Evaluation of lipid profiles in selected fresh and dry-cured game meats – a comparative approach

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Abstract

This study examined and compared the fatty acid (FA) composition and fat quality indices of four types of wild game meat (deer, roe deer, mouflon, and wild boar) from Croatia, and two types of dry-cured game meat products (deer and wild boar) available on the market, in relation to their impact on consumer health. FAs were analysed by gas chromatography coupled with a flame ionization detector, and fat quality indices were calculated based on the determined FAs. Wild boar meat clearly differs from other game meat (ruminants), due to its higher fat content and higher proportion of monounsaturated fatty acids (MUFA) compared to saturated fatty acids (SFA). Palmitic and stearic acids made up the greatest proportion of the SFA component, with stearic acid most represented in mouflon and roe deer meat, and palmitic acid predominating in wild boar and deer meat. Oleic acid was the largest component of MUFAs, with wild boar meat having the significantly highest and deer meat the lowest values. Linoleic acid and α-linolenic acid made up the largest proportion of polyunsaturated fatty acids (PUFAs), with the highest proportion of α-linolenic omega-3 acid found in deer meat. The determined PUFA/SFA ratio was lower, while the thrombogenic index was above the recommended values. Wild boar meat, along with roe deer and mouflon meat, was compliant with the recommendations concerning hypo- to hypercholesterolemic fatty acids and atherogenic indices. The roe deer meat was also acceptable in terms of the n-6/n-3 ratio, along with deer meat, for which that was the only favorable index. According to health recommendations, roe deer meat showed the most favourable values for most fat quality indices, while deer meat showed the least favourable values. When comparing fresh meat and dry-cured products from the same species, no significant differences were observed.

Key words: *deer; mouflon; wild boar; fatty acids; fat indices; nutritional composition*

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Introduction

Game meat is of interest to consumers due to its specific organoleptic properties and health benefits, resulting from its low fat and cholesterol content, high protein and mineral content, and favourable fatty acid profile compared to meat from domesticated species. Additionally, it is notable for the absence of pharmaceuticals (especially antibiotics), the use of organic products (e.g., non-GMO feed), and the extensive nature of the production systems and natural environment from which it originates (Tolušić et al., 2006; Strazdina et al., 2013; Needham et al., 2023). This type of meat is characterised by a dark red meat colour, pungent taste, and firmer texture compared to meat from domestic animals (Fabijanić et al., 2023). Nowadays, there is also a tendency to develop processed game meat products, particularly ready-to-eat offerings, leading to the emergence of dry-fermented and dry-cured meat products from various game species on the market (Paleari et al., 2003; Markov et al., 2013).

Several game meat species are hunted and consumed in Europe, including deer (e.g., red deer, roe deer, fallow deer, sika deer), mouflon, chamois, Alpine ibex, wild boar, hare, pheasant, partridge, grouse, and wild duck. Wild boar and red deer are the main big game species hunted in Europe (Needham et al., 2023). However, the availability of game meat depends on the hunting season and set quotas. The development of cultivation practices for species such as roe deer and wild boar addresses the issue of a constant supply of this type of meat. However, agricultural management should continue to be based on grazing to ensure that the quality of game meat remains as high as possible (Markov et al., 2013; Fabijanić et al., 2023). Apart from nutritional aspects, the characteristics and composition of game meat can also be influenced by factors such as season, mating season, animal age and gender, and others. Additionally, the recipe, production technology, and ingredients can further affect the quality of meat products (Soriano and Sanchez-Silva, 2001; Hoffman et al., 2005; Kos et al., 2016). Fat is usually one of the most variable components of foodstuffs. Scientific information on the effects of extrinsic and intrinsic factors determining the quality of game meat from European species is still quite limited compared to livestock species, making it necessary to generate knowledge through detailed analyses and comparisons in order to improve the quality and uniformity of game meat (Needham et al., 2023).

Game meat is consumed in much smaller quantities in the Republic of Croatia than meat from domestic animals. The consumption of game meat averages only 0.55 kg per household member per year. The main reason for this low consumption is the inadequate accessibility of game meat for a large number of people, both in terms of quantity and price (Tolušić et al., 2006).

Meat, in general, is often criticised for its high fat content and fat composition, while game meat has better properties in this regard. The modern understanding of fat is not limited to the effects of specific fatty acid groups, but more emphasis is placed on the effects of individual fatty acids or their combinations. Research has shown that within the same group, individual fatty acids can have completely opposite effects (Calder, 2015). To assess the nutritional quality of fats and their potential effects on health, various ratios are considered: the ratio of polyunsaturated to saturated fatty acids (PUFA/SFA), the ratio of omega-6 to omega-3 fatty ac-

ids (n-6/n-3), atherogenic index (AI), and thrombogenic index (TI). AI and TI take into account the different effects that certain fatty acids can have on human health and the likelihood that they may increase the frequency of pathogenic changes, such as the formation of atheromas and/or thrombi. Additionally, the index related to cholesterol metabolism, which represents the ratio of hypo- to hypercholesterolemic fatty acids (HH), has also been used (Santos-Silva et al., 2002; Mensink and Katan, 1992; Ulbritch and Southgate, 1991).

