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Effect of sex on growth, biochemical and haematological parameters of blood, carcass value and meat quality in nutrias (*Myocastor coypus*)

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Abstract: Sex differences in growth, blood indicators, carcass values and meat quality in nutrias were evaluated. In the fattening experiment, 136 nutrias of both sexes (1 : 1 ratio) were fattened until 8 months of age. At the end of the experiment, 18 males and 18 females with average weights were selected for the determination of biochemical indicators, carcass value and meat quality. The growth of males was significantly higher than in females; the differences were 12% at three months of age and increased to 24% at eight months of age. The effect of sex on the biochemical indicators of blood was observed in total protein ($P \leq 0.029$), albumin ($P \leq 0.012$), urea ($P \leq 0.019$) and cholesterol ($P \leq 0.026$), with higher values in males. In the case of haematology examination, the significantly higher values in males were in the number of erythrocytes (5.10×10^{12}/l) and in the haematocrit value (55.8%). Dressing out percentage was higher in males ($P \leq 0.039$), and other parameters of carcass value were not affected by sex. For the meat physical properties, only lightness ($P \leq 0.019$) was higher in males. In the case of the chemical composition of meat, ether extract ($P \leq 0.033$) and energetic value ($P \leq 0.024$) were lower in females. The results of this study show high differences in the growth of male and female nutrias, whereas carcass composition, physical meat quality and meat chemical composition are less affected by nutria sex.

Keywords: nutria; live weight; carcass composition; total protein; blood characteristics

In intensive farming, nutrias are reared for the production of quality fur with meat as a by-product; however, at the end of the 20th century the market situation changed, and meat has become the main product. For meat performance, growth is an important parameter that affects the final live weight and composition of the carcass. Growth is affected by many factors, of which breed and sex are the most important. Sexual dimorphism in growth was observed in some animal species. For example, Baeza et al. (2001) found significant sex differences in the growth of Muscovy ducks – by 37.0% higher value in males at the end of fattening. Similarly, the effect of sexual dimorphism was detected in turkeys (Herendy et al., 2004), with higher live weights in males by 33.7% at 24 weeks of age. The issue of sexual dimorphism in the growth of nutrias was observed in the study of Cabrera et al. (2007), who determined the effect of sex on growth from the third month of age, when males reached significantly higher weights by approximately 11.0% and at the age of seven months by approximately 15.6%. Beutling et al. (2008) detected differences between sexes that varied according to the nutria colour type. In Standard nutrias, males reached higher weight at eight months of age by 15.5% and in Greenland nutrias by approximately 17.9%. Tumova et al. (2015)

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observed a weight difference of 25% between the sexes in Standard nutrias, 36% in Silver nutrias and 23.4% in Prestice nutrias at the age of eight months. The biochemical indicators of blood are related to the intensity of growth because the concentrations of total protein and urea are important parameters of protein metabolism and intensity of growth. In nutrias, only the general concentration of total protein, glucose, cholesterol and urea was described by Januskevicius et al. (2015). A similar situation exists in haematological indices. For example, Martino et al. (2012) observed the haematocrit value (HCT), haemoglobin and mean corpuscular volume (MCV) and Jelinek (1984) observed the concentration of erythrocytes, HCT, mean erythrocyte volume and the total number of white blood cells in nutria males.

Slaughter characteristics represent valuable information in meat production. In nutrias, the information about carcass value is variable because the uniform carcass definition is missing. Some authors have reported carcass with head (Hermann and Muller 1991) and others without head (Cabrera et al. 2007). Generally, Mertin et al. (2003) and Tumova et al. (2015, 2017) described the effect of sex on hot carcass weight, with higher values in males at the age of eight months. Beutling et al. (2008) observed differences in hot carcass weights between the sexes in different colour types at eight months of age. In their study, the hot carcass weight in Standard males was approximately 15.0% higher and that of Greenland males approximately 23.8% higher. Similar to the carcass weight, the determination of dressing out percentage (DOP) is not uniform. Mertin et al. (2003), Beutling et al. (2008) and Tumova et al. (2015) presented a higher DOP in males. Additionally, in carcass composition, there is a lack of information because nutrias are usually sold in the form of the whole carcass.

