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4 authors:

Sebila Rekanovic
Univerzitet u Bihaću

Grujic Radoslav
State College of Medicine

Goran Vucic
University of Banja Luka

Elvisa Hodzic

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MINERAL COMPOSITION OF TRADITIONAL SHEEP MEAT PRODUCTS IN DEPENDENCE ON THE THERMAL TREATMENT

Sebila Rekanović[1,2*], Radoslav Grujić[3], Goran Vučić[4], Elvisa Hodžić[1]

[1]Biotechnical faculty Bihać, University of Bihać, Luke Marjanovića bb, 77000 Bihać, Bosnia and Herzegovina
[2]Faculty of Technology Zvornik, University of East Sarajevo, Karakaj 34 A, 75400 Zvornik, Bosnia and Herzegovina
[3]High School of medicine Prijedor, Nikole Pašića 4A, 79101 Prijedor, Bosnia and Herzegovina
[4]Faculty of Technology, University of Banja Luka, Bulevar vojvode Stepe Stepanovića 73, 78000 Banja Luka, Bosnia and Herzegovina

[*]e-mail: sebilarekanovic@outlook.com

Abstract

Sheep meat products are traditionally present in the diet of the population in the Balkan countries. It presents an important source of protein, fat, energy and a large number of well-absorbable mineral substances (iron, calcium, zinc and magnesium). Loss of the mineral matter is possible during the heat treatment of meat, which is a key stage in the process of making traditional sheep meat products. The loss depends on the applied thermal treatment. Manufacturers try to adapt the traditional technology of making sheep meat products to modern industrial conditions and to ensure production throughout the whole year. The aim of this study was a comparative analysis of sheep meat mineral composition produced in modern industrial conditions and ones produced by traditional technology, with the focus being given to the conditions of heat treatment and meat drying.

Four experimental groups of boiled sheep meat samples with temperature variations 55 - 75 ^{0}C, boiling time 15 - 30 minutes and relative humidity 74 - 86%, and four groups of dried sheep meat with temperature variations 14 - 18 0C, drying time 24 h and relative humidity 85 - 88% were included in this study. Inductively coupled plasma mass spectrometry (ICP-MS) with a microwave-assisted digestion treatment was used for determination of mineral matter in all meat samples.

The results show increased value of all elements in the boiled sheep meat in relation to their content in dried products. Also, the content of mineral substances in samples of dried and boiled sheep meat was increased in relation to fresh samples, depending on the applied parameters. Main component analysis showed that all properties observed were present with high value in one of the first five major components. The most important properties in the first major component, which carry 88.47% of the total variability of the experiment, are Na, K, Mg, Cd, Pb and Se.

Mineral matter content was higher in samples of boiled sheep meat than in dried ones. The reduction of smoking time and temperature enhancement had the greatest influence on the increasement of the mineral matter content in boiled and dried sheep meat samples.

***Key words**: Sheep meat, Heat treatment, Mineral matter.*

1. Introduction

The impact of environmental pollution has a huge consequence on livestock breeding, especially on providing high-quality sheep nutrition. In industrial areas, pollution influences the content of essential mineral elements as well as potentially toxic metal content [1].

Meat is well known as an excellent source of essential trace elements such as iron (Fe), zinc (Zn), selenium (Se), vitamins A, B12, and folic acid [2, 3]. Meat is very important source of several micronutrients due the fact that some of them are exclusively present in meat and meat products [4, 5]. Participating in various significant functions in human organism, numeral minerals in meat are vital [6].

Thermal treatment plays a very important role in ensuring consistency, sensory properties and safety of meat and meat products [7, 8]. The thermal treatment can lead to the loss of a part of the mineral matter, thereby reducing the value of the product in human nutrition. The loss of mineral matter depends on the thermal treatment method. The greatest mineral matter reduction is generated if the meat is thermal treated in the aquatic environment [9, 10, and 11].

In mountainous areas of south-eastern Europe, the population produces different dried products according to traditional technology. During the production of these products the meat is salted, smoked and dried at temperatures below 15 ^{0}C, with the fermentation process being carried out in addition to the drying process. Obtained products have specific sensory properties. Literature describes the properties of sheep meat products produced in the European Union and Balkans [12, 13, 14, and 15] while sheep meat products in Bosnia and Herzegovina are very poorly described. Production of sheep meat by traditional technology is related to the winter period, when low temperatures prevent potentially degradation of meat under the influence of microorganisms, and allow drying and fermentation processes to take place slowly in forming sensory properties acceptable to consumers. Sheep meat producers are trying to adapt traditional technology to industrial conditions and produce finished products throughout the whole year. In addition, they want to shorten the processing by applying thermal treatment of meat similar to that used in the production of boiled sausages.