The aim of this study was to investigate and compare the fatty acid composition and nutritional lipid quality index values for different types of game meat (deer, roe deer, mouflon, and wild boar), and for two types of dry-cured game meat products (deer and wild boar) available on the Croatian market, in relation to given recommendations of health organisations and finally to examine their possible effects on consumer health.

Materials and methods

Samples

The study was conducted on three samples each of four types of fresh wild game meat (deer, roe deer, mouflon, and wild boar; total n=12) and on three samples of two types of dry-cured meat products made from the ham of deer and wild boar meat (total n=6). All samples were purchased on the market from small scale producers and stored appropriately according to producers' instructions until analysis.

Samples were homogenized using a laboratory homogenizer (Grindomix GM 200, Retsch, Haam, Germany). After analysis of water content in samples, they were stored in a refrigerator at 4°C until further analysis.

Reagents and standards

Petroleum ether, hydrochloric acid, sulfuric acid, sodium hydroxide, sodium chloride and boric acid were purchased from Sigma (Missouri, USA). Hexane and isooctane were HPLC grade from Merck (Germany). Ultrapure water with an electrolytic conductivity of ≤ 0.05 S/cm was obtained using the Millipore Direct-Q 3UV system (Merck, Germany). The standard solution of fatty acid methyl esters (FAME) was prepared by dissolving 100 mg standard Supelco™ 37 Component FAME Mix (Bellefonte, Pennsylvania, SAD) in 10 mL hexane.

Analysis of chemical composition

The chemical composition of the samples were determined using standard analytical methods foreseen for the analysis of water (ISO 1442:1997), ash (ISO 936:1998), fat (ISO 1443:1973) and total protein content (ISO 937:1978), using an UF75 Plus oven (Memmert, Schwabach, Germany), a LV9/11/P320 furnace (Nabertherm, Lilienthal, Germany), a Soxtherm 416 automated device (Gerhardt, Konigswinter, Germany) and a Vapodest 50 s automated distillation & titration device (Gerhardt, Konigswinter, Germany).

Fatty acid analysis

Sample preparation for the analysis of fatty acid methyl esters was performed according to the ISO standard (ISO 12966-2:2015) with certain modifications, as described in detailed in Vulić et al. (2021). The fatty acid methyl esters were analysed using a 7890B gas chromatograph with flame ionization detector (FID) (Agilent Technologies, Santa Clara, CA, USA) and a DB-23 capillary column (60 m, 0.25 ID, 0.25 μm) according to the standard analytical protocol (ISO 12966-4:2015). Temperature program, flow rates and other instrumental parameters are

also described in detailed by Vulić et al. (2021).

Fatty acid methyl esters were identified by comparing their retention times with those of the fatty acid methyl esters contained in the standard mix (Supelco™ 37 Component FAME Mix, Bellefonte, PA, USA). Since the FAME method was modified from the standard method, the reference material CRM BCR163 (Institute for Reference Materials and Measurements, Belgium) was used for quality control. The content of seven individual fatty acids determined during the analysis of the reference material was compared with the certified values and tolerances were defined.

Fat quality indices

The fatty acid composition results were used to calculate the fat quality indices using the following formulas shown in equations (1) – (3) (Ulbritcth and Southgate, 1991, Santos Silva et al., 2002; Pleadin et al., 2017):

Atherogenic index (AI) = [12:0 + (4 × 14:0) + 16:0]/(sum of monounsaturated fatty acids (MUFA) + UFA n-6 + PUFA n-3) (1)

Thrombogenic index (TI) = (14:0 + 16:0 + 18:0)/[(0.5 x sum of MUFA + 0.5 × PUFA n-6 + 3 × PUFA -3) + (PUFA n-3/PUFA n-6) (2)

Ratio of hypocholesterolemic to hypercholesterolemic fatty acids (H/H) = (C18:1n-9 + C18:2n-6 + C20:4n-6 + C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3)/(C14:0 + C16:0) (3)

Statistical analysis

Statistical analyses were performed using SPSS Statistics Software 22.0 (IBM, New York, NY, USA). The results were tested for the normality of distribution using the Shapiro-Wilks test. To determine the statistical significance of the differences in chemical parameters between the analysed meat types and product types, one-way ANOVA and the independent sample t-test were used, with statistical significance set at $p < 0.05$.

Results and discussion

The results of the chemical composition of four different types of game meat are shown in Table 1. There were no statistically significant differences in the analysed parameters ($p > 0.05$), except for fat content ($p < 0.05$), where the meat from wild boar had a significantly higher fat content than other game meats, i.e., that obtained from ruminants. Generally, the chemical composition of game meat determined in this study resulted with 76% water, 21% protein, and a low fat content of 1-2%.

