is an effective food safety measure. Processing the game meat into dry-cured heat-treated meat products is an option to ensure health safety and extend shelf life (Vinnikova et al. 2019). Wild game meat is generally underutilised in the food industry, and increased industrial processing of this unconventional raw material will allow for a more efficient market introduction of this commodity (Tomasevic et al. 2018). Therefore, processing the meat of problematic wildlife species could provide an incentive to manage their numbers for meat, not just to reduce the overall population. In the Central European region, hunters limit the wild game population and are also the dominant group of consumers. Some of the hunted game can be sold on the market or processed by specialised companies. In general, however, consumers value the game meat for its low fat, low cholesterol and high polyunsaturated fatty acid, protein and iron content (Kudrnáčová et al. 2018).

The aim of this study was to produce meat products from beaver and nutria meat suitable for hunters. The authors of the study based their work on the needs of hunters who will use the information from the utility patterns to determine the optimal procedure for sustainable hunting and the use of products from protected or invasive game species.

These products were compared with the regular product in terms of chemical composition, microbiological and physical properties and sensory analysis. A heat-treated dry-cured sausage was chosen for this purpose.

MATERIAL AND METHODS

Meat, i.e. the muscles extracted from the animal carcasses, was prepared for sausage production in the Meat Pilot Plant of Mendel University in Brno (No. CZ 22067, Czech Republic) according to the usual meat processing conditions and on the basis of applications and documents approved by the State Veterinary Administration. Beaver hunting in the Czech Republic is permitted to authorised hunters. The animals were hunted between February and March 2022 with a permit issued by the Regional Authority of the South Moravian Region, Department of Environment (JMK 107931/2020). However, the nutria is considered a foreign invasive species in the Czech Republic. Hunting is permitted throughout the year by law (Act No. 364/2021 Coll.). All animals were shot in the Pohořelice district between January and March 2022. The hunted animals were eviscerated, the carcasses and internal organs were then examined by a trained person in accordance with the provisions of Regulation (EC) No. 853/2004 (OJ L 226). The samples were

https://doi.org/10.17221/112/2024-CJFS

chilled below 4 °C as soon as possible. The following day, the samples were transported to the Meat Pilot Plant. They were skinned and deboned. Slaughter yields for beaver and nutria averaged 50–54%, but meat yields for use in meat products were much lower (12–14%). Therefore, meat from different numbers of adult males was used (beaver n = 6; nutria n = 12). Lean meat from beaver and nutria legs and shoulders was frozen at –18 °C (ZFC51400WA; ZANUSSI, Italy), and used for sausage production.

Pork was purchased from a local meat company as part of the recipes and for the control and replication groups (CZ 242 ES). Pork lean (under 5% fat) and pork fat meat (under 55%) were processed according to general production requirements (CZ 22067, Ševčík et al. 2014). The temperature of the meat at the time of reception was 4 °C.

Sausage production. The sausages were produced in two 10-kg batches according to the recipe in Table 1. The meat was mechanically minced into 6-mm pieces in a mincer (TMP 32-98; Braher, Spain). The lean meat (contained less than 5% of fat) was mixed with the nitrite salt mixture, crushed spices (both from Masoprofit, Czech Republic) such as pepper, garlic, and cloves in a mixer (RC-10; Manca, Spain), followed by the addition of minced fatty pork (contained at least 55% of fat), and the meat batter was mixed to a homogeneous structure. The meat batter was then filled (HTS 95; HTS Fleischereimaschinen, Austria) into pork intestines (pork 30/32 mm; Masoprofit, Czech Republic), smoked and heat treated (70 °C, 10 min in the product core) in a smoker (Bastramat B 850 FR; Bastra GmbH, Germany). The sausages were then placed in a ripening chamber (KRA-Gen3 M; Lackner, Germany) and dried for 8 days (17 °C, 80% humidity). At the end of the drying process at the standard time of 8 days, water activity was measured, and the products were vacuumed (Boxer 35; Henkelman, Netherlands), and stored at 20 °C. All analyses were performed at the end of the shelf life (21 days).

Water activity and weight loss. The sausages were weighed before and after smoking and after heat treatment. After 8 days, the dry-cured sausages were removed from the chamber, weighed and the water activity of cut cubes with an edge size of 0.5 cm was measured (LabSwift-aw; NOVASINA AG, Switzerland). Weight loss was calculated as a percentage of mass. These analyses were performed in triplicate (Beňo et al. 2023).

