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Original Scientific Paper

Fatty acid composition of Visočka pečenica, a traditional dry-cured meat product from Bosnia and Herzegovina

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ABSTRACT

Visočka pečenica is a traditional dry-cured beef meat product from Bosnia and Herzegovina. It is the first meat product in Bosnia and Herzegovina to be protected by a geographical indication, and it is particularly appreciated for its aroma, taste and smoky properties. In this study, the fatty acid composition of 40 Visočka pečenica made in traditional (artisanal) and industrial production systems was examined. The fatty acid composition was determined by gas chromatography. Of the saturated fatty acids, the most abundant were palmitic and stearic acids (respectively, constituting 23.46% and 15.29% of the total fatty acids - traditional; 23.41% and 16.16% - industrial production). From the group of monounsaturated fatty acids, the most abundant was oleic acid, accounting for 45.61% of the total fatty acids in products from traditional production and 42.48% in industrial products. The most abundant polyunsaturated fatty acid was linoleic acid, which made up 7.61% of the total fatty acids (traditional production) and 7.41% (industrial production). PCA analysis of fatty acid composition showed that twenty fatty acids were characteristic of Visočka pečenica from industrial production and four fatty acids of products from traditional production.

1. Introduction

Cured meat products are highly valued products in the diet of the population both in Bosnia and Herzegovina (BiH) and in the world, and are good sources of high biological value protein. Those products with specific names and from specific geographic regions of a country are more regarded as traditional (*Radovanović et al*., 2003). The properties and quality of these products are greatly influenced by, among other things, the general characteristics of the climate, and especially by the specific climatic conditions of the geographical area in which they are produced (*Radovanović et al*., 2005).Visočka pečenica is a traditional, dry-cured beef meat product from BiH that has been produced in the municipality of Visoko for many years. It is produced from the highest quality parts of beef carcasses, dry salted only with table salt and cold smoked and dried (*Begić et al*., 2023).

Although cured meat products are a source of high-quality protein, negative aspects of this type of product are also known as a result of the high content of animal fat. Lipids in meat are found in muscle tissue and in the associated adipose tissue. Adi-

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pose tissue contains triglycerides and muscle tissue, in addition to triglycerides in the membranes of muscle fibres, which also contains phospholipids (*Barbir et al*., 2014). Research has shown that the fatty acid composition of meat consists of an average of 40% saturated (SFA), 40% monounsaturated (MUFA) and about 2-25% polyunsaturated (PUFA) fatty acids, with oleic acid being the most common in all types of meat and meat products (*Woods and Fearon*, 2009).

The fatty acid composition of cured meat products is influenced by various factors, primarily the type, feeding and breeding of animals, as well as the applied technological processes and parameters during production (*Siciliano et al*., 2013). There has been increased interest in recent years in manipulating the fatty acid composition of meat and meat products. This is because meat is seen to be a major source of fat in the diet and especially of saturated fatty acids, which have been implicated in diseases associated with modern lifestyles, especially in developed countries (*Wood et al*., 2004). A relatively high cholesterol content and a low ratio of polyunsaturated to saturated fatty acids are risk factors for some disorders, such as coronary heart disease (*Cordain et al*., 2005). Saturated fatty acids are well known to raise total and low-density lipoprotein (LDL) cholesterol (*Valsta et al*., 2005). Saturated fatty acids are correlated with increased risk of cardiovascular disease while a high intake of monounsaturated and n-3 polyunsaturated fatty acids has an inverse effect (*Fernández et al*., 2007). Given the importance of fatty acid composition on the nutritional acceptability of meat and meat products, the aim of this study was to examine the fatty acid composition of Visočka pečenica produced traditionally (artisanally) and industrially. Fatty acid composition tests on Visočka pečenica from these two production systems have not been conducted so far.