The quality of meat is given by its physical properties and chemical composition. The acidification of muscles *post-mortem* is one of the fundamental changes that occur during meat maturation. For example, in rabbits, sex had no effect on pH (Dalle Zotte et al. 2005). There is a lack of data about the effect of sex on this parameter; however, Alt et al. (2006) and Cholewa et al. (2009) did not determine differences in the meat pH between males and females. The colour of the meat is given by the content of myoglobin, which could be affected by the sex and age of the animal (Hernandez et al. 2004). In nutrias, the meat colour parameters expressed by L* (lightness) and b* (yellowness) were lower in females, and a* (redness) was slightly higher in females than in males (Cholewa et al. 2009).

The chemical composition of meat can be affected by sex, breed or nutrition. However, in nutrias, sex had no effect on the content of protein (Saadoun et al. 2006; Cabrera et al. 2007; Cholewa et al. 2009), total lipid (Saadoun et al. 2006; Cabrera et al. 2007), cholesterol (Cabrera et al. 2007) and hydroxyproline (Tumova et al. 2015, 2017).

There is relatively little information about the meat performance of nutrias in relation to the effect of sex, biochemical indicators, haematology, carcass value and the quality of meat; therefore, the aim of this study is to evaluate the growth, carcass value and quality of meat between male and female nutrias.

MATERIAL AND METHODS

Animals and experimental design. A total of 136 Standard nutrias at the age of 2–8 months were used for the fattening part of this experiment (4 replications with 17 animals per sex). Nutrias were obtained from 3 small farms at the weaning age of two months. The experiment was approved by the Ethics Committee of the Czech University of Life Sciences Prague and the Central Commission for Animal Welfare at the Ministry of Agriculture of the Czech Republic. During the experiment, the nutrias were housed in eight indoor pens (1.0 m^2 per animal) with a hard, slated floor. A 12-hour light regime was used, and the environmental conditions reflected the needs of the nutrias (temperature 14–16°C; relative humidity 55–60%). Animals were fed a pelleted feed mixture throughout the experiment. The feed mixture contained 19.2% crude protein, 14.6% crude fibre, 31.8% neutral detergent fibre, 3.5% ether extract, 0.9% Ca and 0.6% P. Feed and water were available *ad libitum*. Nutrias were individually weighed every 28 days until the end of the experiment. At the end of the fattening experiment, 36 nutrias with average weights were selected for slaughtering.

Carcass analysis. The nutrias were slaughtered at the Experimental Slaughterhouse of the Institute of Animal Science. Before slaughtering, the animals were fasted for 12 h. The nutrias were electrically stunned and bled. After slaughtering, the nutrias were skinned, and the gastrointestinal tract was

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removed and weighed. The carcass analysis was carried out according to the methodology described in the study of Tumova et al. (2015, 2017) and was performed on cold carcasses. The dressing out percentage was calculated from the cold carcass weight without the head, divided by the live weight and multiplied by 100. The separation of the individual parts of the carcass (front part, hind part, loin and hind leg) was performed in accordance with Tumova et al. (2015, 2017). Each part of carcass was weighed, and this value was used for the calculation of the percentage of the carcass. The percentage of perirenal fat and the meat/bone ratio were calculated by the method described by Blasco and Ouhayoun (1996).

Physical properties of the meat. The meat pH value was determined 24 h *post mortem* in the hind leg with a Jenway pH Meter 3510 (Jenway, UK). The colour of the meat was measured in the hind leg 24 h *post mortem* by a Minolta Spectra Magic TM NX spectrophotometer (Konica Minolta Sensing, Inc., Japan). The determination of meat physical properties was described in detail in the study of Tumova et al. (2017).

