Ann. Anim. Sci., Vol. 20, No. 1 (2020) 245–262 *DOI: 10.2478/aoas-2019-0064*

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QUALITY OF MEAT FROM FEMALE FALLOW DEER (*DAMA DAMA*) AND ROE DEER (*CAPREOLUS CAPREOLUS*) HUNTED IN SERBIA

Snežana Ivanović[1♦], Boris Pisinov[1], Marija Pavlović[1], Ivan Pavlović[2]

[1]Department for Food and Feed Safety, Scientific Veterinary Institute of Serbia, Vojvode Toze 14, 11000 Belgrade, Serbia
[2]Department for Microbiology and Parasitology, Scientific Veterinary Institute of Serbia, Vojvode Toze 14, 11000 Belgrade, Serbia
♦Corresponding author: snezaivanovic57@gmail.com

Abstract

Deer meat is a high quality and valuable food for human consumption. It has high nutritive value because of its high protein and heme iron content, and low levels of fats and saturated fatty acids. The aim of this study was to examine the quality parameters of meat from fallow deer and roe deer that were hunted in Serbia. Parameters studied were live weight, carcass weight, chemical composition of meat, color, fatty acid content of meat, volatile compounds, and sensory characteristics. The results obtained show no significant difference in the chemical composition of these two species of deer meat, but there were differences regarding fatty acid content, volatile compounds, color and sensory properties of meat. The ratios of polyunsaturated to saturated fatty acids in the deer meat ranged from 0.387 to 0.556. The results suggest that deer species has a significant impact on the fatty acid profile and content of volatile compounds of deer meat.

Key words: fallow deer, roe deer, meat quality, fatty acids, volatile compounds

Wild deer are widely distributed in many European countries, thus having significance for the contribution of hunting to the economy. In Serbia, red deer (*Cervus elaphus* L.) and fallow deer (*Dama dama* L.) are indigenous species and are widespread in the country's ecosystems. Roe deer (*Capreolus capreolus* L.) are present in lowland and mountainous regions of Serbia, mostly in areas where forest alternates with agricultural land. These deer species are biologically and economically highly valuable large game animals, along with wild boar and chamois (Gačić et al., 2016). Deer meat is becoming increasingly popular because of its favorable fatty acid content and typical, specific flavor (Razmaitė et al., 2015). On the other hand, in central Serbia, local residents and agricultural and forestry experts consider deer as undesirable because of the damage they can cause to forestry and agriculture (Gačić et al., 2016).

The distribution of deer in Serbia today is probably at the lowest level in the history of these animals in this area. Regrettably, deer have been exterminated in many

mountainous areas of west and south Serbia (Gačić et al., 2016). According to data from the Statistical Office of the Republic of Serbia (2018), in 2017, 6089 red deer and 1510 fallow deer were in the country, and 856 red deer and 85 fallow deer were hunted. In 2017, of 132,642 roe deer in the country, 10,544 were hunted.

Venison from fallow and roe deer is a high-value meat because of its high protein and heme iron content, low level of saturated fatty acids, and high percentage of polyunsaturated fatty acids (Hutchison et al., 2012; Daszkiewicz et al., 2012; Daszkiewicz and Mesinger, 2018). Wild deer meat contains a higher percentage of water compared to meat of domestic ruminants, but at the same time, has higher level of proteins that bind water. Adipose tissue is distributed mainly under the skin and around the internal organs, rather than intramuscularly, and meat color is darker than that of farmed deer, because of wild animals' more active movements and consequent higher levels of myoglobin in their musculature (Ruiz de Huidobro et al., 2003). Deer meat, because of its chemical composition, low fat level, high protein level, and nutritive and energy values, is a favorable food for adolescents, convalescents, diabetics, patients with cardiovascular diseases, etc. (Briggs et al., 2017). Thus, deer meat is a highly valuable red meat.

The chemical composition of deer meat varies according to species, nutrition, hunting season, habitat (mountains, plains, swamp, etc.), forage characteristics, gender, activity and sexual activity of animals (Konjević, 2008; Stanisz et al., 2019). The effects of season (Ruiz et al., 2007; Stanisz et al., 2019), species (Strazdina et al., 2012; Daszkiewicz and Mesinger, 2018), carcass weight, age (Żochowska-Kujawska et al., 2007; Dannenberger et al., 2013; Żochowska-Kujawska et al., 2019), gender (Purchas et al., 2010; Stanisz et al., 2015) and region (Dannenberger et al., 2013; Razmaitė et al., 2015) on chemical composition of meat and venison quality-related characteristics (sarcomere length, myofibrillar fragility, water-holding capacity, color, etc.) were studied. Among other factors, species has a crucial impact on deer meat quality. Sensory evaluation studies have been conducted on different deer species. Meat of each species of deer has a distinctive taste and aroma (Belitz, 2009) and is more intensely flavored than that of farmed deer, which is mainly due to nutrition. Furthermore, region and habitat have important influences on taste, with deer meat from mountainous regions being considered more flavorful than deer meat from lowland areas (Ivanović et al., 2016). Despite these previous studies, information concerning the fatty acid content, and particularly, the contents of volatile compounds in deer meat are scarce. Considering the lack of data on the quality of deer meat originating from Serbia, the aim of this study was to examine and compare meat quality parameters of fallow deer and roe deer hunted in Serbia.