2. Materials and methods

2.1. Production and sampling of Visočka pečenica

Experimental production of Visočka pečenica was performed in traditional and industrial conditions. Altogether, 40 Visočka pečenica were sampled twice for research needs, halfway through and at the end of the smoking processes. Accordingly, 80 samples were analyzed. Visočka pečenica were prepared from different carcass cuts (round-*Musculus gluteobiceps*, *Musculus gluteus medius*, *Musculus semitendinosus* and; back musculature-*Musculus longissimus dorsi* (MLD)). During the smoking phase, the products were spread over two levels. The first level was, in relation to the hearth in the smokehouse, at a height of 2 m. The second height studied was 4 m above the hearth. Looking at the phases, the experimental design meant that during smoking, five samples of both anatomical regions (round and back) were placed on each level of the smokehouse. The experimental design, from the choice of raw material to the technological processing to the method of sampling, was identical for both production systems. However, on comparing the traditional and industrial production systems, differences found were related to the amount of added salt, the length of smoking time, and the parameters of the smoking process (temperature and relative humidity inside the smokehouse, outside air temperature and the temperature of the stokehole).

2.2. Methods

Fatty acid methyl esters were prepared using the standard method (*BAS ISO*, 2018), which involves dissolving glycerides in isooctane and trans-esterification using a methanolic solution of potassium hydroxide; the fatty acid composition was determined using the gas chromatography method. The fat content of the Visočka pečenica was determined using the reference method (*BAS ISO,* 2007), which involves Soxhlet fat extraction with organic solvents. The fat obtained through extraction was further used to determine the composition of fatty acids. Approximately 60 mg of extracted fat was weighed into a glass tube with a glass stopper and 4 mL of isooctane was added. After the fat was dissolved, 200 µL of methanolic potassium hydroxide solution was added. After adding the methanolic potassium hydroxide solution, vigorous shaking was performed twice for 30 s, after which the mixture was left to react at room temperature. After the mixture became clear, a glycerol layer was separated at the bottom of the tube, and 1 g of sodium hydrogen sulphate monohydrate was added to neutralize the mixture. Vigorous shaking was once again performed twice for 30 s. When the crystals had settled, 500 µL of the resulting sample solution was transferred to an injection vial and 1 mL of isooctane was added, after which the vial was closed and shaken. For the determination of fatty acid composition, a Shimadzu QP2010 gas chromatograph with

mass spectrophotometer was used with a Supelco SP - 2560 capillary column (100 m × 0.25 mm × 0.20 μm). The chromatographic determination conditions were as follows: injector and detector temperatures 220°C, column temperature 170°C, injected volume 1 μL. Helium with a flow rate of 0.9 mL/min was used as the carrier gas. Fatty acids methyl esters were identified by comparison with retention times of 37 fatty acids methyl esters of the standard mixture (SupelcoTM 37 Component FAME Mix) analyzed under the same conditions. The fatty acid content was expressed as % of the total identified fatty acids. For the correlation and presentation of the results multivariate data analysis was used - analysis of the basic components or PCA analysis. Statistical analyses were performed using Past software 3.15 (*Hammer et al*., 2001).

3. Results and discussion

The fatty acid compositions of the Visočka pečenica from traditional production are shown in Table 1. The analysis determined that, among the three fatty acid types, Visočka pečenica from traditional production were the richest in monounsaturated fatty acids due to the large amount of oleic acid (C18:1 c n-9), which was also the most abundant fatty acid (it accounted for 45.61% of the total fatty acids). The next-largest share was made up of saturated fatty acids. The most abundant saturated fatty acids were palmitic (C16:0) with 23.46% of total fatty acids and stearic fatty acid (C18:0) with 15.29%. The smallest share was made up of polyunsaturated fatty acids, and the most abundant among them was linoleic fatty acid (C18:2 c n-6) that constituted 7.61% of the total fatty acids. Comparing the composition of fatty acids halfway through and at the end of the smoking process, no major differences in their amounts were found. With the finished smoking process (compared to half-smoked product), there was slightly less of the palmitic, oleic and linoleic fatty acids and more stearic fatty acid. The Visočka pečenica prepared from round had a higher content of stearic fatty acid compared to the MLD products. In contrast, the MLD Visočka pečenica had higher contents of palmitic, oleic and linoleic fatty acids compared to the round Visočka pečenica.

