COMPARISON OF THE CARCASS VALUE AND MEAT QUALITY OF THE RABBIT BREED STUDIED BY SEX

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Abstract

The aim of the experiment was to determine the effect of sex of domestic rabbit on carcass value and meat quality. For the purpose of the experiment, 30 rabbits of the large light silver breed were slaughtered in the ratio of 15 male and 15 female rabbits. At about 125 days of age, the last weighing and slaughter took place. After slaughter, the edible internal organs such as heart, kidneys and liver were weighed. The carcass itself was then weighed and then cut into subdivisions: back, head, front and thighs. From the samples of the back muscle of Longissimus thoracis et lumborum provided, the protein content, intramuscular fat and fatty acid content were determined in the laboratory. Females had a better growth performance compared to males, statistically significant at the significance level (P<0.01) higher carcass yield by 5% and a significant statistically significant difference of P<0.05 was observed in intramuscular fat content in muscle, where twice as much was recorded in females as in males. The weight of individual body parts, including viscera, was recorded higher in females than in males except for the lungs, which were heavier in males. Males were distinguished by a higher content of saturated fatty acids of the SFA group, determined in the muscle, whereas females were found to have a higher content of fatty acids of the PUFA group, unsaturated polyene fatty acids. The highest content of palmitic acid (43.20% and 38.26%, respectively), belonging to the SFA group, was found in the muscle of both sexes. The ratio between PUFA and SFA fatty acids was recorded as 0.26 and 0.41 in males and females, respectively.

Keywords: *rabbit, carcass value, fatty acids, intramuscular fat*

1. INTRODUCTION

Muscle meat from domestic rabbit is nowadays a complementary type of meat, but its important nutritional and sensory properties cannot be overlooked. Due to its rich polyunsaturated fatty acids, protein, essential amino acids, B vitamins, medium energy value, low fat content and low cholesterol (Dalle Zotte & Szendrő, 2011; Siddiqui et al., 2023), eating rabbit meat corresponds to living a healthy lifestyle. As a result, rabbit meat production has seen a rapid increase in the last decade. According to Wu (2022), global rabbit meat production has been steadily increasing over the past 60 years or so. In addition, rabbit meat production contributes to sustaining economic activities in rural peripheral areas. The consumption of this meat is associated with the emerging trend of rational nutrition. Thanks to its composition, it is classified as a 'white meat' with fine muscle fibres and its digestibility reaches approximately 95 %. Rabbit meat has perfectly balanced nutritional values thanks to its high protein content (up to 21 g of protein per 100 g of meat), which contains all essential amino acids, low fat content (5-10 g/100 g of meat) and almost zero carbohydrate content (0,2-0,5 g/100 g). Its cholesterol and fat content is much lower than that of chicken, turkey, beef and pork (Combes, 2004; Cavani et al., 2010). Before the gastronomic preparation of rabbit meat, the meat should be chilled and left to mature for at least 24 h. During maturation, processes related to the degradation of some organic acids occur in the muscle meat (Rafay, 2003).

Of great importance for the flavour and tenderness of rabbit meat is the intramuscular fat, which is distributed between the cells in the form of veins and forms the so-called marbling (Jakobsen, 1999). The intramuscular fat content improves the juiciness, tenderness and flavour of meat, but can also affect its nutritional quality (Zubiri-Gaitán et al., 2022). Hernández et al. (2008) demonstrated in rabbits the effect of intramuscular fat on meat tenderness. Compared to pork, rabbit meat has a lower intramuscular

fat content and this intramuscular fat has a high percentage of unsaturated fatty acids and low cholesterol (Cavani and Petracci, 2008; Hernández et al., 2006).

Unsaturated fatty acids, minerals and some vitamins are highly represented. The most important chemical properties that can be used to characterise the quality of meat are the water, lipid, protein and ash content, the fatty acid composition, the amino acid content and the cholesterol content. Rabbit meat contains mainly saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA). In rabbits, short- and medium-chain fatty acids are predominantly catabolized as an energy source in the muscles, while long-chain fatty acids are directly stored in adipose tissue (Xiccato, 1999). Rabbit meat is characterized by high nutritional and dietetic properties, such as a high ratio of n -3/n -6 fatty acids and low levels of intramuscular fat, cholesterol and sodium (Hernández et al., 2006). Rabbit meat contains a high proportion of polyunsaturated fatty acids compared to other livestock species (Chang-Han and Yeon-hee, 1982; Griffiths et al., 1989). Unsaturated fatty acids generally have a positive effect on the cardiovascular system, joint function and brain function. Rabbit meat has higher proportions of polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids, both known for their health benefits. These benefits include reduced cholesterol as well as reduced risk of chronic diseases such as heart disease, cancer, and arthritis (López Miranda et al., 2006; Wall et al., 2010; Gammone et al., 2018). A possible disadvantage of high PUFA content is a higher susceptibility to oxidation (Dalle Zotte, 2002).