Material and methods

Animals and sampling

In 2018, forty samples of deer meat were collected during respective hunting seasons of following species: fallow deer (*Dama dama* L.) from 1 May 2018 to

30 September 2018, and roe deer (*Capreolus capreolus* L.) from 15 April 2018 to 30 September 2018. Altogether, 20 deer meat (muscle) samples from fallow deer and 20 from roe deer were collected from two different carcass sites: 10 samples of *musculus gluteus superficialis* (GS) and 10 samples of *musculus longissimus thoracis* (LT). Individual muscle samples served as experimental unit for analyses, hence 10 samples for each examined muscle (i.e. 10 replicates) were included in the study.

Fallow deer were about three years old, roe deer were three to four years old, and animals were hunted in the Karadjordjevo hunting grounds located in Vojvodina, Serbia's northern province. The age of animals was estimated based on carcass conformation and teeth (mandibular premolars and molars) (Savić et al., 2014). Fallow and roe deer were females, hunted in accordance with Serbian hunting regulations (Official Gazette 18/2010 and 95/2018). Animals were shot in the head/neck, and the shotguns used were not contaminated with digestive tract contents. After hunting, animals were bled out and eviscerated at the game collection point in the hunting grounds. Deer carcasses were marked according to regulations EC 853/2004 and EC 854/2004 and transported to the slaughterhouse, where carcasses were chilled to 0–4ºC. Within 24 h, the LT and GS muscles were excised from the deer carcasses and packed into the polyethylene bags to protect the meat against drying. After packing and before analyses, the deer meat samples were stored at –20°C. All analyses were conducted within one month of packing.

Chemical composition of meat

Chemical composition, fatty acids and volatile compounds were determined in the deer meat. Meat samples were thawed before examination at refrigerator temperature (+2 ± 2°C). Moisture content was determined by ISO 1442 (1998), fat content by ISO 1443 (1992), and ash content by ISO 936 (1999). The protein content was calculated from the nitrogen content multiplied by 6.25 using ISO 937 (1992). Meat pH was measured according to ISO 2917 (2004).

Fatty acids in meat

The AOAC 996.06 (2001) method was applied for the lipid extraction from the tissue. After the lipid hydrolysis, the fatty acids were esterified to methyl esters, evaporated to dryness in a stream of nitrogen and stored at –18°C. Analysis of fatty acid methyl esters (FAMEs) was performed by an internal standard method using a gas chromatograph (GC6890N, Agilent Tech., USA) with column DB-23 (60 m × 0.25 mm ID, 0.15 μm) and comparing peak areas and retention times with a standard mix of FAMEs 37 (Supelco, USA). Conditions of analyses: detector temperature – 250°C, injector temperature – 225°C, column temperature – 200°C, carrier gas – helium, carrier gas flow rate – 50 mL/min. Obtained data for fatty acids composition were expressed in percentage by weight of the identified total fatty acids.

Volatile compounds in meat

Volatile compounds were analyzed using the Likens-Nickerson extraction procedure (Likens and Nickerson, 1964) and ISO 15303 (2001) using a GCMS-QP2010 Ultra (EIMS, electron energy = 70 eV, scan range = 30–350 amu, and scan rate =

3.99 scans/s) with SUPELCOWAX® 10 Capillary GC Column (30 m × 0.25 mm ID, particle size 0.25 μm). The carrier gas was helium with a flow rate of 1 mL/min, and the injection temperature was 200°C. The oven temperature was programmed to initially hold for 10 min at 40°C, and subsequently programmed from 40ºC to 120ºC at a rate of 3ºC/min and at a rate of 10ºC/min from 120ºC to 250ºC where it was held for another 5 min. Identification of the peaks was based on comparison of their mass spectra with the spectra of the WILEY library and in addition, in some cases, by comparison of their retention times with those of standard compounds.

Color of meat

Meat samples were bloomed for 30 min before the color measurement. CIE L*a*b* (CIE, 1986) color coordinates of meat were determined using Minolta Chromameter CR 400 (Minolta Co. Ltd., Osaka, Japan) in D-65 lighting, with standard angle of 2° of shelter and an 8 mm aperture measuring head. CIE L*a*b* measurements are reported as mean values: L* (lightness), a* (redness) and b* (yellowness).

Sensory analysis

Sensory analysis was conducted according to ISO 8586 (2012, 2015), ISO 8587 (2006, 2013/A1:2016). Overall acceptability was evaluated based on appearance, texture and aroma. For evaluation, the scoring range from one to five was used, with the possibility to assign half and quarter points. For each selected quality property, the coefficient of importance is determined, in order to correct given estimate by multiplication of means. The coefficients of importance were chosen according to the influence of certain properties on the overall quality (for color surface – 4, visual evaluated structure – 3, palpatory evaluated firmness – 3 and olfactory evaluated odor – 10) and their sum is 20. By combining individual scores, a complex indicator is obtained which represents the overall sensory quality and is expressed as "% of the maximum possible quality" (maximum possible quality is 100%). By dividing this value with a set of coefficients of importance, a weighted average score is obtained, which also represents the total sensory quality of the tested samples of raw fallow deer and roe deer meat.