The fatty acid composition of the Visočka pečenica from the industrial production system are shown in Table 2. The largest proportion of the three

Table 1. Fatty acid composition of Visočka pečenica from traditional production (% of total identified fatty acids)

Fatty acid (%)	TRHH	TMHH	TRLH	TMLH	TRHE	TMHE	TRLE	TMLE
C8:0	0.11	0.08	0.10	0.09	0.11	0.06	0.09	0.09
C10:0	0.12	0.06	0.10	0.08	0.14	0.05	0.08	0.10
C12:0	0.09	0.06	0.08	0.05	0.08	0.03	0.06	0.08
C14:0	1.34	1.21	1.38	1.09	1.35	1.16	1.11	1.09
C15:0	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.01
C16:0	22.98	23.73	23.40	23.87	22.36	23.24	24.47	23.63
C17:0	0.24	0.22	0.20	0.16	0.36	0.17	0.11	0.25
C18:0	16.56	14.90	15.20	14.22	16.95	15.44	14.39	14.69
C20:0	0.24	0.22	0.21	0.16	0.35	0.17	0.17	0.30
C14:1	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01
C16:1	3.25	2.76	3.01	2.22	3.61	2.55	2.77	2.98
C17:1	0.48	0.44	0.50	0.43	0.72	0.35	0.50	0.50
C18:1 t n-9	0.14	0.07	0.10	0.05	0.14	0.05	0.11	0.08
C18:1 c n-9	44.05	45.81	45.50	47.54	43.44	46.45	46.84	45.26
C20:1	0.77	0.39	0.60	0.43	0.77	0.35	0.55	0.45
C22:1 n-9	0.29	0.22	0.25	0.22	0.29	0.17	0.22	0.30
C18:2 c n-6	7.47	7.95	7.50	7.70	7.12	8.13	6.65	8.34
C18:2 t n-6	0.01	0.01	0.01	0.00	0.02	0.00	0.01	0.01
C18:3 n-6	0.14	0.14	0.11	0.11	0.23	0.07	0.11	0.15
C20:2 n-6	0.29	0.24	0.30	0.22	0.34	0.23	0.33	0.25
C20:3 n-6	0.19	0.17	0.20	0.16	0.28	0.12	0.22	0.20
C20:4 n-6	0.34	0.34	0.35	0.33	0.36	0.29	0.33	0.34
C18:3 n-3	0.44	0.50	0.45	0.44	0.50	0.46	0.44	0.45
C20:3 n-3	0.44	0.48	0.45	0.43	0.45	0.46	0.44	0.44

*T-traditional production; M-MLD, R-round samples; H-higher, L-lower smoking heights; H-halfway through, E-end of the smoking process.

fatty acid groups in these Visočka pečenica was monounsaturated fatty acids, due to the high proportion of oleic fatty acid (C18:1 c n-9), which was the most abundant fatty acid compared to the others (it constituted 42.48% of the total fatty acids). The next-largest proportion was made up of the saturated fatty acids, of which the most abundant were palmitic (C16:0) with 23.41% and stearic fatty acid (C18:0) with 16.16% of total fatty acids. The smallest proportion was made up of the polyunsaturated fatty acids, of which linoleic fatty acid (C18:2 c n-6) was present in the largest amount, accounting for 7.41% of total fatty acids. In comparing the fatty acid composition of Visočka pečenica from industrial production halfway through and at the end of the smoking process, the longer smoking time resulted in some small changes. Namely, with longer smoking, the contents of stearic and linoleic acids were lower, while the contents of palmitic and oleic acids were numerically higher. On comparing the different cuts, the Visočka pečenica prepared from round were richer in stearic and oleic acids, while those prepared from MLD were richer in palmitic and linoleic acids.

