Original scientific paper
Journal of Central European Agriculture, 2022, 23(1), p.24-30
DOI: /10.5513/JCEA01/23.1.3420

Evaluation of amino acids in meat and liver of nutria (*Myocastor coypus* Molina) depending on age

Hodnotenie aminokyselín v mäse a pečeni nutrie (*Myocastor coypus* Molina) v závislosti od veku

Jana HANUSOVÁ[1] (✉), Martina MILUCHOVÁ[2], Michal GÁBOR[2]

[1] Institute of Animal Husbandry, University of Agriculture in Nitra, A. Hlinku 2, 94976 Nitra, Slovakia

[2] Institute of Nutrition and Genomics, Slovak University of Agriculture in Nitra, A. Hlinku 2, 94976 Nitra, Slovakia

✉ Corresponding author: jana.hanusova@uniag.sk

Received: September 20, 2021; accepted: January 5, 2022

ABSTRACT

The objective of this research was to evaluate the amino acid composition of proteins in the dorsal muscle, femoral muscle, and the liver of female nutrias (*Myocastor coypus* Molina) in relation to age. In this study a total of 50 animals were used. The animals were split into two groups based on their age, i.e. 7 months old and 24 months old. The amino acids were separated and quantitatively determined using an automated analyser. Using a two-way analysis of variance, significant differences (P<0.05) were determined between the tested parameters, muscle type and age. In this study, statistically significant differences were found in the dorsal muscle in the content of glycine, which was higher in young animals and in the content of aspartic acid, which was higher in older animals. In the case of the femoral muscle, significantly higher content of serine, glycine and arginine were found in the group of 7-month-old animals. In contrast, the group of 24-month-old nutria in the femoral muscle showed a higher content of alanine, valine and phenylalanine. In the liver, significantly higher contents of some amino acids were found only in the group of young, 7 months old nutrias. Higher content was observed for aspartic acid, threonine, serine, glutamic acid, proline and histidine. Additionally, nutria meat, particularly meat from the dorsal muscle, is a rich source of amino acids, especially essential amino acid, glutamic acid and aspartic acid, making it yet another quality source of protein in a balanced human diet.

Keywords: dorsal muscle, femoral muscle, liver, *Myocastor coypus*

ABSTRAKT

Cieľom tejto práce bolo vyhodnotiť aminokyselinové zloženie bielkovín v chrbtovom svale, stehennom svale a pečeni samíc nutrií vo vzťahu k veku. V tejto štúdii bolo použitých celkom 50 zvierat. Zvieratá boli rozdelené do dvoch skupín podľa veku, 7 mesiacov a 24 mesiacov. Aminokyseliny boli separované a kvantitatívne určené pomocou automatického analyzátora. Použitím dvojfaktorovej analýzy rozptylu boli zistené významné rozdiely (P<0,05) medzi testovanými parametrami, typom svalu a vekom. V tejto štúdii boli zistené štatisticky významné rozdiely v chrbtovom svale v obsahu glycínu, ktorý bol vyšší u mladých zvierat a v obsahu kyseliny asparágovej, ktorý bol vyšší u starších zvierat. V prípade stehenného svalu boli v skupine 7-mesačných zvierat zistené výrazne vyššie hladiny serínu, glycínu a arginínu. Naproti tomu skupina 24-mesačných nutrií v stehennom svale vykazovala vyšší obsah alanínu, valínu a fenylalanínu. V pečeni boli preukázateľne vyššie hodnoty niektorých aminokyselín zistené len v skupine mladých 7-mesačných nutrií. Vyšší obsah bol pozorovaný pri kyseline asparágovej, treoníne, seríne, kyseline glutámovej, prolíne a histidíne. Mäso nutrie, najmä mäso z chrbtového svalu, je navyše bohatým zdrojom aminokyselín, najmä esenciálnych aminokyselín, kyseliny glutámovej a kyseliny asparágovej, čo z neho robí ďalší kvalitný zdroj bielkovín vo vyváženej ľudskej strave.