Score: 1.00 – very pronounced errors, 2.00 – clearly expressed mistakes, 3.00 – noticeable deviations, 4.00 – minor deviations and 5.00 – fully meets the quality requirements.

In assessing the sensory properties of raw meat quality 20 experienced analysts participated.

Statistical analysis

Data were analyzed by using Graph Pad Prism 6.0. software (Graph Pad Software Inc., San Diego, CA, USA). All values are expressed as means and standard error of means. For the proximal chemical composition, color parameters, pH, fatty acids profile, volatile compounds content and sensory evaluation the differences between means were compared by two-way ANOVA at the level of significance of 95% and 99%. Significance of differences between mean values in groups was determined using the Bonferroni correction. For the live weights, carcass weights and dressing

percentage the comparison was made by t test. In all cases levels of $P<0.05$ and $P<0.01$ were considered as significant and highly significant, respectively.

Results

The mean animal live weights and mean weights of carcasses after evisceration of fallow deer (*Dama dama* L.) and roe deer (*Capreolus capreolus* L.) are presented in Table 1. The differences measured between the examined species were significant ($P<0.001$).

Table 1. Live mean weights and mean carcass weights (kg) after evisceration of fallow deer and roe deer

	Number of animals	Live weight	CV (%)	Carcass weight after evisceration	CV (%)	Dressing percentage (%)	CV (%)
Fallow deer	10	70.83±3.48 a	4.92	42.83±4.16 a	9.73	60.53±5.94	9.81
Roe deer	10	30.67±3.08 b	10.03	17.67±2.16 b	12.23	57.60±3.72	6.64

CV – coefficient of variation.
a, b – means within the same column with different letters differ significantly ($P<0.001$).

Color parameters (L* a* b*) of meat samples taken from GS and LT of fallow deer and roe deer are presented in Table 2. There was a significant difference between most examined parameters ($P<0.05$, $P<0.01$, $P<0.001$), but not in the lightness of GS from fallow and roe deer.

Table 2. Color expressed in the CIE L*a*b* system and pH of fallow deer and roe deer meat

	Fallow deer		Roe deer		P value (ANOVA)		
	LT	GS	LT	GS	muscle	species	muscle × species
L*	36.13±0.59 A	34.99±1.54 b	37.34±0.79 B,a	36.22±1.01	*	**	–
a*	9.26±0.11 a	8.63±0.11 b,c	10.50±0.56 b	10.63±0.37 b	**	–	**
b*	7.37±0.21 a	6.05±0.53 b	5.87±0.19 b	5.43±0.17 b,c	**	**	**
pH	5.70±0.19	5.68±0.04	5.72±0.16	5.69±0.05	–	–	–

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis*.
L* – lightness, a* – redness, b* – yellowness.
A, B – means within the same row with different letters differ significantly ($P<0.05$).
a, b, c – means within the same row with different letters differ significantly ($P<0.01$).
* $P<0.05$, ** $P<0.01$.

Proximate composition of meat (GS and LT) from fallow deer and roe deer are presented in Table 3. There were no significant differences between the examined deer meat samples ($P>0.05$), except for GS having more fat in fallow than in roe deer.

Table 3. Proximal chemical composition of fallow deer and roe deer meat

	Fallow deer		Roe deer		P value (ANOVA)		
	LT	GS	LT	GS	species	muscle	muscle × species
Moisture (%)	72.15±1.44	72.52±3.11	72.80±3.32	73.00±2.90	–	–	–
Fat (%)	1.36±0.23 a	2.73±0.15 b	1.31±0.09 a	2.23±0.13 b,c	**	**	**
Protein (%)	20.40±1.82	22.30±1.90	21.40±2.45	22.80±1.81	–	–	–
Ash (%)	1.14±0.09 A	1.07±0.06	1.11±0.11	0.98±0.11 B	–	*	–

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis.*
A, B – means within the same row with different letters differ significantly (P<0.05).
a, b, c – means within the same row with different letters differ significantly (P<0.01).
* P<0.05, ** P< 0.01.

Results of the fatty acid composition in GS and LT of fallow deer and roe deer are presented in Tables 4 and 5.

There was no significant difference between the lauric acid content in LT of fallow deer and roe deer (P>0.05). Between other examined saturated fatty acids (myristic acid, palmitic acid, stearic acid), there were significant differences (P<0.001, P<0.01, P<0.05, respectively) between the deer species. Arachidic acid was not detected in LT of fallow deer. The content of saturated fatty acids in GS of fallow deer and roe deer differed significantly with respect to all the fatty acids examined (P<0.01, P<0.001), except for arachidic acid, which was not detected in GS of fallow deer.