Chemical analyses. The chemical composition of the meat was determined similarly as in the study of Tumova et al. (2015, 2017) in accordance with the procedure of AOAC (2005). Dry matter was determined by drying in an oven at 105°C. The Kjeltec Auto 1030 Analyser (FOSS Tecator AB, Sweden) was used to determine the protein content, and the Soxtec 1043 apparatus (FOSS Tecator AB) to determine the ether extract according to Skrivanova et al. (2017). The concentration of hydroxyproline (HPR) was analysed according to Diemar (1963). The ash content was determined by mineralisation at 550°C. The cholesterol content was analysed using a photometrical method and a PerkinElmer analyser (model 5000; PerkinElmer, USA). The energetic value of the meat was calculated as follows:

$$\text{Energetic value (MJ/kg)} = ((16.74 \times \text{protein content}) + (37.66 \times \text{fat content}))/1000$$

Blood analyses. Blood samples were taken to determine biochemical markers (total protein, albumin, urea, cholesterol, triacylglycerol, non-esterified fatty acids and glucose) and haematology from 36 nutrias. Blood for biochemical analyses was collected into tubes without anticoagulant after slaughtering. Samples for the determination of haematological characteristics were stored at 4°C for 24 h. The collected blood samples were centrifuged (1000 *g* for 10 min). The obtained serum was stored at –70°C until analysis. Biochemical serum markers were determined photometrically in a Libra S 22 spectrophotometer (Biochrom Ltd., UK) using standard commercial kits (Randox Laboratories Ltd., UK). The samples for detection of haematological characteristics were collected into tubes containing dipotassium salt of ethylenediamine tetraacetic acid (K2 EDTA). In blood, the erythrocytes, haematocrit value, leucocytes and haemoglobin concentration were determined. The haematology analysis method was described in more detail by Chodova et al. (2017).

Muscle fibre characteristics. Muscle fibre characteristics were measured in the right hind leg in the *Biceps femoris*. The samples were treated with myofibrillar ATPase and stained according to the method of Brooke and Kaiser (1970). The individual fibres were classified according to the nomenclature of Ashmore and Doerr (1971): type I (red, slow oxidative), type IIA (red, fast oxide-glycolytic) or type IIB (white, fast glycolytic). For each type of muscle fibre, the mean cross-sectional area (CSA, μm^2) and percentage were calculated using NIS Elements AR 3.1 software (Nikon, Japan). The detection of the number and area of muscle fibres was described in the study of Tumova et al. (2017).

Statistical analyses. The data were analysed using the GLM procedure of SAS (Statistical Analysis System, Version 9.4). All measurements were processed with one-way ANOVA, and the differences between sexes were tested by *t*-test.

RESULTS AND DISCUSSION

Table 1 presents changes in the live weights of nutrias from weaning at the age of two months to the end of the experiment at the age of eight months. At weaning, the nutrias showed no significant differences in body weight between males and females. The inconsistent growth intensity of males and females exhibited significant differences ($P \leq 0.019$) at three months of age, when the males were heavier by 12% than the females. The differences in live weights between the sexes significantly grew to 24.6% at the end of the experiment. Similarly, Cabrera et al. (2007) observed significant differences in body weights between males and females at three months of age (17.9%),

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Table 1. Live weight (g) of nutria males and females during fattening

Months	Males	Females	SEM	Significance
2	1250	1159	45.4	0.322
3	2072	1823	53.1	0.019
4	3029	2565	62.9	< 0.001
5	3859	3135	74.6	< 0.001
6	4593	3711	84.3	< 0.001
7	5226	4058	98.7	< 0.001
8	5974	4505	123	< 0.001

SEM = standard error of the means

Table 2. Effect of sex on blood biochemical indices in nutrias at the age of 8 months

	Males	Females	SEM	Significance
Total protein (g/l)	50.20	41.60	2.01	0.029
Albumin (g/l)	33.50	26.10	1.53	0.012
Urea (mmol/l)	6.28	3.81	0.54	0.019
TAG (mmol/l)	1.22	1.08	0.14	0.649
Cholesterol (mmol/l)	1.58	1.16	0.10	0.026
NEFA (g/l)	0.51	0.44	0.05	0.502
Glucose (mmol/l)	6.03	5.05	0.37	0.186