Feeding and slaughter weight as well as sex (Lebas et al., 2000; Pla et al., 1998) have been described as factors that influence rabbit meat quality. Sex in rearing rabbits for meat production most influences the amount and deposition of fat. Female meat contains 4-6% more fat than male meat (Dvorak, 1973). The storage of more fat in females serves as a reserve and energy supply for subsequent fetal development (Steinhauser, 2000). The fat content of females is 5.7 g/100 g of muscle, which is 0.5 g more than that of males. Cholesterol then accounts for 73.5 mg/100 g of muscle. In the case of males, the cholesterol content is set at 63.7 mg/100g of muscle (Polak et al., 2006). The effect of sex on meat tenderness has not been demonstrated in rabbits (Pla, 2008; Carrilho et al., 2009).

The aim of the study was to investigate the effect of sex in the Large Light Silvery rabbit breed on carcass value and meat quality, including chemical analyses of muscle *Longissimus thoracis et lumborum.*

2. MATERIAL AND METHODS

During the experiment, a total of 7 litters from 4 rabbits of the Large Light Silvery Rabbit breed were observed. Out of a total of 32 individuals, two died, with the first young rabbit dying within 5 days after birth and the second 14 days after birth.

For the purposes of the experiment, 30 individuals were slaughtered in a ratio of 15 males to 15 females.

The breeding of the observed individuals took place in a wooden outdoor rabbit house with 3 floors and a total of 9 pens. The individual pens meet the requirements of the technology of breeding on litter with a wooden solid floor. The dimensions of one pen are 90 x 90 x 25 cm and thus meet the minimum welfare requirements of medium-sized rabbits. Ceramic and stone bowls were used to store cereal feeds, or complete pelleted mixtures and water. A crib located on the left wing of the pen door was used for biting apple branches and dried meadow hay. Observed individuals were fed ad-libitum with periodic checks of cereals, water and hay in the morning and early evening. Bedding consisted of barley straw only. Feces were removed every 7 days and the whole pen was cleaned and disinfected with chloramine every 3 weeks. All animals were also preventively vaccinated against plague and myxomatosis with the proper protection period.

The slaughter took place when the animals were 125 days old. Each animal was checked for its assigned code and its live weight was recorded. Rabbits were stunned with a penetrating stunning instrument at the frontal bone followed by bleeding by cutting the jugular artery. Subsequent slaughtering operations followed the traditional procedure of skinning, deboning and separation of edible organs. The carcass was separated into head, legs and back. All parts of the HUT were then weighed before washing, including the internal organs. The muscle was removed from the spine for further chemical analyses

Longissimus thoracis et lumborum (LTL), which was vacuum packed and prepared for subsequent laboratory work.

Selected individuals were marked with black paint on the inside of the earlobe at an early age, approximately 50 days, to prevent unwanted confusion of data during weighing. At approximately 125 days of age, the last weighing and slaughter took place. After slaughter, the edible internal organs such as the heart, kidneys and liver were weighed. The carcass itself was then weighed and then cut into subdivisions: back, head, front and thighs. Weighing before and after slaughter was carried out using a digital kitchen scale with an accuracy of one gram. Weighing of the gain was carried out by a digital hanging scale with an accuracy of 10 grams. Laboratory analyses were carried out on samples of back muscle *Longissimus thoracis et lumborum* in a laboratory at Mendel University in Brno at the Institute of Animal Breeding. Inntramuscular fat (IMF) content was determined in a laboratory using the method of extraction by ether according to Soxhlet. In relation to the qualitative indicators in the *LTL* and specification of the IMF content, which took place in a laboratory at Mendel University in Brno at the Institute of Animal Breeding.