In general, the protein content varies depending on the type of meat and is in range between 13 and 23% fresh weight. In the study by Strazdina et al. (2013), the protein content of meat from deer, roe deer, and wild boar from Latvia was

Table 1. Chemical composition of fresh game meat

Fresh game meat	Water	Protein	Fat	Ash
Deer	76.37±0.49	20.70±1.02	1.20±0.35^{b}	1.21±0.06
Roe deer	76.53±0.45	21.07±0.25	1.27±0.29^{b}	1.17±0.05
Mouflon	76.30±0.42	21.19±0.52	1.25±0.78^{b}	1.21±0.03
Wild boar	75.73±1.07	20.98±1.83	1.80±0.89^{a}	1.20±0.10

Results are expressed as g/100 and as the mean value ± standard deviation; ^{a,b} values within a column with no common superscript differ significantly ($P<0.05$); P-value refers to results of analysed parameter per column among four type of game meat.

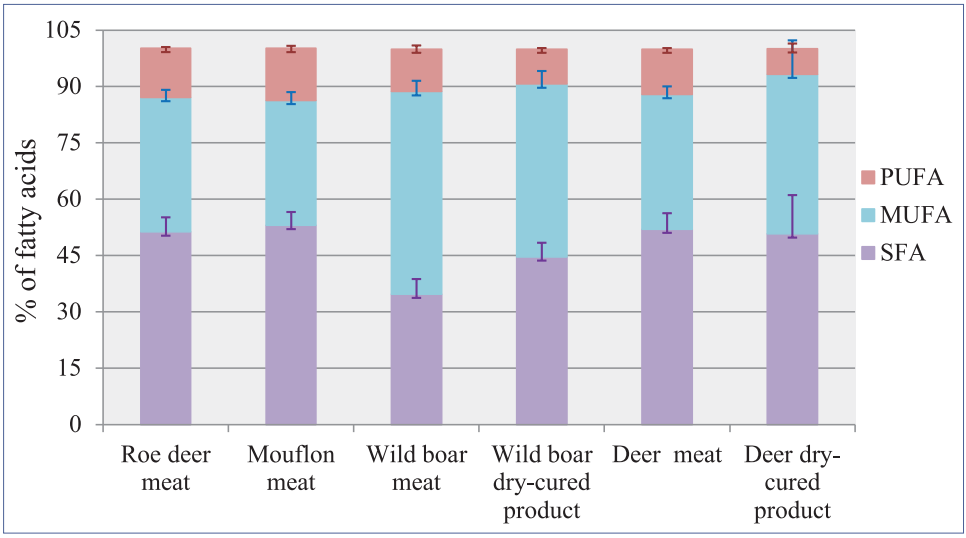

Figure 1. Proportion of fatty acid groups (%) in fresh game meat and dry-cured products SFA saturated fatty acids; MUFA monounsaturated fatty acids; PUFA polyunsaturated fatty acids

similar to obtained in this study, with values of 22–23%, also with no statistically significant differences between species. In the same study, the fat content of ruminant meat was similarly low, with values of 1.33–1.90%, while wild boar meat also had a higher content than ruminant meats with a value of 2.82% (Strazdina et al., 2013). The fat content of red deer from Slovenia was similar to the results of this study, ranging from 1.14 to 1.72%, and was shown to be dependent on the sex and age of the animal (Polak et al., 2008). For consumers, however, the composition of dietary fat is more important than the total fat content. The fatty acid composition of the studied game meat and associated dry-cured products and the fat quality indices calculated on the basis of this composition are shown in Tables 2 and 3, while the proportions of the fatty acid groups are shown in Figure 1.

Studies have shown that the average fatty acid content of meat of domestic animals is around 40% for SFAs, 40% for MUFAs, and around 20–25% for PUFAs (Barbir et al., 2014). The FA groups most commonly found in wild meat from ruminants (deer, roe deer, and mouflon) differ from those found in wild boar meat. In ruminant meat, SFAs were the most abundant (51–53%), followed by monounsaturated fatty acids (MUFAs) (34–35%) and then PUFAs (12–14%). In wild boar meat, MUFAs (54%) were the most abundant, followed by SFAs (35%) and PUFAs (11%). Wild boar meat also had the lowest SFA content in the Latvian study (35%) compared to deer (42%) and roe deer meat (38%) (Strazdina et al., 2013), but in present study, the SFA content had higher values. The ratio of fatty acid groups varies between species and is highly dependent on the diet preferred by each species (Tomljanović, 2012). The fatty acids released during fat digestion in the gastrointestinal tract of non-ruminants can be absorbed and incorporated into tissue lipids in unchanged form. In ruminants, PUFAs undergo biohydrogenation by ru-