Kľúčové slová: chrbtový sval, stehenný sval, pečeň, *Myocastor coypus*

INTRODUCTION

In recent years, there has been an increase in the interest of ensuring healthy nutrition. Meat represents an important part of a balanced human diet, as an essential source of nutrients. One of these important nutrients, found in high abundance, are proteins, which consist of essential amino acids involved in the recovery and growth of body cells (Dalle Zotte and Szendrõ, 2011). In today's market, consumers show a preference for meat with a high protein content and a low cholesterol and fat content, good dietary properties and high nutritional value. Nutria meat satisfies all these requirements for healthy nutrition (Tůmová and Hrstka, 2013).

Nutria meat is consumed primarily in South America, in particular Argentina and Uruguay. In addition to South America, nutria meat is consumed in the southern states of the USA, in Europe in places such as Germany, Poland, Spain, Slovakia and the Czech Republic, as well as in Asia (Cabrera et al., 2007; Jurado et al., 2007; Glogowski and Panas, 2009; Hanusová and Miluchová, 2017). In Europe, nutrias are reared mainly for fur production, with their meat only being a marginal product in terms of their economic value (Cholewa et al., 2012; Migdal et al., 2013). Despite the fact that nutrias have been kept for almost 80 years in Slovakia, their meat has not yet been appreciated. Possible reasons for this are lack of information about the meat, including how to achieve sustainable yields as well as understanding the technical and culinary qualities of the meat (Hanusová and Miluchová, 2017).

In nutria meat, the composition of fatty acids and cholesterol is of particular interest, with it being well established that this type of meat is low in fat and in cholesterol (Tulley et al., 2000; Cabrera et al., 2007; Glogowski and Panas, 2009; Glogowski et al., 2010). According to Simon (2008), the nutritional quality of nutria meat increases in the presence of dietary minerals such as sodium, potassium, iron, zinc, copper, chromium, selenium, cobalt, and manganese. The chemical composition of meat is an important feature of its quality. Specifically, the chemical composition of nutria meat is known to be important in determining the nutritional value, the taste, the culinary qualities as well as the safety of the meat for human consumption (Saadoun and Cabrera, 2019).

Previous research has focused on the chemical composition and nutritional value of nutria meat, as well as its contribution to human nutrition; however, very little information is available about the amino acid profile of the meat.

The objective of this study is to evaluate effect of slaughter age on the amino acid composition in three morphologically, functionally and metabolically different body tissues of nutrias and to compare amino acid content of the tissues themselves.

MATERIALS AND METHODS

Animals

In this study, a total of 50 female nutrias bred in one of the fur farms in Slovakia were used. The nutrias were kept in the boxes with the utilization of some intensifying elements (partially slatted floor). The boxes were partially covered, without booth space, wall height 80 cm. In one box there were 10 animals (area 1 m^2 per 1 animal). The microclimatic regime depended on external climatic conditions. The nutrias were fed by the complete fodder mixture containing wheat bran, alfalfa, maize, sugar beet pulp, triticale, sunflower oil meat, barley, chaff, rape cake, beet molasses, and maize germs. Content of feed mixture: protein 15.3%, fat 3.0%, fibre 16.2%, ash 7.0%, Ca 0.9%, and P 0.6%. Green fodder was fed in summer and root crops (beets, carrots) and hay (ad libitum) in winter. Drinking water was at disposal.

The group of young animals constituted of 25 female nutrias who were at the age of 7 months and the group of adult animals constituted of 25 female nutrias who were slaughtered at the age of 24 months. Particular criteria were used to choose the animals in this study and ensured a balance of both physical development and body weight (body weight averaged were 3940 g ± 210.9 g at the age of 7 months and 5120 g ± 602.9 g at the age of 24 months) for each of the animals. The nutrias were slaughtered by electric stunning, weighted, bled, skinned, and eviscerated. The samples were taken 40 minutes after slaughter in the quantity of 0.20 – 0.24 g from the back muscle (*musculus latissimus dorsi*), femoral muscle (*musculus femoris*), and liver (*hepar*).