Table 4. Saturated fatty acids (mean % of total fatty acids) in fallow deer and roe deer meat

Fatty acid	Fallow deer		Roe deer		P value (ANOVA)		
	LT	GS	LT	GS	species	muscle	muscle × species
Lauric acid C12:0	11.74±0.01 A	13.34±0.01 B,a	10.98±0.87 b	11.59±0.82 b	**	**	–
Myristic acid C14:0	11.89±0.01 a	10.27±0.01 b	8.89±0.23 c	6.26±0.25 d	**	**	*
Palmitic acid C16:0	16.10±0.02 a	13.97±0.01 b	17.38±0.54 c	15.99±0.53 c	**	**	*
Stearic acid C18:0	17.60±0.01 A,a	14.71±0.01 b	16.28±0.59 B,a	16.64±0.59 B,a	–	**	**
Arachidic acid C20:0	nd	nd	0.21 ± 0.01	0.23 ± 0.02	–	–	–

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis.*
nd – not detected.
A, B – means within the same row with different letters differ significantly (P<0.05).
a, b, c, d – means within the same row with different letters differ significantly (P<0.01).
* P<0.05, ** P<0.01.

Differences were found in percentages of all unsaturated fatty acids between the two deer species (Table 5) (myristoleic acid, palmitoleic acid, elaidic acid, oleic acid, eicosenoic acid, linolelaidic acid, linoleic acid, eicosapentaenoic acid) (P<0.01 and P<0.05), except for linoleic acid in LT (P>0.05). Determined differences in contents

of unsaturated fatty acids in GS of fallow deer and roe deer were significant for myristoleic acid, oleic acid, linolelaidic acid, linoleic acid and eicosapentaenoic acid ($P<0.01$ and $P<0.001$), but not significant for palmitoleic acid, elaidic acid, eicosenoic acid and linoleic acid ($P>0.05$).

Table 5. Unsaturated fatty acids (% of total fatty acids) in fallow deer and roe deer meat

Fatty acid	Fallow deer		Roe deer		P value (ANOVA)		
	LT	GS	LT	GS	species	muscle	muscle × species
Myristoleic acid C14:1	1.74±0.01 a	1.71±0.01 a	0.89±0.01 b	0.37±0.05 c	**	**	**
Palmitoleic acid C16:1	4.64±0.01 A	4.45±0.01	3.93±0.27 B	4.21±0.19	**	–	–
Elaidic acid C18:1*n9t*	1.72±0.01 a	1.03±0.005 b	1.47±0.06 c	0.98±0.13 b	**	**	*
Oleic acid C18:1*n9c*	11.78±0.01 a	11.00±0.01 a	13.99±0.78 b	15.64±0.32 c	**	–	**
Eicosenoic acid C20:1*n9*	0.57±0.01 A	0.46±0.005	0.37±0.053 B	0.42±0.04 B	**	–	**
Linolelaidic acid C18:2*n6t*	0.18±0.005 a	0.078±0.004 b	0.11±0.03 c	0.98±0.11 d	**	**	**
Linoleic acid C18:2*n6c*	17.08±0.02 a	23.51±0.02 b	19.87±1.28 c	20.53±1.19 c	–	**	**
Linoleic acid C18:3*n3*	4.27±0.01 A,a	4.76±0.01 B	4.65±0.44	4.99±0.24 b	*	**	–
Eicosapentaenoic acid C20:5*n3*	0.68±0.004 a	0.71±0.004 a	0.98±0.10 b	1.17±0.08 c	**	**	*

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis*.
A, B – means within the same row with different letters differ significantly ($P<0.05$).
a, b, c, d – means within the same row with different letters differ significantly ($P<0.01$).
* $P<0.05$, ** $P<0.01$.

The sums and ratios of fatty acids in the deer meats are presented in Table 6. The ratio of unsaturated to saturated fatty acids in fallow deer LT was 1.34; in roe deer LT, it was 1.16; in fallow deer GS, it was 1.10; and, in roe deer GS, it was 1.03.

The presence of specific volatile substances in GS and LT of fallow deer and roe deer is presented in Table 7. Volatile compounds within the following groups were detected in the analyzed deer meat samples: aldehydes, ketones, heterocyclic compounds, aromatic hydrocarbons, phenols, alcohols, organic acids and alkanes.

Isopropenyl acetate and ethyl isovalerate were not detected in fallow and roe deer meat. Hexanal and thiophene were not detected in LT of fallow deer and roe deer. Furfural, propionic acid and thiophene were not detected in roe deer meat, and benzaldehyde was not detected in fallow deer meat. Ethyl acetate and butyl acetate were detected in LT of fallow deer, but not in any other deer meats.