Table 2. Fatty acid profile of fresh game meat and dry-cured meat products

Fatty acids (%)		Fresh meat				Dry-cured products	
		Roe deer	Mouflon	Wild boar	Deer	Wild boar	Deer
SFA	C10:0	n.d.	0.22±0.10	0.22±0.04	n.d.	0.09±0.00	0.05±0.03
	C12:0	n.d.	0.19±0.04	0.11±0.03	0.33±0.00	0.11±0.01	0.26±0.09
	C14:0	1.32±0.15^{b}	2.66±0.46^{b}	1.47±0.11^{b}	8.09±0.23^{a}	1.61±0.03^{b}	6.28±1.98^{a}
	C15:0	0.66±0.06^{a}	0.87±0.21^{a}	0.07±0.01^{b}	0.67±0.13^{a}	n.d.	0.54±0.17^{a}
	C16:0	18.02±1.18^{b}	21.01±1.09^{b}	22.20±0.99^{ab}	28.98±1.45^{a}	27.82±1.16^{ab}	31.22±2.20^{a}
	C17:0	1.64±0.15^{b}	3.04±0.44^{a}	0.35±0.06^{c}	0.77±0.11^{c}	0.23±0.01^{c}	0.64±0.15^{c}
	C18:0	29.01±2.09^{a}	24.98±1.05^{a}	10.13±1.00^{b}	13.21±1.02^{b}	14.35±2.46^{b}	11.73±5.63^{b}
	C20:0	0.69±0.08	0.30±0.14	0.20±0.18	n.d.	0.32±0.10	0.05±0.08
MUFA	C14:1	n.d.	n.d.	0.08±0.01b	3.12±0.09^{a}	n.d.	2.66±0.27^{a}
	C16:1n-7*t*	n.d.	0.48±0.02	0.45±0.06	0.21±0.05	0.51±0.10	0.26±0.05
	C16:1n-7*c*	0.45±0.06^{d}	1.69±0.15^{c}	3.81±0.59^{b}	13.48±1.00^{a}	3.49±0.64^{b}	14.22±4.61^{a}
	C17:1	n.d.	0.43±0.05	0.17±0.02	0.21±0.04	0.08±0.11	0.29±0.06
	C18:1n-9*t*	1.21±0.18^{b}	3.25±0.30^{a}	3.33±0.09^{a}	0.68±0.13^{c}	0.41±0.07^{c}	0.28±0.25^{c}
	C18:1n-9*c*	31.06±2.00^{b}	26.13±1.09^{bc}	40.24±2.56^{a}	14.17±0.94^{c}	36.84±2.98^{ab}	19.26±1.98^{c}
	C18:1n-7	3.09±0.21^{b}	1.31±0.23^{c}	3.30±0.15^{b}	3.99±0.16^{b}	3.83±0.13^{b}	5.33±2.63^{a}
	C20:1n-9	n.d.	n.d.	2.36±0.12a	n.d.	0.83±0.25^{b}	0.21±0.06^{c}
PUFA	C18:2n-6*t*	0.15±0.05^{c}	1.59±0.19^{a}	0.14±0.02^{c}	0.56±0.04^{b}	n.d.	0.33±0.30^{bc}
	C18:2n-6*c*	9.62±0.42^{a}	10.23±0.92^{a}	10.19±0.89^{a}	6.89±0.23^{b}	8.37±0.15^{ab}	5.61±1.05^{b}
	C20:2n-6	0.27±0.04	n.d.	0.40±0.06	0.89±0.23	0.32±0.12	n.d.
	C20:4n-6	0.32±0.12	n.d.	0.16±0.02	0.29±0.04	0.22±0.13	0.24±0.10
	C18:3n-3	2.71±0.25^{a}	2.01±0.19^{ab}	0.45±0.03^{b}	3.46±0.05^{a}	0.41±0.21^{b}	0.59±0.14^{b}

Results are expressed as the mean value in % of total fatty acids ± standard deviation; n.d. – not detected; SFA saturated fatty acids; MUFA monounsaturated fatty acids; PUFA polyunsaturated fatty acids; $^{a\text{-}c}$values within a row with no common superscript differ significantly ($P<0.05$); *P*-value refers to results of analysed parameter per row among four type of game meats and two type of dry-cured products

men anaerobic microorganisms to SFAs (mostly C18:0). As a result, lower amounts of PUFAs are absorbed from the gastrointestinal tract and incorporated into tissue lipids, including muscle tissues, in ruminants than in non-ruminants (Scollan et al., 2014).

Polak et al. (2008) reported the SFA, MUFA, and PUFA content of red deer to be 36–42%, 27–37%, and 26-37%, respectively, differing according to the age and sex of the animal. The distribution of FA groups in the mentioned studies was consistent with our study, but in our study, a higher SFA and a lower PUFA content (about 2x) was found. Polak et al. (2008) showed that the SFA content was highest in older animals (more than 2 years old), while the PUFA content was highest in younger animals (6 months old). Daszkiewicz and Mesinger (2018) reported that the SFA content in roe deer and red deer was 50% and 58%, MUFA content was 38% and 32%, and PUFA content was 13% and 10%, in accordance with values from this study. The difference between the studies can be attributed to factors that can affect fatty acid composition, including diet, age, gender, muscle type, etc. (Hoffman et al., 2004; Polak et al., 2008; Lorenzo et al., 2018; Daszkiewicz and Mesinger, 2018; Razmaite et al., 2020).

The composition of dry-cured products can be affected by the production technology. When comparing fresh meat and dry-cured products from the same species, fresh wild boar meat has a lower SFA content compared to dry-cured meat, while fresh deer meat has a higher PUFA content compared to dry-cured meat; however, the difference is not significant (P>0.05). The results of Paleari et al. (2003) on the FA groups in dry-cured products from deer and wild boar meat showed: 44.9±1.81% and 35.5±1.54% SFAs, 30.3± 2.01% and 45.7±1.32% MUFAs, and 19.6±1.99 % and 16.2±0.80 % PUFAs, respectively. These PUFAs values were 2–3x higher than those reported here for both wild boar and deer meat products.