Chemical analysis. Protein content (%), fat content (%), water content as loss on drying (%), and salt content (%) after homogenisation of the sample (250 g) were analysed for each group [Association of Official Analytical Chemists (AOAC) methods: AOAC 928.08; AOAC 950.46; AOAC 935.47]. All analyses were carried out in triplicate.

Texture properties. The texture properties of sausages were measured with a TIRATEST 27 025 texturometer (TIRA Maschinenbau GmbH, Germany). The surface hardness of sausages was measured by the Meullenet-Owens Razor Shear (MORS) method at a crosshead speed of 50 mm·min^{-1} and penetration to 10 mm. The core hardness of sausages was measured in cylindrical samples of 1 cm in diameter and 1 cm in height by the compression using a 50% compression rate with a crosshead speed of 50 mm·min^{-1}. The diameter of the compression plate was 100 mm. All analyses were performed at least twelve times.

Colour measurement. The CIELAB colour space or L^* (lightness), a^* (redness), and b^* (yellowness) was measured using a CM-3500d spectrophotometer (Konica Minolta, Japan). The colour of the samples

Table 1. Ingredients used to prepare 100 kg of the pork, beaver, and nutria sausages [kg·(100 kg)$^{-1}$]

Ingredients	Pork sausage	Beaver sausage	Nutria sausage
Pork lean meat	51.0	0.0	0.0
Beaver lean meat	0.0	51.0	0.0
Nutria lean meat	0.0	0.0	51.0
Pork fatty meat	46.0	46.0	46.0
Nitrite salt mixture	2.0	2.0	2.0
Black pepper, crushed	0.4	0.4	0.4
Garlic, dried	0.4	0.4	0.4
Cloves, crushed	0.2	0.2	0.2

Lean meat – less than 5% of fat; fatty meat – at least 55% of fat; according to the analysis of the authors of the study and documents CZ 22067

https://doi.org/10.17221/112/2024-CJFS

was measured on the surface of the sausages as well as in the cross-section. Surface measurements were taken immediately after unpacking and then immediately after cutting (D 65, 6 500 K) with SCE (Specular Component Excluded) and an 8 mm slot in triplicate.

Microbiological assessment. The following groups of microorganisms were determined in the resulting meat products 7 days after the end of the drying process and after 21 days of storage at 20 °C: total plate count (TCM; PCA, Biokar Diagnostics, France; 30 °C for 72 h), *Escherichia coli* and other coliforms (Harlequin *E. coli* / Coliform Agar, Neogen; 37 °C for 24 h). The preparation of meat and meat product samples and the evaluation itself were performed according to the methodology of Kalhotka et al. (2012).

Sensory analysis. The analysis was carried out in the sensory laboratory of Mendel University in Brno. The laboratory meets the requirements of ISO 8589 and is equipped with individual booths with white light. The samples were taken from the centre of the sausage by cutting off a 3-cm piece from each end. Two-millimetre slices were prepared using a slicing machine. The samples were tempered to room temperature (20 °C) and served immediately after slicing. The samples were evaluated by ten trained evaluators according to ISO 8586-1 (International Organization for Standardization, ISO, 1993). A 100 mm unstructured line scale with anchor points located at both ends of the line scale was used for all descriptors. The following attributes were hedonically evaluated: overall appearance, cross-section appearance, odour, colour, flavour, and texture (0 points for an unsatisfactory sample, 100 points for an excellent sample). In addition, off-flavour intensity was assessed (0 points absent, 100 points very strong).

Statistical analysis. The data were sorted, and normality was tested using the Shapiro-Wilk test. Analysis of variance (one-way ANOVA) and Tukey's test were then used to compare groups of samples in STATISTICA (version 14). Differences were considered significant at the 95% confidence level ($P < 0.05$).