Table 6. Indicators of the nutritional value and health benefits of fat determined based on an analysis of the fatty acid profile of fallow deer and roe deer meat

Indicator[a]	Fallow deer		Roe deer		P value (ANOVA)		
	LT	GS	LT	GS	muscle	species	muscle × species
ΣSFA	57.33±1.49	52.2±0.97	53.74±3.07	50.71±3.09	–	–	–
ΣUFA	42.67±1.95	47.72±2.54	46.26±2.34	49.29±2.47	–	–	–
ΣMUFA	20.46±2.04	18.66±1.94	20.65±2.53	21.62±2.92	–	–	–
ΣPUFA	22.21±3.94	29.06±5.51	25.61±4.59	27.67±4.63	–	–	–
UFA/SFA	0.74±0.01 a	0.91±0.008 b	0.86±0.007 c	0.97±0.007 d	**	**	**
MUFA/SFA	0.357±0.03 a	0.357±0.03 a	0.384±0.01 A	0.426±0.02 b,B	–	**	–
PUFA/SFA	0.387±0.02 a	0.556±0.03 b	0.476±0.01 c	0.546±0.01 b	**	**	**
DFA	60.27±1.58 a	62.43±1.84 a	62.539±1.85 A	65.93±0.67 b,B	**	**	–
OFA	39.73±1.12 a	37.57±1.16 b	37.461±0.62 b	34.07±0.69 c	**	**	–
EFA	21.53±0.62 a	28.348±0.79 b	24.63±0.18 c	26.50±0.61 d	**	*	**
Nutritional value[b]	18.44±0.39 a	15.57±0.46 b	17.17±0.21 c	17.68±0.26 c	**	**	**

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis*; SFA – saturated fatty acids; UFA – unsaturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; DFA – hypocholesterolemic fatty acids (UFAs + C18:0); OFA – hypercholesterolemic fatty acids (SFAs – C18:0); EFA – essential fatty acids (C18:2 + C18:3)

[a]Calculations of all indicators in Table 6 were made according to Daszkiewicz and Mesinger (2018).

[b]Nutritional value was calculated according to the equation C18:0 + C18:1/C16:0.

A, B – means within the same row with different letters differ significantly ($P<0.05$).

a, b, c, d – means within the same row with different letters differ significantly ($P<0.01$).

* $P<0.05$, ** $P<0.01$.

Table 7. Volatile substances of fallow deer and roe deer meat

VOC (μg/kg)	Fallow deer		Roe deer		P value (ANOVA)		
	LT	GS	LT	GS	species	muscle	muscle × species
1	2	3	4	5	6	7	8
Aldehydes							
Hexanal	nd	3.10±0.24 a	nd	1.7 ±0.26 b	–	–	–
Furfural	nd	0.02±0.001	nd	nd	–	–	–
Heptanal	0.02±0.003 a	0.09±0.005 b	0.54±0.06 c	0.32±0.05 d	**	**	**
Octanal	0.04±0.005 a	0.05±0.004 b	0.62±0.04 c	0.66±0.06 d	**	**	**
Phenylacetaldehyde	0.10±0.02 A	0.01±0.002 c	0.07±0.03 B	0.11±0.03 d	**	–	–
Benzaldehyde	nd	nd	0.03±0.002	0.02±0.001	–	–	–
Ketones							
2-Butanone	0.43±0.04 a	29.66±3.80 b	0.61±0.06 c	5.23±0.47 d	**	**	**
2,3-Butanedione	0.25±0.04	1.38±0.15 a	0.27± 0.03	2.05±0.14 b	**	**	**
2-Heptanone	0.20±0.03 a	0.03±0.002 b	0.08± 0.03 a	0.04±0.03 c	**	**	**
3-Methyl-2(5H)-furanone	0.56±0.06 a	0.89±0.05 b	0.20±0.03 c	0.65±0.04 d	**	**	**
Heterocyclic compound							
Furan	0.03±0.002 a	3.82±0.55 b	0.95±0.13 c	3.33±0.38	–	**	**
β-butyrolactone	0.21±0.03 a	3.80±0.21 b	0.09±0.24 c	1.25±0.37 d	**	**	**
2-pentylfuran	0.02±0.001 a	0.24±0.03 b,A	0.01±0.001 c,	0.18±0.03 b,B	*	**	*
2-methyl pyrazine	3.33±0.46 a	3.10±0.18 b	0.12±0.03 c	1.27±0.10 d	**	**	**
2,5-dimethyl pyrazin	2.40±0.30 a	0.08±0.005 b,	0.08±0.03 b	0.09±0.02 b,	**	**	**
2,6-dimethyl pyrazin	1.50±0.18 a	0.08±0.01 b	0.08±0.04 c	1.31±0.13 a,c	–	–	**
Thiophene	nd	0.70±0.06	nd	nd	–	–	–

Table 7 – contd.