The chemical analysis of the muscle - protein and intramuscular fat content - was determined from the provided samples. The content of selected fatty acids was also determined - myristic, palmitic, palmitoleic, stearic, vaccenic, oleic, linoleic, γ-linolenic, α-linolenic.

Determination of fatty acids

Gas chromatography was used to determine fatty acids. First, a sample of the extracted lipids without residue in the range of 40-60 mg is weighed and evaporated to dryness under nitrogen. The solid residue is weighed in a reaction flask and 1 ml of BHT is added to prevent oxidation. After ultrasonic homogenization, 2 ml of 0.5N methanolic CH3ONa solution (1.15 g Na/100 ml CH3OH) is added and boiled under reflux. Next, a 14% solution of BF3 in CH3OH was added and the mixture was refluxed for an additional 5 minutes. After heating, the sample was shaken with isooctane, allowed to stand for 1 minute and then 5 ml of saturated aqueous NaCl solution was added and shaken. The organic layer was transferred to a gas chromatography dispenser. Fatty acid methyl esters (FAME) were separated using an HP 4890 chromatograph and a 30 m x 0.25 mm x 0.25 µm Innowax capillary column. The carrier gas was N2. The fatty acid content is determined as a percentage. Furthermore, the total saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acid contents were calculated and their relative ratios were calculated.

All the data obtained were then categorized into groups according to male and female sex and compared with each other using statistical methods. STATISTICA 12 software was used for statistical evaluation. A Scheffe test was used to determine the conclusiveness of differences between groups and the probability of differences was determined at a level of $P<0.05$ and $P<0.01$.

3. RESULTS AND DISCUSSION

Table 1 shows the average live weights before slaughter for both sexes of rabbits of the Large Light Silvery breed. It is clear from these data that the slaughter weight of the females of 2820 g exceeds that of the males by more than 150 g, as the males only averaged 2643.67 g. However, it should be noted that the males showed much better weight balance and less deviation from the group average, see maximum and minimum values.

Table 1. Average live weight in kg before slaughter

Sex	n	Mean	SD	V (%)	Min - Max
Male	15	2 643.67	233.93	8.85	2250-2950
Female	15	2 820.00	280.60	9.95	2175-3310

SD – Standard deviation, V – Coefficient of variation

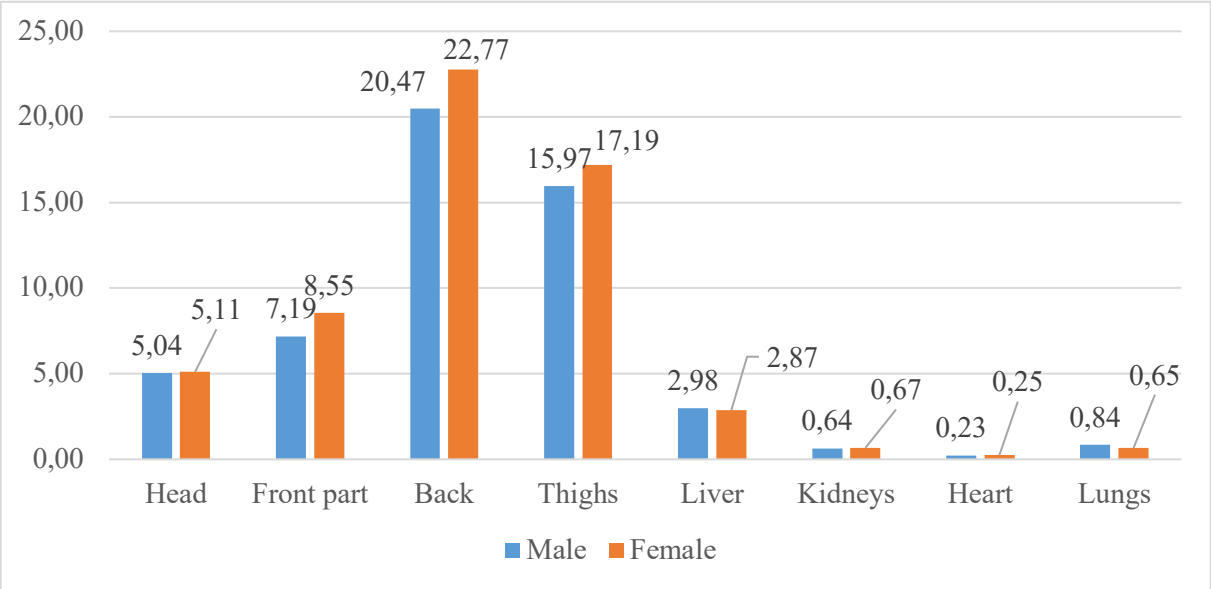
Table 2 shows the average carcass yield of the observed individuals. The male sex averages 53 % and lags behind the female sex in carcass yield by 5 %, which is quite a significant difference. At the significance level (P<0.01), there was a highly significant statistical difference between the carcass yields of the different sexes. The highest carcass yield of 70% was recorded in females. The average carcass yield of female rabbits was 58%. The observed carcass yield was at the same level as reported by Kvartnikov (2021) in his study - the carcass yield of experimental rabbits was 55.1-55.5%. A carcass yield of 52.2% of rabbits was found by Szendro (2012) in his research. Similar values of carcass yield as achieved in our experiment were also reported by Tůmová et al. (2014) in their study.