TAG = triacylglycerol, NEFA = non-esterified fatty acid, SEM = standard error of the means

and this difference increased to the end of fattening to 19.5% at eight months of age. Faverin et al. (2005) presented differences between sexes at a weaning age of 40 days (7.13%) and at six months of age (37.0%). Tumova et al. (2017) described increased differences in live weight between males and females of 15.8%, 19.6% and 23% at 6, 7 and 8 months, respectively. A previous study (Tumova et al. 2015) revealed that the differences in live weights between the sexes of nutrias were affected by the colour type of nutrias. The highest differences were detected in Moravian Silver (36.9%), in Standard nutrias (25.9%) and the lowest in Prestice nutrias (23.4%). A comparison of the results and literature shows that the range of the differences in live weights between sexes could be affected by the colour type and environmental conditions. On the other hand, in wild nutrias, Tulley et al. (2000) did not find significant differences in live weights between sexes in young nutrias, but adult males were significantly heavier (by 11.4%). These data indicate that domestication increased the differences in the live weights of male and female nutrias, and further selection of environmental conditions might increase the live weight variability.

Differences in growth may affect the blood biochemical characteristics (Table 2). The concentration of total protein is associated with better utilization of the protein in the feed mixture and a higher intensity of growth. In the present study, a higher concentration of total protein was found in males ($P \leq 0.029$), which grew faster than females. A similar trend was observed in the other blood biochemical indicators of protein metabolism, albumin ($P \leq 0.012$) and urea ($P \leq 0.019$), which were also higher in males. On the other hand, three indicators of lipid metabolism (cholesterol, triacylglycerol and non-esterified fatty acid) were evaluated, while cholesterol was affected by sex ($P \leq 0.026$). In the literature, the effect of sex on blood biochemical measurements in nutrias has not been described; however, the range of concentrations of these indicators corresponds with the levels described by Jelinek (1984) and Januskevicius et al. (2015). In comparison with other species, e.g. male rats had higher concentrations of cholesterol and TAG than did their females (Marounek et al. 2017). Glucose is an indicator of energetic metabolism, and in the present study, it was not affected by sex. These values are not comparable with the literature because these data are missing. The differences in biochemical indicators show the effect of sex on the biochemical measurements of protein metabolism and cholesterol and are presumably associated with sex differences in the growth of nutrias. On the other hand, the variability between males and females is within a range described in the literature (Jelinek 1984; Martino et al. 2012). Of haematological indicators (Table 3), the counts

Table 3. Haematological indices of nutria males and females at the age of 8 months

	Males	Females	SEM	Significance
ER (10^{12}/l)	5.10	4.48	0.15	0.033
HCT (%)	55.80	49.50	1.60	0.048
MCV (fl)	110	110	1.08	0.595
LC (10^{9}/l)	10.30	9.99	0.53	0.781
HB (g/l)	146	136	3.28	0.125

ER = erythrocytes, HCT = haematocrit value, MCV = mean corpuscular volume, LC = leucocytes, HB = haemoglobin concentration, SEM = standard error of the means

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of erythrocytes ($P \leq 0.033$) and HTC ($P \leq 0.048$) were higher in males. However, MCV, leucocytes (LC) and haemoglobin concentration were not affected by the sex. There is limited information about haematology of nutrias, none of which is related to sex. In addition, data on MCV and LC are missing.

Most of the carcass composition characteristics (Table 4) were not affected by the sex of the nutrias. On the other hand, the carcass weight of females was 23% lower than in males, which corresponded with differences in slaughter weight. In the study of Glogowski and Panas (2009), the difference between the sexes in live weight at nine months of age was only 3.2%. The significant effect of sex was determined in DOP ($P \leq 0.039$), with lower values in females, which is in agreement with the study of Mertin et al. (2003) and Tumova et al. (2015). The percentage of the individual components of the carcass (hind part, hind leg and hind leg meat) was not affected by sex, with numerically higher values in males, and corresponds with the trend in percentages observed in the studies of Tumova et al. (2015, 2017). The percentage of internal organs was not affected by sex, with the exception of the kidneys. The higher percentage of kidneys ($P \leq 0.036$) in males is in contrast with the study of Mertin et al. (2003), who did not detect an effect of sex on the proportion of kidneys. In the present study, the liver percentage was not affected by sex, but Mertin et al. (2003) observed its significantly higher values in females. Similar to the study of Mertin et al. (2003), our heart percentage results did not differ between males and females. The differences in the proportion of organs could be due to the different live weights at the slaughter age. In comparison with other species, for example, rabbits (New Zealand White), the study of Yalcin et al. (2006) did not determine the effect of sex on the proportion of the kidneys, liver and heart. Renal fat is a good indicator of fatness, and its amount increases with age (Tumova et al. 2017). The percentage of renal fat was not affected by sex in the present study, but a slightly higher value was observed in males ($P \leq 0.05$). In studies conducted by Tumova et al. (2015, 2017), a similar trend was found.