1	2	3	4	5	6	7	8
			Phenolic compound				
Guaiacol	0.28±0.03 a	0.28±0.03	0.74±0.16 b	0.48±0.02	**	–	–
			Aromatic hydrocarbons				
1,2-dimethoxybenzene	0.40±0.05 a	0.01±0.001 b	0.32±0.01 a	0.02±0.01 c,b	–	**	–
			Sulphuric compound				
2,5-dimethyl thiophene	0.10±0.02 a	0.02±0.001 b	0.03±0.02 b	0.04±0.03 b	*	**	**
2-methyl thiophene	0.60±0.07 a	1.50±0.18 b	0.05±0.02 c	1.06±0.07 d	**	**	–
2-buthanethiol	0.04±0.005 a	0.48±0.03 b	0.02±0.01 a	0.39±0.07 c,b	*	**	–
2-methyl-3-furanthiol	0.50±0.06 a	0.04±0.002 b	0.2±0.03 c	0.03±0.02 c	**	**	**
			Alcohols				
2-butanol	1.84±0.23 a	13.59±1.02 b	0.08±0.03 c	4.46±1.05 d	**	**	**
2-pentanol	0.01±0.002 a	0.03±0.001 aA	0.16±0.03 b	0.01±0.004 aB	**	**	**
3-methyl-1-butanol	39.66±5.10 a	21.48±3.05 b	13.25±1.67 c	32.56±1.3 d	**	–	**
2,3-Butanediol	1.40±0.18 a	7.70±0.55 b	0.69±0.09 c	8.12±0.33 b	–	**	**
1-Octen-3-ol	0.74±.0.09 a	1.07±0.09 b	0.35±0.04 c	0.76±0.03 d	–	**	**
			Organic acids				
Propionic acid	0.60±0.07	3.80±0.25 a	nd	0.69±0.03 b	–	–	–
3-Methylbutanoic acid	0.60±0.07 A,a	1.50±0.10 b	0.22±0.02 B,a	2.09±0.09 c	–	**	**
Hexanoic acid	0.02±0.003 a	0.08±0.01 b	0.01±0.001 a	0.09±0.02 b	–	**	*
Nonanoic acid	0.11±0.03 a	0.07±0.005 b	0.12±0.02 a	0.08±0.02 a,b	–	**	–
			Ester				
Isopropenyl acetate	nd	nd	nd	nd	–	–	–
Ethyl acetate	0.09±0.01	nd	nd	nd	–	–	–
Isobutyl acetate	0.20±0.02 a	1.50±0.12 b	0.06±0.02 c	0.99±0.06 d	**	**	**
Butyl acetate	5.70±0.65	nd	nd	0.56±0.03	–	–	–

2-methylbutyl acetate	9.31±0.95 a	0.09±0.005 b	4.56±0.06 c	0.26±0.03 d	**	**	**
3-methylbutyl acetate	0.10±0.02 a	0.06±0.004 b	0.06±0.02 c	0.02±0.01 d	**	**	–
Hexyl acetate	0.60±0.04 a	0.01±0.001 b	0.13±0.02 c	0.39±0.02 d	–	**	**
Ethyl butanoate	12.72±1.80 a	6.13±0.44 b	7.87±0.15 c	11.66±0.28 d	**	**	**
Ethyl isovalerate	nd	nd	nd	nd	–	–	–
Ethyl 2-methylbutanoate	1.20±0.14 a	0.07±0.004 b	0.98±0.07 c	0.09±0.02 b	**	**	**
Ethyl octanoate	1.30±0.21 a	0.01±0.002 b	1.10±0.05 c	0.01±0.005 b	**	**	**
			Alkanes				
Heptane	0.10±0.02 a	0.08±0.01 b	3.21±0.10 c	1.14±0.03 d	**	**	**

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis*.
nd – not detected.
A, B – means within the same row with different letters differ significantly ($P<0.05$).
a, b, c, d – means within the same row with different letters differ significantly($P<0.01$).
* $P<0.05$, ** $P<0.01$.

In GS of both examined deer species, the content of guaiacol, a heterocyclic compound, and 1,2-dimethoxybenzene, an aromatic hydrocarbon, did not differ significantly (P>0.05). There was no significant difference between the content of 2-buthanethiol (aromatic hydrocarbon) in all examined deer meats (P>0.05). The mean content of 3-methyl-1-butanol ranged from 13.25 to 39.66 μg/kg in the deer meats. The other volatile compounds determined were significantly different (P<0.05, P<0.01, P<0.001) between the two deer species.

Table 8 shows statistical analysis of sensory evaluations of the examined deer meat samples. There was no significant difference in examined sensory parameters for LT and GS obtained from fallow deer and roe deer. The best weighted average was for LT from fallow deer.

Table 8. Sensory evaluation of fallow deer and roe deer meat

20[a]	Attributes				Percentage of maximal possible quality	Weighted average
	Appearance	Texture		Flavor		
	color surface	visual evaluated structure	palpatory evaluated firmness	olfactory evaluated odour		
	Coefficient of importance					
	4	3	3	10	100	100/20
Fallow deer – LT	18.80±0.28	14.10±0.25	13.80±0.23	48.00±0.32	94.70	4.73
Fallow deer – GS	19.20±0.25	13.80±0.18	13.50±0.18	46.00±0.13	92.50	4.62
Roe deer – LT	18.40±0.28	13.50±0.16	12.90±0.39	47.00±0.20	91.80	4.59
Roe deer – GS	18.20±0.22	13.20±0.17	13.05±0.16	46.50±0.19	90.95	4.55
Muscle	–	*	–	–	–	–
Species	*	**	**	–	–	–
Muscle × species	–	–	*	–	–	–

LT – *m. longissimus thoracis*; GS – *m. gluteus superficialis.*
* P<0.05, ** P<0.01.
[a]The sum of all coeficients of importance.