In comparing the two production systems, it can be concluded that the largest proportion of fatty acids in the Visočka pečenica from both production types was monounsaturated fatty acids, with a higher proportion in traditionally produced than in industrially produced products. Oleic fatty acid was the most abundant fatty acid in Visočka pečenica from both production systems, in a higher quantity in those from traditional production (45.61%) compared to those from industrial production (42.48%). *Subašić* (2024) and *Saičić et al.* (2010) indicated that oleic acid was the most abundant of the fatty acids in beef prosciutto, with higher levels (59.18% and 49.92% reported, respectively) compared to those listed in our current study. After monounsaturated fatty acids, the largest proportion of fatty acids in Visočka pečenica from both types of production was saturated fatty acid group, with a higher proportion in industrial than in traditional Visočka pečenica. The most abundant saturated fatty acids in the Visočka pečenica were palmitic (C16:0) (23.46% - traditional and 23.41% - industrial) and stearic (C18:0) (15.29% - traditional and 16.16% - industrial) acids. In accordance with the above, *Saičić et al*. (2010) and *Subašić* (2024) also recorded palmitic and stearic acid as the most abundant of the saturated fatty acid group in beef prosciutto. Among the three fatty acid types, the low-

Table 2. Fatty acid composition of Visočka pečenica from industrial production (% of total identified fatty acids)

Fatty acid (%)	IRHH	IMHH	IRLH	IMLH	IRHE	IMHE	IRLE	IMLE
C8:0	0.16	0.14	0.13	0.14	0.13	0.13	0.12	0.12
C10:0	0.17	0.17	0.16	0.15	0.14	0.16	0.14	0.13
C12:0	0.13	0.11	0.10	0.09	0.09	0.12	0.09	0.09
C14:0	1.63	1.55	1.58	1.59	1.57	1.59	1.55	1.19
C15:0	0.07	0.04	0.04	0.04	0.05	0.04	0.04	0.02
C16:0	23.28	23.78	22.82	23.43	24.06	23.03	23.27	23.60
C17:0	0.52	0.39	0.39	0.42	0.28	0.49	0.37	0.35
C18:0	15.87	16.77	16.15	16.13	16.75	15.49	16.15	15.94
C20:0	0.34	0.35	0.31	0.26	0.19	0.31	0.27	0.22
C14:1	0.06	0.05	0.04	0.04	0.04	0.04	0.05	0.04
C16:1	4.07	3.11	3.51	3.66	3.05	3.98	3.10	3.63
C17:1	0.83	0.71	0.75	0.82	0.46	0.71	0.50	0.51
C18:1 t n-9	0.25	0.22	0.22	0.23	0.19	0.22	0.18	0.18
C18:1 c n-9	41.53	41.35	42.92	42.19	42.11	42.67	43.80	43.28
C20:1	0.80	0.84	0.79	0.79	0.74	0.71	0.73	0.75
C22:1 n-9	0.29	0.31	0.29	0.26	0.28	0.27	0.27	0.25
C18:2 c n-6	7.47	7.55	7.29	7.37	7.40	7.61	7.12	7.48
C18:2 t n-6	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.01
C18:3 n-6	0.13	0.17	0.13	0.09	0.14	0.12	0.09	0.09
C20:2 n-6	0.42	0.44	0.39	0.41	0.42	0.40	0.37	0.40
C20:3 n-6	0.38	0.43	0.37	0.34	0.42	0.35	0.32	0.35
C20:4 n-6	0.49	0.45	0.48	0.45	0.46	0.44	0.46	0.40
C18:3 n-3	0.55	0.57	0.58	0.53	0.56	0.53	0.50	0.53
C20:3 n-3	0.55	0.48	0.53	0.55	0.46	0.58	0.50	0.44

* I-industrial production; M-MLD, R-round samples; H-higher, L-lower smoking heights; H-halfway through, E-end of the smoking process.