Amino acid analysis

The average contents of amino acids were measured by the apparatus AAA 400 (Ingos, Prague, Czech Republic) using hydrochloric acid hydrolysis. The sample was weighed out at the bottom of the test tube so that the material does not adhere to the walls. Then it was pipetted 6 NHCl in 200-multipled surplus. The top of the test tube was contracted to the inner diameter about 2 mm by the oxigen flame. The test tube was placed into the air thermostat and kept for 20 hours at the temperature of 110±1 °C. After the hydrolysis, the test tubes were chilled and opened. The acid evaporated in the vacuum rotation evaporator at 40 °C. The principle of the method is the division of the amino acids by the ionic exchange chromatography. The amino acids were determined by the reaction with ninhydrin by the photometric detection at 570 nm (440 nm for proline). The following amino acids were determined: aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine, arginine. The experiment was performed in triplicate.

Statistical analysis

The amino acid content in proteins of the dorsal muscle, femoral muscle, and the liver of the two testing age was evaluated using basic variation indexes. The objective of the statistical analyses was to assess the effect of tissue and age on the amino-acid composition in nutrias. Differences between amino acids content observed within groups were tested using a two-way analysis of variance (ANOVA) (P<0.05), according to the following model:

$$y = \mu + A_i + M_j + e_{ij}$$

where *y* is the amino acid (aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine, arginine), μ is the mean value, A_i is the fixed effect of age (i = 1, 2), M_j is the fixed effect of the tissue (j = 1, 2, 3) and e_{ij} is any residual effect.

All statistical analysis was performed using SAS 9.3 of SAS Enterprise Guide 5.1 (SAS Institute, Cary, North Carolina, USA).

RESULTS AND DISCUSSION

The results of the evaluation of the amino acid content of proteins isolated from the dorsal muscle, femoral muscle, and the liver of nutrias are presented in Table 1. The differences in the amino acid content between tissues as well as the variation between the two age categories, 7 and 24 months, were evaluated using a two-way analysis of variance.

In this study, differences in the amino acid content between the dorsal and femoral muscles were detected only in the 7-month-old animals. These significant differences were found in the amino acids, serine, alanine, arginine and isoleucine. Higher values for these amino acids were determined in the femoral muscle. Additionally, differences in the amino acid content between the dorsal muscle and liver in the 7- month-old animals were also found. These differences were found for aspartic acid, serine, threonine and glutamic acid. Higher levels for these amino acids were measured in the liver.

When comparing the average amino acid content of proteins in the femoral muscle and liver of nutrias at the age of 7 months, highly significant differences were detected in the amino acids threonine, glycine, isoleucine, histidine, glutamic acid, alanine, leucine and proline. Furthermore, in the femoral muscle higher levels of glycine, alanine, isoleucine, and leucine were measured, whereas the liver contained more threonine, glutamic acid, proline, and histidine. However, these differences were not necessarily present in the 24-month-old animals. In the 24-month-old animals, highly significant differences were detected for the amino acids threonine, glutamic acid, aspartic acid, and serine. Additionally, higher values of these amino acids were measured in the dorsal muscle compared to the liver. In this age category, highly significant differences were noted between femoral