Discussion

There is lack of data from Serbia on large game meat quality, especially meat of fallow deer and roe deer. The live weights and weights of carcasses after evisceration of fallow deer and roe deer differed significantly. The differences were expected, because the animals were different genera. Dressing percentage, as a more objective indicator of slaughter value did not differ significantly. Body weight may be affected by environment, age, sex, condition of animal (Stanisz et al., 2019), and along with dressing percentage may reflect carcass and meat quality parameters. The fallow deer and roe deer weights are generally in agreement with some other authors (Żochowska-Kujawska et al., 2007; Żochowska-Kujawska et al., 2019). Volpelli et al. (2002) and Stanisz et al. (2015) reported lower weights of these animals. That could be a consequence of different ages of the animals, as in those studies, the

animals were younger than the animals we studied. Furthermore, different carcass weights were measured in different regions, genders, and in wild and farmed deer (Stanisz et al., 2015; Okuskhanova et al., 2017). Thus, experimental approach could cause the differences in deer weights reported.

The contents of moisture, proteins and ash in the fallow deer and roe deer meat did not differ significantly, which is in agreement with Strazdina et al. (2012) who stated there were no differences in chemical composition between fallow deer, roe deer and elk meat. The chemical composition of the deer meats in the current study are in line with the results of some other authors (Daszkiewicz et al., 2012; Dominik et al., 2013; Blaška et al., 2016; Razmaitė et al., 2017). Our results regarding protein and fat content in deer meat are in line with the results of Wiklund et al. (2014) for roe deer meat, but not for fallow deer meat. Okuskhanova et al. (2017) reported higher fat content and lower protein content in deer meat (protein 18.71%, fat 2.26%), but in that study, red deer meat was examined. Differences in properties between wild and farmed deer meat were proven (Razmaitė et al., 2017), and the type of muscle can affect the results (Razmaitė et al., 2015), as can animals' nutrition. The pH of our deer meats did not differ significantly between deer species, which is consistent with findings of some other authors (Dominik et al., 2013; Wiklund et al., 2014; Razmaitė et al., 2017; Okuskhanova et al., 2017).

The composition of dietary fat is more significant for consumers than total fat content of food. Therefore, one of the aims of this study was to determine the fatty acid compositions of fallow deer and roe deer meats. Palmitic and stearic acid were the predominant saturated fatty acids in these deer meats, which is in agreement with the findings of some other authors (Daszkiewicz et al., 2012; Daszkiewicz and Mesinger, 2018). However, lauric and myrisitc acids were found in lower amounts in our deer meat. Furthermore, myristic acid, palmitic acid, and stearic acid contents differed in the meat from the two deer species. That is consistent with the results of some other authors (Strazdina et al., 2012; Purchas et al., 2010). Kim et al. (2017) reported similar contents of myristic acid, palmitoleic acid and stearic acid in deer meat. Our results disagree with Razmaitė et al. (2017) for all saturated fatty acid amounts, which could be due to the different type of muscle examined in their study and ours. Daszkiewicz and Mesinger (2018) reported considerably lower amounts than us for all saturated fatty acids in roe deer meat, except for palmitic and stearic acid. Our results are not in agreement with those of Milovanović et al. (2007) regarding fatty acid profiles of both fallow and roe deer meat. These disagreements could be the consequence of differences in methodological approaches – *m. semimembranosus* was examined, animals' ages were different, as were meat storage conditions until analyses (samples were vacuum packed and kept at 2±2°C).

Lauric, myristic and palmitic acids exert atherogenic effects. They inhibit the expression of the LDL (low-density lipoprotein) receptor gene, thus increasing LDL cholesterol synthesis and total cholesterol levels (Howell et al., 1997). Stearic acid has no effect on total and LDL cholesterol concentrations in blood. Thus, the significantly lower contents of myristic and palmitic acids along with reasonable levels of stearic acid observed in this study point to the greater health benefits of roe deer meat over fallow deer meat.

Unsaturated fatty acid amounts between the two deer species differed, except for linoleic acid in LD and palmitoleic acid, elaidic acid, eicosenoic acid and linoleic acid in GS. The predominant unsaturated fatty acid in all analyzed deer meats was linoleic acid, followed by oleic acid. This is agreement with Razmaitė et al. (2015) and Strazdina et al. (2012).

The total saturated fatty acids in our roe deer meat was higher than reported by Daszkiewicz and Mesinger (2018), who found about 50% of total saturated fatty acids, along with lower total unsaturated fatty acids (around 51%) than we measured. However, the ratios of unsaturated to saturated fatty acids were similar in both studies (it was 1.02 in Daszkiewicz and Mesinger (2018)).

Wood et al. (2008) suggest the ratio of polyunsaturated fatty acids to saturated fatty acids in foods should be >0.4. In the present study, the polyunsaturated fatty acid to saturated fatty acid ratios ranged from 0.387 to 0.546 and so was higher than recommended for all examined deer meats, except for LD of fallow deer. Similar polyunsaturated fatty acid to saturated fatty acid ratios in deer meat, from 0.50 to 0.68, were reported by Strazdina et al. (2012). Razmaitė et al. (2015) state the polyunsaturated fatty acid to saturated fatty acid ratio in LD of roe deer was 1.12, while Daszkiewicz and Mesinger (2018) reported a considerably lower polyunsaturated fatty acid to saturated fatty acid ratio of 0.26, i.e. lower than recommended.