The analysed game meats differed significantly in their fatty acid compositions. The most common individual fatty acids in roe deer and mouflon were similar, with oleic acid (C18:1n-9*c*) and stearic acid (C18:0) being equally represented (about 30% and 25%, respectively), followed by palmitic acid (C16:0) (about 20%) and linoleic acid (C18:2n-6*c*) (about 10%). In deer meat, the proportion of the most abundant fatty acid was different, with C16:0 most abundant at around 30%, followed by C18:1n-9*c*, palmitoleic acid (C16:1n-7), and C18:0 at around 14%, and then by myristic acid (C14:0) (8%) and C18:2n-6*c* at around 7%. As expected, wild boar meat had the highest content of oleic acid (40%), similar to pork fat, followed by C16:0 (22%) and C18:2n-6c and C18:0 at around 10%. Oleic acid is usually the fatty acid with the highest content in pig fat (45–50% of all FAs) (Barbir et al., 2014).

The significant dominance of MUFA content in wild boar is mainly due to oleic acid, which was significantly higher than in other game meat. Roe deer and mouflon had similar levels of oleic acid, while deer had the lowest level. Regarding the specificity of MUFA composition, the proportion of C16:1n-7 MUFA, which is significantly different in all animals, was highest in deer and lowest in roe deer. In addition, eicosenoic acid (C20:1n-9) was only found in wild boar, and the proportion of vaccenic acid (C18:1n-7) was significantly lower (about two times) in mouflon than in other meat species. In Lorenzo et al. (2018) and Razmaite et al. (2020), in red deer meat, C18:1n-9*c* was followed by C18:1n-7 and isomers of palmitoleic (C16:1n-7) fatty acids, as seen in the present study for roe deer, while in mouflon, wild boar, and

deer, C18:1n-9*c* was followed by palmitoleic and then vaccenic acids.

A special feature of the SFAs between the meat types is the dominance of C14:0 and C16:0 in deer compared to other types of meat, and the dominance of C18:0 and C17:0 in roe deer and mouflon. The study of Strazdina et al. (2013) also reported that SFAs other than C14:0, C16:0, and C18:0 are found in very small amounts in meats. Values similar to ours for C14:0 and C16:0 in roe deer (1.32 and 18.72%) and in wild boar (2.92 and 32.23%) were obtained by Strazdina et al. (2013), while in deer meat, values were slightly lower (4.57% and 21.2%). The dominance of C14:0 in deer meat compared to others was also confirmed (Strazdina et al., 2013). Razmaite et al. (2020) reported similar values for C18:0 in free-living red deer (14–15%), with much lower values for C16:0 (15–16%) and C14:0 (2–2.5%), but differing depending on the type of skeletal muscle. The literature review showed that fat high in C18:0 is no longer considered to increase plasma LDL-cholesterol concentrations and the TC/HDL-cholesterol ratio compared with the cholesterol-raising saturated C16:0 (Hunter et al., 2010). The fatty acid profile of the cured meat products naturally matched the profile of the meat from which it was produced, with small differences that were not statistically significant.

The dominance of n-6 PUFAs over n-3 PUFAs in all four species was primarily due to C18:2n-6*c*, which accounted for 57–74% of total PUFAs, with the content being significantly lower in deer meat. On the other hand, deer had the highest content of C18:3n-3, *i.e.*, omega-3 FA, followed by roe deer, while the content was significantly lower in wild boar. The meat of wild ruminants is low in total fat but rich in C18:2n-6*c* and C18:3n-3 (Davidson et al., 2011). Razmaite et al. (2020) reported the content of C18:2n-6*c* in red deer to be slightly higher than in the present study, with 14–15%, accounting for 44% of total PUFAs, and C18:3n-3 content around 3%, consistent with values for deer and roe deer in this study (3.46±0.05% and 2.71±0.25%) and slightly higher than in mouflon (2.01±0.19%).

To meet health recommendations for lowering the risk of developing cardiovascular and other chronic diseases, the

Table 3. Fat quality indices of fresh game meat and dry-cured products

Animal species	Type of sample	n-6/n-3	PUFA/SFA	AI	TI	HH
Roe deer	Fresh meat	3.82±1.01^{a}	0.25±0.05^{ab}	0.48±0.02^{a}	1.54±0.09^{ab}	2.33±0.24^{c}
Mouflon	Fresh meat	5.88±1.32^{b}	0.26±0.03^{ab}	0.68±0.03^{a}	1.69±0.10^{b}	1.83±0.15^{bc}
Wild boar	Fresh meat	24.20±3.58^{c}	0.33±0.05^{ab}	0.43±0.03^{a}	1.00±0.05^{a}	2.32±0.16^{c}
	Dry-cured product	21.73±2.82^{c}	0.21±0.02^{ab}	0.62±0.02^{a}	1.75±0.09^{b}	1.58±0.12^{b}
Deer	Fresh meat	2.49±0.78^{a}	0.23±0.05^{ab}	1.29±0.05^{b}	1.33±0.04^{ab}	0.73±0.05^{a}
	Dry-cured product	6.93±0.97^{b}	0.13±0.04^{a}	1.15±0.04^{b}	1.95±0.08^{b}	0.70±0.06^{a}