Table 2. Average slaughter yield in %

Sex	n	Mean	SD	V (%)	Min - Max
Male	15	53.00**	2.00	3.73	49.00-56.00
Female	15	58.00**	5.00	9.17	52.00-70.00

**P<0.01 SD – Standard deviation, V – Coefficient of variation

Graph 1 includes all body parts of the animal contributing to the total carcass value, including internal organs. Females have a higher proportion of the front, back and hind legs. The head and heart differ only minimally in the values found. On the other hand, males excel in the percentage of liver and lung. The highest difference in weight and percentage of carcass value was observed for the carcass. According to Wang (2016), liver and kidney are important organs that ensure that the animal has a healthy body and high productivity.



Graph 1. Percentage contribution of each body part and internal organ to carcass value

Table 3 shows the weights of each body part and internal organ. It can be seen that the heads of females were distinguished by their higher weight in contrast to males. At the significance level (P<0.05), this difference could be statistically demonstrated. When the higher slaughter weight of females is taken into account and the proportion of the total carcass is compared, it is concluded that the proportion of the head from the carcass is 5.04% for males and 5.11% for females. These values show that sex does not significantly affect head weight.

At the significance level (P<0.01), we were able to demonstrate a highly significant statistical difference in anterior carcass weight depending on gender. While the mean weight in females and males was recorded to be 241 g and 190 g respectively. This part contributes 7.19% and 8.55% to the composition of the carcass in males and females, respectively.

The highest difference in weight between carcass parts was observed in the weight of the back. The results show that this part of the carcass has the highest difference between the different parts of the carcass. At the significance level (P<0.01), this difference can be considered as highly statistically significant. The back also constitutes the largest part of the carcass at slaughter. Males and females were 20.46 % (540.87 g) and 22.77 % (642.13 g), respectively. A statistically significant difference at the significance level (P<0.01) was observed between sexes for thigh weights. Compared to other edible rabbit viscera, the liver is the highest weight and thus the most culinarily useful. Again, the two groups can be considered balanced after taking into account the higher weights of the females.

Table 3 also shows the kidney weight with kidney fat and heart weight of the observed individuals. All these internal organs contribute a negligible proportion to the carcass weight and in both cases they are practically the same regardless of sex. We can also note a difference in the weight of the lungs of the two sexes. In this case, the male group has a higher weight (22.33 g) than the female group, which has an average weight of only 18.33 g.

Table 3. Average weight in grams of individual body parts from the carcass and internal organs of rabbits by sex

Traits	Male (n = 15)	Female (n= 15)
Head (g)	$133.33^{A} \pm 10.03$	$144.07^{B} \pm 13.87$
Front part (g)	$95.46^{C} \pm 8.67$	$90.82^{D} \pm 10.51$
Back (g)	$540.87^{C} \pm 57.52$	$642.13^{D} \pm 123.21$
Thighs (g)	$422.20^{C} \pm 42.80$	$484.67^{D} \pm 70.44$
Liver (g)	78.73 ± 16.86	80.93 ± 15.46
Kidneys (g)	16.87 ± 2.58	18.93 ± 5.05
Heart (g)	6.00 ± 1.84	6.93 ± 1.84
Lungs (g)	22.33 ± 2.73	18.33 ± 4.58