RESULTS AND DISCUSSION

The results of the chemical analyses of pork, beaver, and nutria sausages are shown in Table 2. The beaver sausages showed lower water content ($P < 0.05$) compared to the pork and nutria sausages. In the study by Żochowska-Kujawska et al. (2016), the meat products from beaver meat showed higher losses during heat treatment compared to the pork products. However, in our study, the weight loss after heat treatment

Table 2. Values of chemical analysis, water activity, colour measurement, and textural analysis of pork, beaver, and nutria sausages at the end of the shelf life (21 days)

Parameter	Pork sausage	Beaver sausage	Nutria sausage
Moisture (%)	32.93 ± 0.22^{a}	29.14 ± 0.20^{b}	31.61 ± 0.58^{a}
Fat (%)	29.74 ± 0.23^{a}	26.38 ± 0.12^{b}	28.46 ± 0.21^{a}
Protein (%)	33.32 ± 0.32^{b}	38.53 ± 0.25^{a}	34.60 ± 0.27^{b}
Salt (%)	3.70 ± 0.01	3.87 ± 0.01	3.86 ± 0.02
Water activity	0.840 ± 0.004	0.839 ± 0.002	0.842 ± 0.004
Weight loss (%)	41.51 ± 0.21^{b}	42.48 ± 0.15^{a}	41.21 ± 0.18^{b}
L^* (surface)	29.54 ± 1.10^{a}	24.09 ± 0.56^{c}	26.27 ± 0.18^{b}
a^* (surface)	11.99 ± 0.65^{a}	7.80 ± 0.39^{c}	10.09 ± 1.02^{b}
b^* (surface)	11.20 ± 1.13^{a}	4.67 ± 0.60^{c}	8.42 ± 0.41^{b}
L^* (cut)	37.53 ± 0.01^{a}	27.99 ± 0.02^{b}	27.54 ± 0.09^{c}
a^* (cut)	11.46 ± 0.03^{a}	9.64 ± 0.02^{b}	10.04 ± 0.40^{b}
b^* (cut)	5.65 ± 0.02^{a}	3.62 ± 0.02^{b}	4.29 ± 0.33^{b}
MORS force (N)	19.35 ± 4.54	19.10 ± 7.20	22.84 ± 4.16
Core hardness (N)	65.49 ± 20.05^{b}	97.51 ± 19.36^{a}	53.65 ± 10.93^{b}

$^{a–c}$ Means in the same row marked with different letters show significant differences ($P < 0.05$); data are expressed as mean ± SD (standard deviation); pork sausage – 97% pork meat; beaver sausage – sausage with 51% of beaver lean meat; nutria sausage – sausage with 51% of nutria lean meat; L^* – lightness; a^* – yellowness; b^* – redness; MORS – Meullenet-Owens Razor Shear

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was the same for all product variants, with an average weight loss of 5.00% (± 0.30). During the drying process, the pork sausages had a weight loss of 41.51% (± 0.21), the beaver sausages 42.48% (± 0.15), and the nutria meat product 41.21% (± 0.18). Water loss during the drying process was almost identical for all products. Beaver sausages contained the significantly lowest fat compared to the other two products ($P < 0.05$), which is related to the higher fat content of lean pork and nutria meat (Okrouhlá et al. 2008; Florek et al. 2017; Saadoun and Cabrera 2019). Therefore, in the raw state, more fat was expected in the final meat products. This is also reflected in the protein content, which is also higher in raw beaver meat than in pork and nutria meat according to our analysis of the input meat and the results of Florek et al. (2017) and Saadoun and Cabrera (2019). As a result, beaver sausages had the significantly higher protein content ($P < 0.05$) than the other two variants (Table 2).

Based on the chemical composition of each sausage, it can be concluded that there are significant differences in the characteristics of different variants of the meat product. During the drying process, water was removed from the heat-treated meat products. This not only reduced the overall water content, but also it reduced the water activity, making the products more resistant to undesirable microorganisms (Ranucci et al. 2019). This ensures a longer shelf life of the meat products and allows hunters to store such products for a much longer period of time. As the same amount of the salt mixture was used in the sausages, no difference in salt content was expected in the final products. The final water activity was also identical for all products. The average water activity measured for all products was between 0.839 and 0.842. This value is well below the legislative limit for preserved meat products. In the Czech Republic, meat products should have a water activity of 0.930 or less in order to be classified as durable (dried). The lower value of the water activity makes the meat products even more durable.