Results are expressed as the mean value ± standard deviation; SFA saturated fatty acids, PUFA polyunsaturated fatty acids; n-6 omega 6 fatty acids; n-3 omega 3 fatty acids; H/H hypo-/hypercholesterolemic fatty acids ratio, AI atherogenic index, TI thrombogenic index; $^{a\text{-}c}$values within a column with no common superscript differ significantly ($P<0.05$); *P*-value refers to results of analysed parameter per column

n-6/n-3 ratio should not exceed 4, and the PUFA/SFA ratio should be greater than 0.4, but usually the normal ratio for meat is around 0.1 (Simpoulos, 2002). Values recommended for AI and TI are lower than 1, while the recommended HH is higher (Santos Silva et al., 2002).

Statistically significant differences were found in fat quality indices for the analysed game meat and dry-cured game meat products ($P<0.05$). The determined PUFA/SFA ratio was lower, while the TI index was higher than the recommended values; only fresh wild boar meat was at the limit of the recommended value of 1. Regarding the n-6/n-3 ratio, deer and roe deer meat complied with the recommendation; mouflon meat was slightly above the recommended value, while wild boar fresh meat and dry-cured products were about six times above the recommended value. Lorenzo et al. (2018) showed a more favourable n-6/n-3 ratio for young (3.54) than for older animals (4.33), which was higher than 4 and therefore exceeding recommendations. On the other hand, deer meat was the least acceptable in terms of AI, HH, and TI indices, while wild boar meat, along with roe deer and mouflon meat, was acceptable in terms of HH and AI indices.

Similar values to those of our findings for AI and n-6/n-3 indices in roe deer were reported for red deer (around 0.50 and 2.80), while red deer also had a favourable TI (around 0.7) and PUFA/SFA ratio (around 1) (Razmaite et al., 2020), unlike in the present study. Daszkiewicz and Mesinger (2018) also reported lower PUFA/SFA values than recommended, similar to obtained values, for red deer and roe deer (0.17 and 0.26), while the typical value for meat from ruminants is reported to be even lower (about 0.1) (Wood et al., 2004). On the other hand, Polak et al. (2008) reported a favourable ratio for deer meat (0.63–1.09). According to De Smet et al. (2004), differences in fat content affect the fatty acid composition of meat, where concentrations of SFAs and MUFAs increase with increasing fat content at a faster rate than the levels of PUFAs. This leads to a decrease in the relative PUFA content, followed by a decrease in the PUFA/SFA ratio. Between the ruminant game meats in this study, no differences in fat content and the associated PUFA/SFA ratio were observed. Polak et al. (2008) determined a higher AI index for older deer (0.72) than for younger animals (0.4), and also noted differences in the type of muscles analysed.

Conclusions

Wild boar meat clearly differs from game meats from ruminants due to its higher fat content and a higher proportion of MUFAs compared to SFAs. The determined PUFA/SFA ratio was lower, while the TI index was higher than the recommended values. Wild boar meat, along with roe deer and mouflon meat, was acceptable in terms of the HH and AI indices. The roe deer meat was also acceptable in terms of the n-6/n-3 ratio, along with deer meat, for which that was the only favorable index. According to health recommendations, roe deer meat showed the most favourable values for most fat quality indices, while deer meat displayed the least favourable values. When comparing fresh meat and dry-cured products from the same species, no significant difference was observed. The results of this study suggest that not all game meat meet the desired fatty acid profiles and fat quality indices. These parameters likely differ under the influence of factors such as region, gender, age, feeding regime (farmed or wild) and other, which should be further investigated, as fat and fatty acids, among

other nutritional properties, are particularly susceptible to the influence of these factors.