A,B: means with different suprscript are significantly different at P<0.05

C,D: means with different suprscript are significantly different at P<0.01

The estimated amount of intramuscular fat contained in the extracted LT muscle is recorded in Table 4. It is clear from these values that female meat contains twice as much intramuscular fat as male muscle. There were statistically significant (P<0.05) differences in the IMT content values in the muscle: 0.30% in males and 0.60% in females. The intramuscular fat (IMF) value here was much lower than the IMF value in lean meat (5.4±0.9) found in hybrid rabbits produced by crossing two genotype lines of SIKA in Slovenia (Polak et al, Similar values to those found in our study were reported by Daszkiewicz and Gugolek (2020), who determined intramuscular fat content of 0.72% and 0.77% in females and males, respectively, in the California rabbit breed. The intramuscular fat content in rabbits was also investigated in an experiment by Martínez-Álvaro et al. (2016).

Table 4. Percent intramuscular fat content in rabbit muscle

Sex	n	Mean	SD	V (%)	Min - Max
Male	11	0.30*	0.06	19.36	0.22-0.40
Female	11	0.60*	0.36	59.86	0.35-1.27

*P<0.05 SD – Standard deviation, V – Coefficient of variation

A higher determined protein percentage of 1 % in the muscle was found in the female (23.01 %) compared to the male (22.05 %), which can be seen from Table 5. 40% of protein content in rabbit back meat was found by Króliczewska et al. (2018) and Petraci and Cavani (2013) in their experiment. According to Kvartnikov (2021), the highest value in his research was only 17.42%. On the other hand, the authors of Gál et al. (2022) reported 21.54% protein, a value very close to our research.

Table 5. Protein content in % of rabbit muscle meat

Sex	n	Mean	SD	V (%)	Min - Max
Male	11	22.05	0.64	2.89	20.81-22.95
Female	11	23.01	1.37	5.94	21.41-24.93

SD – Standard deviation, V – Coefficient of variation

The content of selected fatty acids is given in Table 6. The content of selected carboxylic acids was determined in the muscle of both groups compared by sex and the values recorded were then compared with each other. These are saturated fatty acids of the SFA group namely myristic, palmitic and stearic. From the group of unsaturated monoenoic FAs, the so-called MUFAs, the occurrence of palmitoleic, vaccenic and oleic acids was observed. Within the group of polyenoic FAs, PUFAs, the content of linoleic, γ-linolenic and α-linolenic acids was determined. SFAs were the most abundant fatty acids, followed by MUFAs and PUFAs were the least abundant. In their experiment, Zubiri-Gaitán et al. (2022) found that the SFA and PUFA groups were the most abundant fatty acids (26.46 g SFA/100 g IMF and 28.32 g PUFA/100 g IMF, respectively), while the MUFA group was the least represented group (18.14 g MUFA/100 g IMF). In terms of individual fatty acids, linoleic, palmitic and oleic acids were the most abundant.

If we compare the fatty acid content between the observed groups of rabbits, we find that the female sex exceeds the male sex in the content of unsaturated fatty acids: MUFA - palmitoleic and PUFA - linoleic, γ-linolenic and α-linolenic. On the contrary, the male sex is characterized by a higher content of saturated FAs - myristic, palmitic, stearic and unsaturated monoenic FAs - vaccenic and oleic.

Palmitic acid was the most abundant in the meat of both experimental groups. It is a saturated fatty acid of the long-chain SFA group (LCFA) with 43.20% and 38.26% in males and females, respectively. Cullere (2022) in his work reports a lower content of 25.9 %. Different values are reported by Straka and Malota (2006), namely an amount of 32 %. This value is similar to those found in our experiment of 38.26% for females and 43.20% for males. A lower value of 27.35% is reported by Króliczewska et al. (2018). Myristic acid was the least abundant of the observed fatty acids of the SFA group. Its amount was slightly higher in the male group (5.30%). The female group reached an amount of 4.95%. These observed values were confirmed by Straka and Malota (2006) who reported a value of 4%. In contrast, Cullere (2022) reported a value of only 2.19% and Króliczewska et al. (2018) 2.87%.

Saturated stearic fatty acid in muscle was 8.96% in females and 9.85% in males. The values were confirmed by Straka and Malota (2006), who reported an amount of 8%, which is very close to the values reported by us. A very similar amount (7.98%) was reported by Cullere (2022) and Wang (2012) also reported a similar value of 8.67%. Total fatty acids of the SFA group were recorded as 58.38% in

males and 52.17% in females, which are higher values than the 37.17% found by Króliczewska et al. (2018) in their work.