Table 1. Effect of slaughter age on amino acid composition of nutria meat

Amino acid	Dorsal muscle			Femoral muscle			Liver		
	7 months[(2)]	24 months[(3)]		7 months[(2)]	24 months[(3)]		7 months[(2)]	24 months[(3)]	
	Mean±SD	Mean±SD	Significance[(1)]	Mean±SD	Mean±SD	Significance[(1)]	Mean±SD	Mean±SD	Significance[(1)]
	[g/kg]			[g/kg]			[g/kg]		
Aspartic acid	23.03±4.95^{a}	30.08±5.26^{x}	*	27.05±1.20	24.37±0.64	ns	30.88±0.84^{b}	17.29±7.13^{y}	*
Threonine	7.81±2.98^{ab}	9.34±0.32^{xy}	ns	9.15±0.0.7^{b}	9.33±0.06^{y}	ns	10.80±0.08^{c}	7.37±0.53^{z}	*
Serine	7.96±0.48^{a}	8.00±0.51^{xy}	ns	8.65±0.07^{bc}	7.73±0.12^{y}	*	8.88±0.05^{c}	7.29±0.71^{z}	*
Glutamic acid	30.00±6.39^{ab}	35.22±0.58^{xy}	*	34.55±0.21^{b}	35.47±0.12^{y}	ns	40.28±0.15^{c}	22.95±1.37^{z}	*
Proline	8.25±3.03	6.68±3.75	ns	8.95±0.50^{a}	10.10±0.30	ns	10.58±0.70^{b}	7.73±2.23	*
Glycine	9.97±1.15	8.94±0.61	*	10.35±0.07^{a}	8.67±0.06	*	9.33±0.13^{b}	9.24±0.64	ns
Alanine	11.18±1.57^{ac}	12.46±0.76	ns	13.15±0.07^{b}	13.37±0.06	*	12.50±0.22^{c}	10.27±2.99	*
Valine	10.56±1.04	11.32±0.72	ns	10.40±0.08	11.03±0.06	*	10.58±0.34	10.52±0.93	ns
Isoleucine	6.27±3.32^{ac}	8.84±1.01	*	9.23±0.08^{b}	9.33±0.29^{x}	ns	8.15±0.10^{c}	8.34±0.62^{y}	ns
Leucine	16.71±1.75	16.58±2.23	ns	17.85±0.21^{a}	18.20±0.10^{x}	ns	16.50±0.29^{b}	15.98±0.92^{y}	ns
Tyrosine	7.50±0.81	5.96±3.37	ns	7.95±0.07	8.03±0.21	ns	6.68±4.45	7.79±1.17	ns
Phenylalanine	10.09±1.42	7.74±4.33	ns	8.14±0.08	12.57±0.25^{x}	*	7.08±4.73	9.33±0.52^{y}	ns
Histidine	9.33±3.61	7.06±3.97	ns	9.25±0.07^{a}	8.97±0.64	ns	10.40±0.22^{b}	8.81±0.57	*
Lysine	13.63±7.23	18.20±0.85	ns	12.97±3.22	11.87±1.29^{x}	ns	12.88±3.60	17.29±1.06^{y}	*
Arginine	14.46±0.94^{a}	15.28±0.93	ns	15.75±0.07^{b}	14.77±0.31	*	11.08±7.39	14.67±0.78	ns

[1] Significant level for the effect of the slaughter age on amino acid composition of nutria meat within a row is indicated by: ns – nonsignificant, * $P<0.05$

[2] Significant level for the differences in amino acid composition among tissues within a row for 7 months old animals is indicated by: a, b, c - values in the row marked with different letters differ significantly $P<0.05$

[3] Significant level for the differences in amino acid composition among tissues within a row for 24 months old animals is indicated by: x, y, z - values in the row marked with different letters differ significantly $P<0.05$

muscle and liver proteins in their content of threonine, glutamic acid, leucine, phenylalanine, isoleucine, serine and lysine. Additionally, proteins from the femoral muscle contained more threonine, serine, glutamic acid, isoleucine, leucine and, phenylalanine in their composition whereas the liver showed higher levels of lysine.

When differences in the amino acid content of proteins found in the dorsal muscle, femoral muscle, and liver were compared across the two age categories, a number of discrepancies were found. Significant differences in glycine, glutamic acid, isoleucine, and aspartic acid were noted in the dorsal muscle, with a higher glycine content in 7-month-old animals and a higher content of aspartic acid, glutamic acid, and isoleucine in the 24-month-old animals. Whereas, in the femoral muscle, there were highly significant differences found for the amino acids valine, phenylalanine, serine, glycine, arginine, and alanine. Higher levels of serine and glycine were found in the 7-month-old animals, whereas alanine, valine, and phenylalanine were more abundant in the 24-month-old animals. Finally, in the liver, highly significant differences in the content of serine, proline, histidine, threonine and glutamic acid, aspartic acid and alanine were found, with all amino acids having an increased abundance in the 7-month-old animals. Furthermore, significant differences were noted in the content of lysine, with higher content in 24-month-old animals.