References

1. BARBIR, T., A. VULIĆ and J. PLEADIN (2014): Masti i masne kiseline u hrani životinjskog podrijetla. Vet. stn. 2, 97-110.
2. CALDER, P. (2015): Functional roles of fatty acids and their effects on human health. JPEN 39, 18-32. 10.1177/0148607115595980
3. DAVIDSON, B., J. MACIVER, E. LESSARD and K. CONNORS (2011): Meat Lipid Profiles: A Comparison of Meat from Domesticated and Wild SouthernAfrican Animals. In Vivo 25, 197-202.
4. DASZKIEWICZ, T. and D. MESINGER (2018): Fatty acid profile of meat (Longissimus lumborum) from female roe deer (Capreoluscapreolus L.) and red deer (Cervus elaphus L.). Int. J. Food Prop. 21, 2276-2282. 10.1080/10942912.2018.1508160
5. De SMET, S., K. RAES and D. DEMEYER (2004): Meat Fatty Acid Composition as Affected by Fatness and Genetic Factors: A Review. Anim. Res. 53, 81-98. 10.1051/animres:2004003
6. FABIJANIĆ, N., M. KONJAČIĆ, Z. LUKOVIĆ, Z. PRPIĆ, Z. KELAVA and N. UGARKOVIĆ (2023): Physical parameters of wild boar meat quality: A review. JCEA 24, 340-348. 10.5513/JCEA01/24.2.3843
7. HOFFMAN, L. C., B. KRITZINGER and A. V. FERREIRA (2005): The effects of region and gender on the fatty acid, amino acid, mineral, myoglobin and collagen contents of impala (Aepyceros melampus) meat. Meat Sci. 69, 551-558. 10.1016/j.meatsci.2004.10.006
8. HUNTER, J. E., J. ZHANG and P. M. KRIS-ETHERTON (2010): Cardiovascular disease risk of dietary stearic acid compared with trans, other saturated, and unsaturated fatty acids: A systematic review. Am. J. Clin. Nutr. 91, 46-63. 10.3945/ajcn.2009.27661
9. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 12966-4:2015(2015): Animal and Vegetables Fats and Oils-Gas Chromatography of Fatty Acid Methyl Esters-Part 4: Determination by Capillary Gas Chromatography. Genève, Switzerland.
10. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 11132:2012, Sensory Analysis -Methodology-Guidelines for Monitoring the Performance of a Quantitative Sensory Panel; International.Organization for Standardization: Genève, Switzerland, 2012.
11. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 12966-2:2015. Animal and Vegetables Fats and Oils-Gas Chromatography of Fatty Acid Methyl Esters-Part 2: Preparation of Methyl Esters of Fatty Acids; International Organization for Standardization: Genève, Switzerland, 2015.
12. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 1442:1997. Meat and Meat Products-Determination of Moisture Content; International Organization for Standardization: Genève, Switzerland, 1997.
13. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 1443:1973. Meat and Meat Products-Determination of Total Fat Content; International Organization for Standardization: Genève,Switzerland, 1973.
14. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 8589:2007. Sensory Analysis-General Guidance for the Design of Test Rooms; International Organization for Standardization: Genève, Switzerland, 2007.
15. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 936:1998. Meat and Meat Products-Determination of Total Ash; International Organization for Standardization: Genève, Switzerland, 1998.
16. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO Standard 937:1978. Meat and Meat Products-Determination of Nitrogen Content; International Organization for Standardization: Genève, Switzerland, 1978.
17. KOS, I., D. BEDEKOVIĆ, I. ŠIRIĆ, I. VNUČEC, M. PEĆINA, A. GLUMPAK and K. CAROVIĆ (2017):Technological characterization and consumer perception of dry fermented game sausages with bay leaf (Laurus nobilis L.) essential oil. JCEA 18, 794-805. 10.5513/JCEA01/18.4.1961
18. LORENZO, J. M., A. MAGGIOLINO, L. GALLEGO, M. PATEIRO, M. PEREZ SERRANO, R. DOMINGUEZ, A. GARCIA, T. LANDETE-CASTILLEJOS and P. DE PALO (2018): Effect of age on nutritional properties of Iberian wild red deer meat. J. Sci. Food Agric. 99, 1561-1567. 10.1002/jsfa.9334
19. MARKOV, K., J. PLEADIN, M. HORVAT, M. BEVARDI, D. SOKOLIĆ MIHALAK, F. DELAŠ and J. FRECE (2013): Mikrobiološke i mikotoksikološke opasnosti za zdravstvenu ispravnost i karakterizacija domaćih kobasica od mesa divljači. Vet. stn. 44, 177-186.
20. MENSINK, R. P. and M. B. KATAN (1992): Effect of dietary fatty acids on serum lipid and lipoproteins. A meta-analysis of 27 trials. Aterioscler. Thromb. 12, 911- 919. 10.1161/01.ATV.12.8.911
21. NEEDHAM, T., D. BUREŠ, J. ČERNY and L.C. HOFFMAN (2023): Overview of game meat utilisation challenges and opportunities: A European perspective. Meat Sci. 204, 109284. 10.1016/j.meatsci.2023.109284
22. PALEARI, M.A., V.A. MORETTI, G. BERETTA, T. MENTASTI, T. and C. BERSANI (2003): Cured products from different animal species. Meat Sci. 63, 458-489. 10.1016/S0309-1740(02)00108-0
23. PLEADIN, J., T. LEŠIĆ, G. KREŠIĆ, R. BARIĆ, T. BOGDANOVIĆ, D. ORAIĆ A. VULIĆ, A. LEGAC and S. ZRNČIĆ (2017): Nutritional quality of different fish species farmed in the Adriatic sea. Ital. J. Food Sci. 29.