The water activity value and chemical composition of meat products significantly influence their texture (van Schalkwyk et al. 2011). In our experiment, the measurement of textural properties by the MORS test showed no difference between the products. However, the compression method measured a significant difference ($P < 0.05$) between the beaver product and both the pork and nutria variants. This was due to the lower water content of the beaver variant ($P < 0.05$). Żochowska-Kujawska et al. (2016) stated that a higher amount of beaver meat in the meat product results in higher hardness, cohesiveness, and gumminess. The increase in hardness of the beaver meat product was also evident in our study. The nutria sausage did not differ from the pork sausage in this attribute and was also significantly softer than the beaver product ($P < 0.05$). The textural measurements showed no differences between the products in terms of surface firmness. It can therefore be concluded that the beaver product was harder in the core and that this characteristic was not negatively reflected in the subsequent sensory analysis. The colour of meat products is an important feature that influences the consumer buying decision (Ranucci et al. 2019). However, experimental products will serve as a suitable recipe for experienced hunters who are not subject to the general tendencies and experiences of ordinary consumers. Game meat is also characterised by its specific structure, as the muscles consist of finer muscle fibres with firm consistency (Dumalisile et al. 2020). In general, the colour of beaver meat is a distinctive dark red, influenced by the overall concentration of muscle pigment, which increases with age. Adult meat was significantly darker on the surface than that of young individuals (Jankowska et al. 2005). Nutria meat is also redder than pork, but not as significantly dark. According to Saadoun and Cabrera (2019), nutria meat is close to the colour of pork or rabbit. The L^* values in the study by Migdał et al. (2013) ranged from 31.7 to 44.1, indicating a darker shade of nutria meat compared to pork or chicken. The L^* value decreases with age, so meat from older animals is darker (Tůmová et al. 2021). In this experiment, instrumental colour measurements showed colour differences both on the surface and in the cross-section of all the products analysed. According to the L^* parameter (lightness), the pork sausages were the lightest ($P < 0.05$) on the surface with 29.54 ± 1.10, while the beaver meat product was the darkest ($P < 0.05$) with $L^* = 24.09 \pm 0.56$. Thus, the distinct dark red colour of beaver meat (Florek et al. 2017) was evident in the meat products analysed. There were also statistically significant differences between the products ($P < 0.05$) in the b^* parameter (yellowness). The highest ($P < 0.05$) average a^* (redness) value was 11.99 ± 0.65 for the pork variant, while the lowest ($P < 0.05$) was 7.80 ± 0.39 for the beaver meat product. When evaluating the colour parameter b^*, we observed the same trend as for the a^* parameter. The highest value was observed for the pork sausage with 11.20 ± 1.13 and the lowest value for the beaver sausage with 4.67 ± 0.60. These values again reflect

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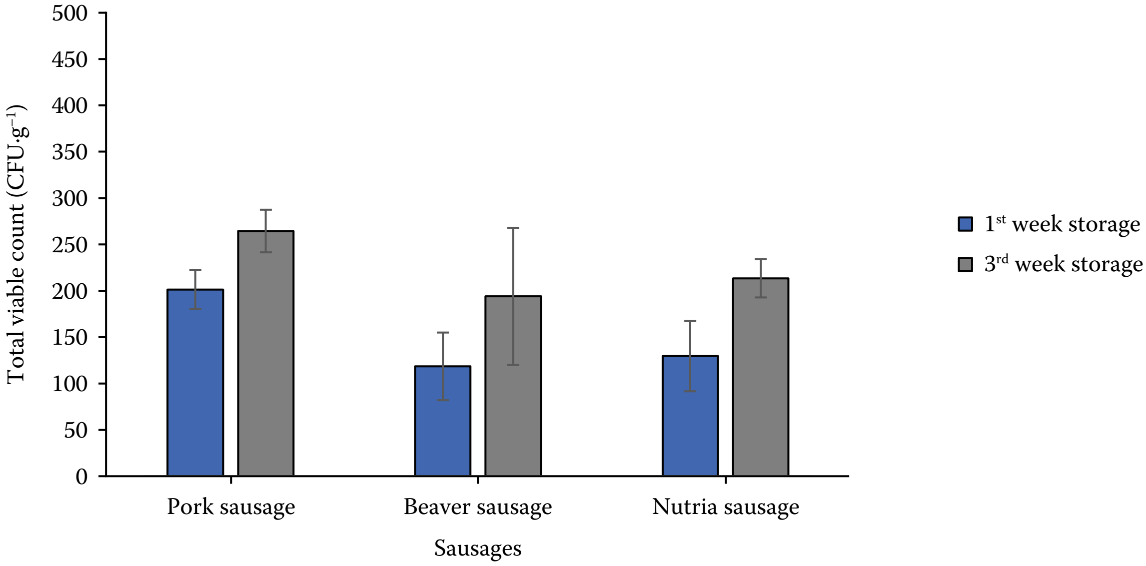