Nutria meat seems to be an excellent source for the most important amino acids for human nutrition (Shoveller et al., 2018; Saadoun and Cabrera, 2019), especially those that are limiting for child growth and also important to compensate for loss of protein mass in adults (FAO, 2013; Soultoukis and Partridge, 2016). This study demonstrates that the amino acids profile in nutria meat varies according to tissue type. Tůmová et al. (2016) presented that meat quality is affected by muscle fibre composition. Muscles are composed of several fibre types, the composition can vary markedly in different muscles depending on their function. Because fibre types have different contractile and metabolic properties (Lefaucher, 2010), differences in muscle amino acid profiles may be related to the fibre type composition. The results of our study are consistent with those reported by Conde-Aguolera et al. (2014) in pigs. The current study also suggests that age at slaughter has a significant effect on amino acid profile. However, these results are not in agreement with data presented by Domíngez et al. (2015), according to which age at slaughter has very little or no significant effect on the amino acid content of foals. The results were not compared with literature for nutrias meat because of lack of information.

In the context of meat produced by different livestock, our results suggest that the amino acid content of proteins found in nutria meat is closest to that of rabbit and beef meat (Migdal et al., 2013; Ahmed et al., 2018). Previously, it has been shown that the amino acid content in rabbit meat is higher than that of other slaughtered animals (Dalle Zotte and Szendrõ, 2011). The results for the content of glutamic acid, which is associated with the highest impact for meat flavour (Jarudo et al., 2007), correspond with a result of the study by Migdal et al. (2013). The same value for glutamic acid content in the meat of the chicken was detected in a study by Dalle Zotte et al. (2020). In contrast, in a study by Ribiero et al. (2019), the content of glutamic acid in lamb was lower compared to nutrias. Our results also suggest that the amount of essential and semi-essential amino acids is in favor of the femoral muscle compared to the dorsal muscle and liver. A comparison of the results of amino acid content in the femoral muscle between our study and the study of Migdal et al. (2013) confirmed the corresponding values for essential and non-essential amino acids and the similarity of the nutritional composition of both rabbit and nutria meat. However, the same study (Migdal et al., 2013) showed significantly lower levels of glutamic acid in rabbits compared to the levels in the dorsal muscle of nutrias from this study. A recent study by Vinauskiene and Leskauskaite (2019) reported similar results in the amino acid content of chinchillas, nutria, and rabbits and confirmed their potential for healthy nutrition. Finally, in accordance with our data, Migdal et al. (2013) also stated that the femoral muscle of the rabbit contains more essential amino acids (about 2.44 g/kg in fresh tissue) compared to that of the femoral muscle of nutrias, whereas the dorsal muscle of rabbit contained less essential amino acids (about 2.6 g/kg in fresh tissue) compared to the same muscle of nutrias. The nutritional characteristic of the liver of nutria performed by our research recorded a higher content of essential amino acids leucine and lysine and also a higher content of non-essential amino acids such as glutamic acid and aspartic acid. The results of essential and non-essential amino acids determined in the liver are consistent to those found in goats, camels (Bayomy and Rozan, 2017), and beef (Li et al., 2014; Bayomy and Rozan, 2017).

Therefore, utilizing nutria meat, as part of a balanced human diet, increases the range of quality sources of protein that can be consumed. Thus, breeding of nutrias for meat production could be a promising practice in the future.

CONCLUSIONS

From the results on meat quality of nutria, it can be concluded that the age at slaughter has a significant effect on the amino acid profile. Regardless of age and type of tissue, nutria meat contained the highest levels of glutamic acid and aspartic acid. Of the essential and semi-essential amino acids, the group of 7-month-old animals had the highest content of arginine in femoral muscle and of threonine and histidine in the liver. In the case of the group of 24-month-old nutria, the highest content of the essential amino acids valine and phenylalanine were found in femoral muscle. In conclusion, nutria meat is a rich source of amino acids, especially essential amino acids, glutamic acid and aspartic acid. It can be considered a good source of protein for a balanced diet.