A higher content of unsaturated fatty acids, in particular polyunsaturated fatty acids in meat is a favorable, health-promoting characteristic. On the other hand, unsaturated fatty acids have limited oxidative stability that can cause undesirable changes in the aroma and taste of meat and, furthermore, the formation of toxic compounds and compounds that decrease the nutritional value of meat (Daszkiewicz and Mesinger, 2018). In view of this and in order to more completely define the qualitative properties of deer meat, volatile compounds were determined in the two species of deer meat. Besides the content and ratio of different fatty acids in meat and the presence of unsaturated fatty acids that are sensitive to oxidation, another factor that contributes greatly to meat aroma is the presence of low molecular weight volatile compounds (aldehydes, ketones, aromatic hydrocarbons and alcohols). Aroma and taste are some of the most important meat properties for consumers. Species, breed, sex, and nutrition can affect fat content of meat and so affect meat aroma (Ivanović et al., 2012; North and Hoffman, 2015).

Alcohols were the most common group of compounds identified in the deer meats, with 3-methyl-1-butanol predominating among the volatiles (up to 39.66 μg/kg) in most deer meat samples. LD of roe deer had the highest content of 2-butanone. Other volatiles were found in the order: heterocyclic compounds > esters > ketones > aromatic hydrocarbons.

The measured concentrations of volatiles point to differences in the properties of deer meat compared to meat of domestic ruminants. Aldehydes and ketones dominate the volatiles in fresh domestic ruminant meat (Villalobos-Delgado et al., 2014; Ivanović et al., 2016), with the most common being hexanal. In the present study, hexanal was not detected in LD of fallow deer or roe deer, and in GS, we found it only in small amounts. Hexanal mainly derives from linoleic and arachidonic acid (Martin et al., 2002), which fits with our measured concentrations of those fatty ac-

ids in our deer meats. It is considered that aldehydes are formed as a result of lipid oxidation, while ketones generally correlate with animal diet (Ivanović et al., 2016). Phenolic compounds, aromatic hydrocarbons and alkanes were detected in low concentrations, but they probably have synergistic effects with other compounds in the formation of aroma and taste of deer meat.

Without doubt, differences in volatile compounds between animals are related to diet composition. The main feed of wild animals is natural feed/forages. Furthermore, wild ruminants choose "preferred feeds" and avoid "non-preferred" feeds, which could cause the variation of compounds that contribute to formation of taste and aroma of the resultant meat (Gačić et al., 2016). Sources of feed differ between regions, so this can have a significant impact on overall taste and aroma properties of deer meat. There is a lack of data about the presence of volatile compounds in deer meat. To the best of our knowledge, there are no literature data about the presence of volatile compounds in fallow deer meat and roe deer meat originating from Serbia.

On average, our roe deer meat was much darker than the fallow deer meat. Literature data regarding the color of deer meat are very variable. Purchas et al. (2010) shows deer meat color can be lighter if animals are younger. Hutchison et al. (2012) found deer meat obtained from younger animals was even lighter, compared to our current results and compared to Purchas et al. (2010). A review shows differences in colors of deer meat (obtained from three-year-old deer) between different authors (Kudrnáčová et al., 2018). Our color results are not in accordance with the results of some other authors (Cawthorn et al., 2018; Razmaitė et al., 2017).

Fresh meat's overall acceptability is based on sensory evaluation of organoleptic properties, color and aroma. The meat obtained from fallow deer was more acceptable compared to roe deer meat. Furthermore, meat obtained from LT was more acceptable than GS, for both species. Sensory evaluation is very difficult to compare with the findings of other authors, who evaluated deer meat originating from different conditions (climate, nutrition, living system etc.).

As mentioned above, the quality of deer meat is determined by various factors (species, age, gender, diet etc.). The disagreements in the literature data could be the consequence of differences in experimental and methodological approaches. Additionally, according to the literature, the region from which animals originate impacts the fatty acid composition of deer meat, as animal feeds vary regionally.

Conclusion

This reports quantified physio-chemical factors affecting the meat quality of fallow deer (*Dama dama* L.) and roe deer (*Capreolus capreolus* L.) from Serbia. Our results suggest that fatty acid profile and volatile compounds in deer meat, along with color and sensory properties of meat, differ significantly among these two deer species. Based on the colour measurements along with sensory analysis, fallow deer meat would be selected by consumers.

On the other hand, the chemical composition of the meat did not differ among the two deer species. Deer meat is favorably regarded by consumers in Serbia, regarding its perceived high quality, animal welfare and product management by the use of simple technology with low environmental impacts. Furthermore, because

natural forage is the main feed, deer meat is considered to be naturally organic and so is highly appreciated. In Serbia, the deer meat market is undeveloped within the meat industry, and venison is not as commonly available as pork or beef. Consumers primarily focus on meat's properties (organoleptic properties, taste, aroma and technological properties), so the data reported herein is valuable, particularly if the deer market rises and becomes economically sustainable.

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Received: 18 III 2019
Accepted: 12 IX 2019