For the physical properties of the hind leg meat (Table 5), pH was not affected by sex, with a numerically higher value in males, which is in agreement with the studies of Alt et al. (2006) and Migdal et al. (2013). On the other hand, Tumova et al. (2017) described significantly lower values in females. For the colour parameters of the hind leg meat, only differences in L* parameter between males and females were registered, with a higher value in males. In the limited information about nutria meat lightness, Cholewa et al. (2009) and Tumova et al. (2017) did not find significant differences between males and females. In agreement with studies by Cholewa et al. (2009) and Tumova et al. (2017), the effect of sex was not observed on the meat parameters a* and b*. Meat colour is affected by the muscle structure, and negligible differences in the proportion of muscle fibres are assumed to be the main reason for the lack

Table 4. Body and carcass composition of nutria males and females at the age of 8 months

Characteristics	Males	Females	SEM	Significance
Live weight (g)	5650	4448	149	< 0.001
Weight of skin (g)	1179	1072	34.50	0.016
Skin (%)	22.90	20.90	0.54	0.065
Carcass weight without head (g)	2702	2084	78.40	< 0.001
DOP (%)	52.20	50.60	0.41	0.039
Hind part (%)	41.60	41.30	0.73	0.858
Hind leg (%)	25.30	24.10	0.77	0.428
Hind leg meat (%)	20.40	20.30	0.44	0.919
Meat/bone ratio (%)	32.00	31.80	1.90	0.958
Liver (%)	6.39	6.36	0.24	0.951
Heart (%)	0.70	0.70	0.03	0.938
Kidneys (%)	1.47	1.29	0.04	0.036
Digestive tract (%)	16.70	15.60	1.95	0.669
Renal fat (%)	3.08	2.76	0.35	0.661

DOP = dressing out percentage, SEM = standard error of the means

Table 5. Physical properties of *Biceps femoris* muscle in nutrias at the age of 8 months

	Males	Females	SEM	Significance
pH	6.30	6.18	0.07	0.436
L*	43.60	40.30	0.73	0.019
a*	11.50	9.99	0.41	0.059
b*	7.27	6.31	0.69	0.494
Shear force (N)	27.70	22.40	0.93	0.003

L* = lightness, a* = redness, b* = yellowness, SEM = standard error of the means

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Table 6. Chemical composition of hind leg meat in nutrias at the age of 8 months

	Males	Females	SEM	Significance
Dry matter (%)	25.70	24.90	1.65	0.017
Crude protein (%)	21.20	21.20	0.65	0.927
Ether extract (%)	2.93	2.23	1.66	0.033
Cholesterol (%)	0.056	0.055	18.80	0.874
Ash (%)	1.13	1.12	0.07	0.813
Hydroxyproline (%)	0.10	0.10	0.06	0.766
Energetic value (MJ/kg)	4.65	4.39	0.06	0.024

SEM = standard error of the means

of significance (Tumova et al. 2017). The shear force of the hind leg meat was significantly higher ($P \leq 0.019$) in males and might be related to the higher cross-sectional area of muscle fibres and the collagen content in males. In comparison with other species, e.g. in geese, Uhlirova et al. (2018) did not find the effect of sex in the Czech goose, but in the Eskildsen goose, the shear force was significantly higher in females.

In the chemical composition of hind leg meat (Table 6), the protein content was not affected by sex, which agrees with Saadoun et al. (2006), Cabrera et al. (2007), Glogowski and Panas (2009) and Tumova et al. (2015, 2017). The effect of sex was determined in ether extract ($P \leq 0.033$), with higher values in males, corresponding with Tumova et al. (2015, 2017). However, in the studies of Saadoun et al. (2006), Cabrera et al. (2007) and Januskevicius et al. (2015), sex had no effect on the parameter. Tulley et al. (2000) determined a lower content of total fat in wild nutrias, without the effect of sex. Glogowski and Panas (2009) found higher values in females. The differences between studies could be due to different genotypes, feed mixtures or environmental conditions. HPR is an indicator of the collagen content in meat, and in the present study, the differences were not found. A similar trend was observed by Tumova et al. (2015, 2017) but with significant differences between sexes. On the other hand, Migdal et al. (2013) observed a negligibly lower collagen content in females. Additionally, in the case of cholesterol content, sex showed no effect on its level, which agrees with findings by Saadoun et al. (2006) and Cabrera et al. (2007).