ACKNOWLEDGMENTS

To the Scientific Grant of the Agency of the Slovak Republic (grant no. VEGA 1/0511/15), and Operational Programme Integrated Infrastructure within the project: Sustainable smart farming systems taking into account the future challenges 313011W112, co-financed by the European Regional Development Fund, for financial support.

REFERENCES

Ahmad, R.S., Imran, A., Hussain, M.B. (2018) Nutritional Composition of Meat. In M.S. Arshad, ed. Meat Science and Nutrition. Intech Open. DOI: https://doi.org/10.5772/intechopen.77045

Bayomy, H., Rozan, M. (2017) Comparative Studies of Amino Acid, Fatty Acids and Proximal Chemical Composition Content of Donkey, Dog, Camel, Beef and Goat Liver. Egyptian Journal of Food Science, 45, 95-102.

Cabrera, M.C., Del Puerto, M., Olivero, R., Otero, E., Saadoun, A. (2007) Growth, yield of carcass and biochemical composition of meat and fat in nutria (*Myocastor coypus*) reared in an intensive production system. Meat Science, 76 (2), 366-376. DOI: https://doi.org/10.1016/j.meatsci.2006.12.005

Cholewa, R., Beutling, D., Mleczek, M., Arndt, G. (2012) Study on mineral content in leg muscles and liver of coypu (*Myocastor coypus*) farmed in Western Poland. Journal of Animal Science Advances, 2 (2), 194-200.

Conde-Aguolera, J.A., Cobo-Ortega, C., Mercier, Y., Tesseraud, S., Van Milgen, J. (2014) The amino acid composition of tissue protein is affected by the total sulfur amino acid supply in growing pigs. Animal, 8 (3), 401-409. DOI: https://doi.org/10.1017/S1751731113002425

Dalle Zotte, A., Gleeson, E., Franco, D., Cullere, M., Lorenzo, J.M. (2020) Proximate Composition, Amino Acid Profile, and Oxidative Stability of Slow-Growing Indigenous Chickens Compared with Commercial Broiler Chickens. Foods, 9 (5), 546. DOI: https://doi.org/10.3390/foods9050546

Dalle Zotte, A., Szendrő, Z. (2011) The role of rabbit meat as functional food. Meat Science, 88 (3), 319-331. DOI: https://doi.org/10.1016/j.meatsci.2011.02.017

Domínguez, R., Crecente, S., Borrajo, P., Agregán, R., Lorenzo, J.M. (2015) Effect of slaughter age on foal carcass traits and meat quality. Animal, 9 (10),1713-1720. DOI: https://doi.org/10.1017/S1751731115000671

FAO (2013) Dietary protein quality evaluation in human nutrition: Report of an expert consultation. FAO Food Nutrition Papers, 92, 1-66. Available at: http://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf [Accessed 20 January 2018].

Glogowski, R., Czauderna, M., Rozbicka, A., Krajewska, K.A., Clauss, M. (2010) Fatty acid profile of hind leg muscle in female and male nutria (*Myocastor coypus* Mol.) feed green forage diet. Meat Science, 85 (3), 577-579. DOI: https://doi.org/10.1016/j.meatsci.2010.03.008

Glogowski, R., Panas, M. (2009) Efficiency and proximate composition of meat in male and female nutria (*Myocastor coypus*) in an extensive feeding system. Meat Science, 81 (4), 752-754. DOI: https://doi.org/10.1016/j.meatsci.2008.11.002

Hanusová, J., Miluchová, M. (2017) Meat yields of standard nutrias. Nitra: Slovak University of Agriculture, 71 p.