est proportion in the Visočka pečenica was the polyunsaturated fatty acids, with a higher proportion in industrial than in traditional products. The most abundant of the polyunsaturated fatty acid group was linoleic acid (both production types), with a higher proportion in traditional (7.61%) than in industrial (7.41%) products. In relation to the above results, *Subašić* (2024) reported higher amounts of linoleic acid (11.30%), while *Saičić et al*. (2010) reported lower amounts (3.13%) in beef prosciutto. *Tomić et al*. (2009) conducted a study of the fatty acid composition of Uzice beef prshuta produced from *M. semitendinosus* and *M. longissimus lumborum et thoracis* using two different salting processes. The study determined the palmitic, stearic and oleic acids were the highest of all the fatty acids in all tested samples. Considering the salting processes used, there were no significant differences in the fatty acid composition of the tested samples (*Tomić et al*., 2009). In the fatty acid composition of the dried beef product, *cecina*, *Fernández et al*. (2015) and *Molinero et al*. (2008) found the most abundant fatty acids were oleic, palmitic, stearic and linoleic, which is in line with the results of our study. These same fatty acids were also the most abundant in pastirma, the Turkish dry meat product (*Çakıcı et al*., 2015; *Aksu and Kaya* 2002; *Aksu et al*., 2017), in Kazakh dry-cured beef (*Sha et al*., 2016), and in Dalmatian and Istrian prosciutto (*Marušić Radovčić et al*., 2018; *Marušić et al*., 2013). Approximate results of the fatty acid composition were given by *Pleadin et al.* (2017) in their study of prosciutto originating from households in BiH. The most abundant saturated fatty acids were palmitic acid, accounting for 23.73% and stearic acid, accounting for 13.81% of total fatty acids. The most abundant of the monounsaturated fatty acid group was oleic acid, accounting for 45.40%, and from the polyunsaturated fatty acid group, linoleic acid making up 10.65% of total fatty acids (*Pleadin et al*., 2017). *Pleadin et al*. (2016) examined the fatty acid composition of traditional cured meat products from Croatia and Slovenia, including Dalmatian and Karst prosciutto. The authors found the composition of fatty acids was in the order of monounsaturated > saturated > polyunsaturated acids, and oleic, palmitic and stearic fatty acids as the most abundant in the products. *Pleadin et al*. (2015) examined seasonal variations in the composition of fatty acids in Istrian and Dalmatian prosciutto, with the highest proportion of total fatty acids being oleic acid, followed by palmitic, stearic and linoleic acids. The authors stated that the season of production can significantly affect the composition of fatty acids in the cured meat products (*Pleadin et al*. 2015).

Figure 1 shows the principal component analysis (PCA) of the Visočka pečenica from traditional and industrial production according to the composition of fatty acids. It can be seen that the Visočka