The amount of palmitoleic acid was very low compared to vaccenic acid belonging to the same group of MUFA acids. The value was higher in females, reaching 2.74%, while in males it was only 1.83%. Compared to the result of Straka and Malota (2006), the result differs as they report an amount of 6%. On the other hand, the resultant quantity agrees with Culler (2022) and Li et al. (2012) who reported 1.40% and 1.89% respectively. Vaccenic acid was present in almost equal amounts in both groups (22.06% in males and 21.91% in females). Wang (2016) also reported the same values in his experiment with a content of 21.9%.Oleic acid was the least abundant of all MUFAs, with only 1.19% found in male muscle. In females, its content was also lower at 0.94 %. Total MUFA group acids were found to be 25.08% in males and 25.59% in females. Almost identical values (24.29%, 25.65%, 26.50%) were found in the experiment by Kowalska et al. (2020). Króliczewska et al. (2018) reported a higher value of 34.25 % .

Of the polyenoic unsaturated fatty acids (PUFA), linoleic acid was the highest in content. It was present in higher levels in female rabbits, reaching 17.36 %. In males, an average value of 13.95 % was calculated. Both mean values are lower, 2 % for females and 4 % for males, than those reported by Straka and Malota (2006), whose reported amount is 19 %. γ-linolenic acid, belonging to the PUFA group, was the least represented of all fatty acids. The lowest amount, only 0.04% of the muscle content, was found in the observed group of males. The female muscle showed a slightly higher content (0.13 %). A similar amount (0.07 %) was also obtained by Guedes (2022). For α-linolenic acid, the content of polyenoic acid was found to be 1.47% in the male group, but the female group showed a content more than twice as high, more precisely 3.76%. A lower content was reported by Wang (2016) who determined the amount to be 0.86%. On the other hand, very similar values (2.6%) are reported by Guedes (2022). The total fatty acid content of the PUFA group was 15.46% in males and 21.25% in females.

The ratio between PUFA and SFA was recorded as 0.26 and 0.41 for males and females, respectively. Mattioli et al. (2017) in their experiment in the New Zealand White rabbit found values in the range of 0.9-1.1. A higher value of 0.74 was reported by Króliczewska et al. (2018). The ratio between saturated and polyunsaturated acids is very important in this issue. The recommended ratio (PUFA:SFA) should be around 0.4 (Esner, 2001). Regarding the nutritional value of foods, the Department of Health and Social Security in 1994 in London recommended a ratio of 0.45 or higher for PUFA/SFA in foods to prevent cardiovascular disease (Kumar et al. 2023).

Table 6. Fatty acid content in % of rabbit muscle meat

Traits	Male (n = 6)	Female (n= 6)
SFA		
C 14:0 (myristic)	5.33	4.95
C 16:0 (palmitic)	43.20	38.26
C 18:0 (stearic)	9.85	8.96
Total SFA	58.38	52.17
MUFA		
C 16:1 (palmitoleic)	1.83	2.74
C18:1n7cis (vaccenic)	22.06	21.91
C 18:1 (oleic)	1.19	0.94
Total MUFA	25.08	25.59

PUFA		
C 18:2n6 (linoleic)	13.95	17.36
C 18:3n6 (y-linolenic)	0.04	0.13
C 18:3n3 (α–linolenic)	1.47	3.76
Total PUFA	15.46	21.25
PUFA/SFA	0.26	0.41

CONCLUSION

From the results obtained, it can be concluded that females had better growth ability compared to males, expressed in terms of average slaughter weight. The results show a higher carcass yield of female rabbits than that found for males. A significant difference was observed in the intramuscular fat content of the muscle, with twice the amount recorded in females than in males. The weight of individual body parts, including viscera, was recorded higher in females than in males, except for the lungs, which were heavier in males. Males were higher in saturated fatty acids (SFA), whereas females were found to be higher in PUFAs (polyunsaturated polyene fatty acids). The study showed the highest content of palmitic acid, belonging to the SFA group, in both sexes. The unsaturated fatty acid content of palmitoleic, oleic, α-linolenic and γ-linolenic acids was less than 5 % in both groups.

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