Jurado, Á., Garcia, C., Timón, M.L., Carapiso, A.I. (2007) Effect of ripening time and rearing system on amino acid-related flavour compounds of Iberian ham. Meat Science, 75 (4), 585-594. DOI: https://doi.org/10.1016/j.meatsci.2006.09.006

Lefaucher, L. (2010) A second look into fibre typing – relation to meat quality. Meat Science, 84 (2), 257-270. DOI: https://doi.org/10.1016/j.meatsci.2009.05.004

Li, R.R., Yu, Q.L., Han, L., Cao, H. (2014) Nutritional Characteristics and Active Components in Liver from Wagyu×Qinchuan Cattle. Korean Journal of Food Science and Animal Resources, 34 (2), 214-220.

Migdal, L., Barabasz, B., Niedbala, P., Lapinski, S., Pustkowiak, H., Živkovič, B., Migdal, W. (2013) A comparison of selected biochemical characteristic of meat from nutrias (*Myocastor coypus* Mol.) and rabbits (*Oryctolaguscuniculus*). Annals of Animal Science, 13 (2), 387-400. DOI: https://doi.org/10.2478/aoas-2013-0018

Ribeiro, D.M., Madeira, M.S., Kilminster, T., Scanlon, T., Oldham, C., Greeff, J., Freire, J.P.B., Mourato, M.P., Prates, J.A.M., Almeida, A.M. (2019) Amino acid profiles of muscle and liver tissues of Australian Merino, Damara and Dorper lambs under restricted feeding. Journal of Animal Physiology and Animal Nutrition (Berl), 103 (5), 1295-1302. DOI: https://doi.org/10.1111/jpn.13148

Saadoun, A., Cabrera, M.C. (2019) A review of productive parameters, nutritive value and technological characteristics of farmed nutria meat (*Myocastor coypus*). Meat Science, 148, 137–149. DOI: https://doi.org/10.1016/j.meatsci.2018.10.006

SAS Institute Inc. (2011) Administering SAS® Enterprise Guide® 5.1. Cary, Version 9.3,NC: SAS Institute Inc.

Shoveller, A.K., Mcknight, L.M., Wood, K.M., Cant, J.P. (2018) Lessons from animal nutritionists: Dietary amino acid requirement studies and considerations for healthy aging studies. Annals of the New York Academy of Sciences, 1418 (2018), 20-30. DOI: https://doi.org/10.1111/nyas.13546

Simon, O. (2008) Mineralstoffe und Waser. In: Jeroch, H., Drochner, W., Simon, O., eds. Ernährung landwirtschaftlicher Nutztiere: Ernährungsphysiologie, Futtermittelkunde, Fütterung (2nd ed.). Stuttgart: Eugen Ulmer, pp. 75-85.

Soultoukis, G.A., Partridge, L. (2016) Dietary Protein, Metabolism, and Aging. Annual Review of Biochemistry, 85, 5-34. DOI: https://doi.org/10.1146/annurev-biochem-060815-014422

Tulley, R.T., Malekian, F.M., Rood, J.C., Lamb, M.B., Champagne, C.M., Redmann, S.M., Patrick, R., Kinler, N., Raby, C.T. (2000) Analysis of the nutritional content of *Myocastor coypus*. Journal of Food Composition and Analysis, 13 (2), 117-125. DOI: https://doi.org/10.1006/jfca.1999.0865

Tůmová, E., Chodová, D., Uhlířová, L., Vlčková, J., Volek, Z., Skřivanová, V. (2016) Relationship between muscle fibre characteristic and meat sensory properties in three nutria (*Myocastor coypus*) colour types. Czech Journal of Animal Science, 61, 217-222. DOI: https://doi.org/10.17221/59/2015-CJAS

Tůmová, E., Hrstka, Z. (2013) A comparison of the quality of nutria meat and rabbit meat. Maso, 24, 47-50.

Vinauskiene, R., Leskauskaite, D. (2019) Nutritional composition of farm chinchilla (*Chinchilla lanigera*) meat. Journal of Food Composition and Analysis, 84, 103303. DOI: https://doi.org/10.1016/j.jfca.2019.103303