24. POLAK, T., A. RAJAR, L. GAŠPERLIN and B. ŽLENDER (2008): Cholesterol concentration and fatty acid profile of red deer (Cervus elaphus) meat. Meat Sci. 80, 864-869. 10.1016/j.meatsci.2008.04.005
25. RAZMAITE, V., V. PILECKAS, A. ŠIUKŠČIUS and J. JUŠKIENE (2020) Fatty Acid Composition of Meat and Edible Offal from Free-Living Red Deer (Cervus elaphus). Foods 9, 923. 10.3390/foods9070923
26. SANTOS-SILVA, J., R. J. B. BESSA and F. SANTOS-SILVA (2002): Effect of genotype, feeding system and slaughter weight on the quality of light lambs II. Fatty acid composition of meat. Livest. Prod. Sci. 77, 187-194. 10.1016/S0301-6226(02)00059-3
27. SCOLLAN, N. D., D. DANNENBERGER, K. NUERNBERG, I. RICHARDSON, S. MACKINTOSH, J. F. HOCQUETTE and A. P. MOLONEY (2014): Enhancing the Nutritional and Health Value of Beef Lipids and Their Relationship with Meat Quality. Meat Sci. 97, 384-394. 10.1016/j.meatsci.2014.02.015
28. SIMPOULOS, A. P. (2002): The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed. Pharmacother. 56, 365-379. 10.1016/S0753-3322(02)00253-6
29. SORIANO, A. and C. SANCHEZ-GARCIA (2021): Nutritional composition of game meat from wild species harvested in Europe. In: Lal Ranhababt, C.: Meat and nutrition. London, UK. 10.5772/intechopen.97763
30. STRAZDINA, V., A. JEMELjANOVS and V. ŠTERNA (2013): Nutrition Value of Wild Animal Meat. Proceedings of LAS B, 67, 373-377. 10.2478/prolas-2013-0074
31. TOLUŠIĆ, Z., T. FLORIJANČIĆ, I. KRALIK, M. SESAR and M. TOLUŠIĆ (2006): Game meat market in Eastern Croatia. Poljoprivreda 12, 58-63.
32. TOMLJANOVIĆ, K. (2012): Proizvodnost i kvaliteta mesa krupne divljači iz prirodnoga uzgoja na različitim staništima. Disertacija. Fakultet šumarstva i drvne tehnologije Sveučilišta u Zagrebu.
33. ULBRITCTH, T. L. V. and D. A. T. SOUTHGATE (1991): Coronary heart disease: Seven dietary factors. Lancet 338, 985-992. 10.1016/0140-6736(91)91846-M
34. VULIĆ, A., N. KUDUMIJA, T. LEŠIĆ, S. TANKOVIĆ, V. JELUŠIĆ, J. FRIZBEGOVIĆ, N. BILANDŽIĆ and J. PLEADIN (2021): Chemical composition and fatty acid profile of Alpine and Saanen goat milk from Bosnia and Herzegovina. Vet. stn. 52, 13-21. 10.46419/vs.52.1.12
35. WOOD, J. D., R. I. RICHARDSON, G. R. NUTE, A. V. FISHER, M. M. CAMPO, E. KASAPIDOU, P. R. SHEARD and M. ENSER (2004): Effects of Fatty Acids on Meat Quality: A Review. Meat Sci. 66, 21-32. 10.1016/S0309-1740(03)00022-6

Procjena lipidnog profila odabranih vrsta svježeg mesa divljači i suhomesnatih proizvoda od divljači – komparativni pristup

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U ovom su istraživanju ispitani i uspoređeni sastav masnih kiselina (MK) i indeksi kvalitete masti u odnosu na njihov utjecaj na zdravlje potrošača-konzumenata za četiri različite vrste mesa divljači (jelen, srna, muflon i divlja svinja) iz Hrvatske te dvije vrste suhomesnatih proizvoda od divljači (jelena i divlje svinje) dostupnih na tržištu. MK su analizirane plinskom kromatografijom (GC) spregnutom s plameno-ionizacijskim detektorom (FID), a na temelju utvrđenih MK izračunati su indeksi kvalitete masti. Zbog većeg udjela masti i većeg udjela mononezasićenih masnih kiselina (MUFA) u odnosu na zasićene masne kiseline (SFA) meso divlje svinje jasno se razlikuje od mesa ostale divljači (preživača). Palmitinska i stearinska kiselina čine najveći udio SFA, pri čemu je stearinska kiselina najzastupljenija u mesu muflona i srne, a palmitinska kiselina dominantna je u mesu divlje svinje i jelena. Oleinska kiselina čini najveći udio MUFA, pri čemu je meso divlje svinje imalo znatno više, a meso jelena najniže vrijednosti (P<0,05). Linoleinska kiselina i α-linolenska kiselina čine najveći udio polinezasićenih masnih kiselina (PUFA), s najvećim udjelom α-linolenske omega-3 kiseline u mesu jelena. Utvrđeni omjer PUFA/SFA bio je niži, dok je TI (indeks tromobgenosti) bio viši od preporučenih zdravstvenih vrijednosti. Meso divlje svinje, uz meso srne i muflona, bilo je u skladu sa zdravstvenim preporukama u pogledu HH (omjer hipo-/hiperkolesterolemične MK) i AI (indeks aterogenosti), dok

je svježe meso jelena bilo u skladu s preporukama samo u pogledu omjera omega-6/omega-3 MK, zajedno sa svježim mesom srne. Prema zdravstvenim preporukama, najpovoljnije vrijednosti za većinu indeksa kvalitete masti imalo je svježe meso srne, a najnepovoljnije svježe meso jelena. Usporedbom svježeg mesa i suhomesnatih proizvoda od iste vrste divljači nije uočena značajna razlika.

Ključne riječi: *jelen, muflon, divlja svinja, masne kiseline, indeksi masti, nutritivni sastav*