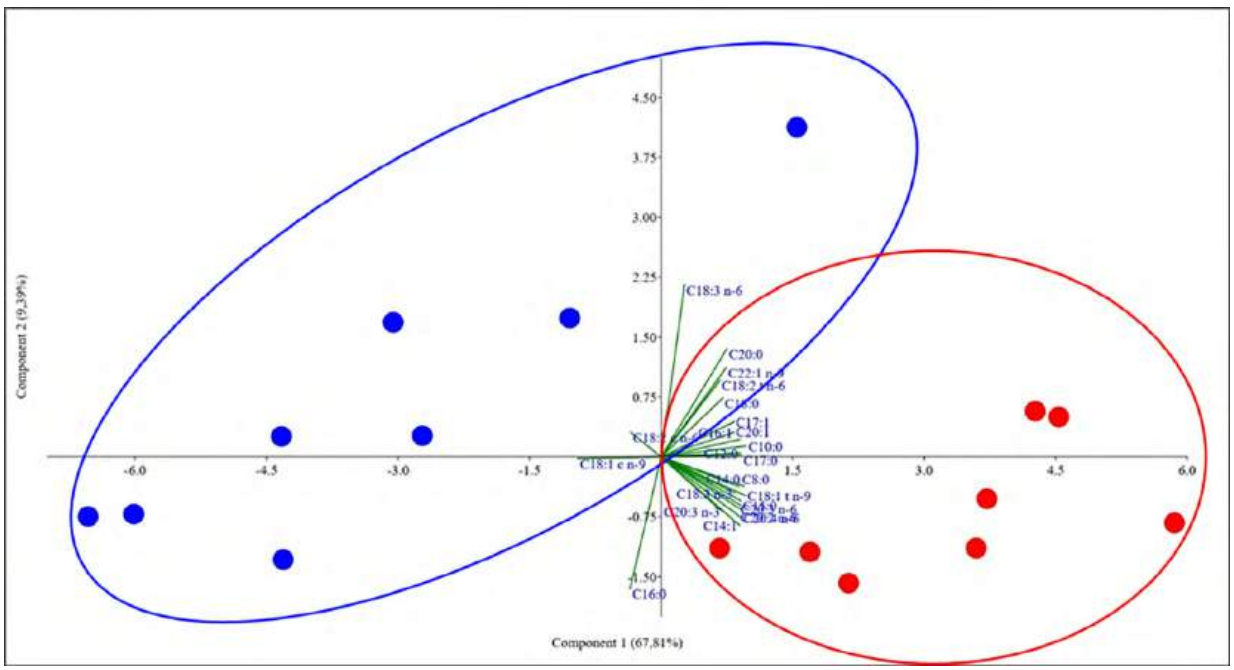

Figure 1. Principal component analysis of Visočka pečenica from traditional and industrial production according to the composition of fatty acids
(*T-traditional, I-industrial production; M-MLD, R-round samples; H-higher, L-lower smoking heights; H-halfway through, E-end of the smoking process)

pečenica from industrial production were grouped in relation to 20 fatty acids out of a total of 24 identified (red ellipsoid). The reason for this grouping was due to the larger amount of those 20 fatty acids in the industrial products than in the traditional products. Visočka pečenica from traditional production were more dispersed and positioned in three quadrants (blue ellipsoid; Figure 1).

The Visočka pečenica made from round, smoked at the higher height and sampled at the end of the smoking process from traditional production (TRHE) were completely separated from all other products and were characterized by a high content of γ-linolenic acid (C18:3 n-6). A similar group of products, only smoked only at the lower 2 m height, was positioned completely opposite on the graph in Figure 1, characterized by the highest content of palmitic fatty acid (C16:0). Oleic fatty acid (C18:1 c n-9) was characteristic of Visočka pečenica from traditional production (TMLH, TRLE and TMHE) which had the highest contents of this fatty acid. Linoleic fatty acid (C18:2 c n-6) was positioned in relation to traditionally produced MLD Visočka pečenica smoked at the lower height of 2 m and sampled at the end of the smoking process, which had the highest content of this fatty acid. Fatty acids C20:0, C22:1 n-9, C18:2 t n-6 and C18:0 were characteristic of Visočka pečenica from both production systems (TRHE, IRLH and IMHH). Other fatty acids were characteristic of and found in the highest amounts in industrial Visočka pečenica, as can be seen in Figure 1.

4. Conclusion

This study presents the first results of the fatty acid composition of Visočka pečenica. The largest proportion of the fatty acid composition of products from both production systems (traditional and industrial) was the monounsaturated fatty acids, of which oleic acid the most abundant acid in relation to all identified fatty acids. Both the monounsaturated fatty acids and oleic acid content were higher in Visočka pečenica from traditional than from industrial production. The content of saturated fatty acids was lower than that of monounsaturated fatty acids in both production systems. Palmitic and stearic fatty acids were the most abundant saturated fatty acids, with a higher proportion in Visočka pečenica from industrial than traditional production. The content of polyunsaturated fatty acids was the lowest of the three fatty acid types in the Visočka pečenica, with a higher proportion in industrial than in traditional products. The most abundant polyunsaturated fatty acid was linoleic fatty acid. With a longer (finished) smoking process, in Visočka pečenica from both production systems, there was a slight decrease in the content of polyunsaturated fatty acids. In industrial Visočka pečenica with the longer smoking process (compared with half-smoking), the content of saturated fatty acids was lower, while the content of monounsaturated fatty acids was higher. The opposite trend was observed in traditionally produced Visočka pečenica. In both production systems, Visočka pečenica made from round were richer in saturated fatty acids, but the MLD Visočka pečenica contained more polyunsaturated fatty acids. To date, many studies have been conducted on the modification of the fatty acid composition of meat and meat products in order to improve their nutritional value. The results of this study can serve as a basis for future research aimed at improving the nutritional value of the fatty acid composition of traditional Visočka pečenica.

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