Figure 1. The values (CFU·g^{-1}) in pork, beaver, and nutria sausages after 7 and 21 days from their production

CFU – colony-forming unit; pork sausage – 97% pork meat; beaver sausage – sausage with 51% of beaver lean meat; nutria sausage – sausage with 51% of nutria lean meat

the colour characteristics of the raw meat used for each species (Florek et al. 2017; Saadoun and Cabrera 2019; Gagaoua et al. 2023). The colour in the cross-section showed the same differences as on the surface ($P < 0.05$). However, all products were lighter in the cross-section than on the surface.

The results of the microbiological analysis are shown in Figure 1. The results of the microbiological analysis confirmed that sufficient heat treatment leads to the elimination of microorganism contamination ($P > 0.05$). An important finding in relation to food safety principles is that neither *E. coli* nor other coliform microorganisms were detected (ND). Apart from the price, the quality of the food is mainly determined by the combination of its health safety and important information for the consumer (Jůzl et al. 2024).

The results of the sensory analysis are shown in Table 3. The sensory evaluators observed only one statistically significant difference ($P < 0.05$), specifically in terms of colour acceptability. Beaver sausage was rated the lowest of all samples. The very dark colour of this dry-cured product, which is attributed to the dark red colour of the beaver meat (Florek et al. 2017), was too strong for the evaluators and they rated this product rather neutrally. Undesirable odour and flavour were not pronounced in any of the products evaluated. For the other descriptors, the products were rated quite positively by the evaluators.

Table 3. The values of sensory analysis of pork, beaver, and nutria sausages

Descriptor	Pork sausage	Beaver sausage	Nutria sausage
Overall appearance	72.10 ± 17.30	73.80 ± 20.10	77.30 ± 11.29
Appearance in the cut	83.50 ± 14.39	76.40 ± 21.01	85.80 ± 11.42
Colour	77.80 ± 14.76^{a}	56.90 ± 17.78^{b}	74.30 ± 18.14^{ab}
Texture	73.40 ± 19.44	67.90 ± 22.92	68.60 ± 16.74
Odour	84.40 ± 10.47	80.00 ± 15.22	85.00 ± 8.31
Flavour	73.40 ± 18.05	71.60 ± 20.28	66.50 ± 16.71
Off-flavour	6.90 ± 9.18	13.60 ± 14.80	10.40 ± 9.81

$^{a–b}$ Means in the same row marked with different letters show significant differences ($P < 0.05$); data are expressed as mean ± SD (standard deviation); pork sausage – 97% pork meat; beaver sausage – sausage with 51% of beaver lean meat; nutria sausage – sausage with 51% of nutria lean meat

https://doi.org/10.17221/112/2024-CJFS

CONCLUSION

Processing wild beaver and nutria meat into dry-cured, heat-treated meat products is a good way to preserve these raw materials for a longer period of time. This process presents challenges and opportunities that could be of interest to both hunters and potential consumers. The result is a sensory appealing product with no significant negatives, which must be emphasized to hunters. The colour of the beaver meat product is very dark, and some consumers may be surprised by this intense colour. However, given the rarity of beaver meat, a beaver meat product could appeal to people looking for unusual foods. Processing nutria meat into a meat product will provide additional opportunities to motivate hunters to hunt this invasive species in Europe, and the sausages meet the best practices in sustainable hunting according to the International Council for Game and Wildlife Conservation and FAO (Baldus et al. 2008).

Acknowledgement. We thank to Internal Grant Agency of Mendel University in Brno 'AF-IGA2022-IP-030: Quality parameters of meat of nutria (*Myocastor coypus*) and its technological evaluation in meat products' for supporting and great thanks to hunters for their valuable help.

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Received: June 6, 2024
Accepted: August 27, 2024
Published online: October 25, 2024