The results of the measurements of muscle fibre characteristics in the *Biceps femoris* are summarized in Table 7. The differences in the number of muscle fibres can be affected by sex (Staron et al. 2000) and breed (Ruy et al. 2008). However, in the present study, the number of all types of muscle fibres was not affected by sex, with numerically higher values in males. In an experiment with age-related changes, Tumova et al. (2017) observed that the proportion of muscle fibre types I, IIA and IIB was numerically higher in males. In a previous study, Tumova et al. (2015) evaluated the effect of the colour types and in Standard and Moravian Silver males observed a significantly higher percentage of type I muscle fibres, but the percentage of type IIB muscle fibres was higher in females ($P \leq 0.05$). The percentage of type IIA fibres was higher in females of the Standard and Prestice nutria. Concerning the CSA of muscle fibres, type IIB had the significantly highest CSA ($P \leq 0.001$), and this agrees with Tumova et al. (2015, 2017). The CSA of all muscle fibre types was numerically higher in males, which presumably

Table 7. Muscle fibre characteristics of *Biceps femoris* of nutria males and females at the age of 8 months

	Fibre type	Males	Females	SEM	Significance
Fibres *n* (per mm^2)	I	33.50	20.40	4.39	0.143
	IIA	15.60	8.67	2.51	0.188
	IIB	175	144	9.06	0.087
Percentage of total fibres (%)	I	18.20	9.37	2.36	0.063
	IIA	7.41	4.43	1.03	0.166
	IIB	85.90	84.30	2.60	0.780
Cross sectional area (μm^2)	I	2242	2173	107	0.752
	IIA	2383	2107	117	0.300
	IIB	4094	3666	59.50	< 0.001

SEM = standard error of the means

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reflected higher live weights. In contrast, Tumova et al. (2015) observed significantly higher CSA of all muscle fibre types in males in all three colour types. In the following study, Tumova et al. (2017) found that the effect of sex was significant on the CSA of all muscle fibre types. Regarding the age, higher values of CSA were in males at 7 and 8 months of age, whereas at 6 months the values were higher in females. The CSA of muscle fibre types plays an important role because it is associated with meat quality. For example, muscle fibre type I has a higher content of myoglobin, which affects the lightness of meat (Ruy and Kim 2006); higher collagen content of this type correlates with tenderness (Renand et al. 2001). Muscle fibre type IIB is fast glycolytic, which may be related to intramuscular fat and therefore affect also meat tenderness (Renand et al. 2001; Tumova et al. 2016).

CONCLUSION

The study describes sexual dimorphism in growth, carcass value and the quality of meat in nutrias and provides new information about the biochemical and haematological indicators in blood. The differences in growth were determined from three months of age, with the faster growth intensity of males. Sexual dimorphism also affected blood biochemical characteristics, as higher indicators of protein metabolism were seen in males, which is presumably related to the higher intensity of growth. As for the haematology indicators, leukocytes and erythrocyte counts, haematocrit value and haemoglobin were lower in females. Carcass composition was moderately affected by sex, except for DOP, which had higher values in males, which might be related to a higher proportion of fur in females. The physical properties of the meat were only significantly higher in parameter L* in males, and we assume that this parameter was correlated with a higher proportion of muscle fibre type I in males. The nutritional value of the meat was not affected by sex, except for ether extract and the energetic value, which was higher in males. In the case of muscle fibres, the effect of sex was determined only in the CSA of type IIB. Higher CSA in males is related to more intensive growth and higher live weights. The study provides the first detailed data on the differences between male and female nutrias in the effect of sex on performance and meat quality; however, further studies are needed to confirm the effect of sex on the studied parameters.

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