The aim of this study is to examine the impact of two thermal treatment methods (cold drying as part of traditional technology and boiling as part of industrial production) on the content of mineral matter in sheep meat.

2. Materials and Methods

2.1 Production of sheep meat products

Four experimental groups of boiled sheep meat samples with temperature variations of 55 - 75 ^{0}C, boiling time of 15 - 30 minutes and relative humidity of 74 - 86%, and four groups of dried sheep meat with temperature variations 14 - 18 ^{0}C, time drying up to 24h and relative humidity between 85 and 88% were analyzed (Table 1).

In this study, sheep meat cultivated in the mountain regions of Bosnia and Herzegovina was used. Animals were fed exclusively by grass from mountain pastures. Twelve, well-fed female throats, ages 9 to 12 months, are separated from the same herd. Animals were slaughtered in MS Alem meat industry, Bosanska Krupa, B&H. In four weeks, every 7 days, three animals were slaughtered for sampling and cooled for 24 hours at temperature of 1^{0}C. After cooling (the reached temperature in the middle of the tights < 4^{0}C), the tights were separated, and used for further analysis. The tight bone is separated from the tights, and the excessive connective tissue and fat tissue were removed. Samples were cut to shaped pieces (length 20 - 25 cm, width 4 - 5 cm and thickness 3 - 4 cm). Shaped meat samples were then dry marinated. Marinade consisted of a kitchen salt (2.5%), with pepper and garlic used as spices. Marinating process was carried out under controlled conditions (temperature 2 - 4 ^{0}C, during 10 days). From each sample (obtained from 12 sheep), 24 pieces of meat were formed and divided into 4 experimental groups. Experimental groups were formed according to the conditions of thermal treatment obtained. In each experimental group, 24 pieces of meat were used, of which twelve was thermally treated by boiling (thermodynamic chamber with friction generator), and twelve was smoked and dried at low temperatures (Universal thermodynamic chamber, Doleschal, Austria).

After thermal treatment, the products were packed in a vacuum, using plastic bags sealed for air and water vapor. Products were stored at 1 - 2 ^{0}C to analysis. Prior to the analysis four samples (pieces) were taken randomly and analyzed from each experimental group.

2.2 Mineral content analysis

Mineral content analysis was carried out at the Technological faculty Banja Luka, Bosnia and Herzegovina in the Laboratory for chemical food safety. Fresh and thermal treated meat samples were cooled to 4 ^{0}C and homogenized in stainless steel rotating knife homogenizer (Tecator 1094, Foss, Hillerod, Denmartk). All samples were digested in duplicate using microwave digestion system, in accordance with the NF EN 13805 standard "Food stuffs-Determination of trace elements-Pressure digestion" [16]. ICP OES measurements were performed three times for each duplicate using Optima 8000 Optical Emission Spectrophotometer (Perkin Elmer, USA). The sample solutions were pumped by a peristaltic pump from tubes arranged on a Perkin Elmer auto-sampler model 510. The following analytes were determined: Na, K, Ca, Mg, P, Fe, Mn, Cu, Zn, Se, Mo, Ni, Cd, Pb.

2.3 Statistical analysis

The data were analyzed using SPSS Statistics 23 (2013). Analysis of variance (ANOVA) was conducted and significance of differences among treatments and in time dependence were tested using the least significant difference (LSD). Differences were significant at the $^*p < 0.05$ probability level.

Table1. Parameters of thermal treatment by drying and boiling of sheep meat samples used in thermodynamic chamber, Doleschal, Austria

Drying process					
	Process	**T (°C)**	**Time (min/h)**	**Air circulation %**	**Relative humidity (%)**
I Experimental group	Drying	16 - 18	2 h	50	86 - 88
	Smoking	18	2 h	40	86
	Aeration	18	10	100	86
	Rippening	17	10	50	86
	Smoking	17	2 h	40	85
	Aeration	17	10	100	85
	Rippening	16	24 h	40	85
II Experimental group	Drying	17 - 18	2 h	50	86 - 88
	Smoking	15	3 h	40	86
	Aeration	15	15	100	86
	Rippening	14	50	50	86
	Smoking	14	3 h	40	85
	Aeration	14	10	100	85
	Rippening	14	24 h	40	85
III Experimental group	Drying	17 - 18	2 h	50	86 - 88
	Smoking	15	2 h	40	86
	Aeration	15	20	100	86
	Rippening	14	10	50	86
	Smoking	14	2 h	40	85
	Aeration	14	15	100	85
	Rippening	14	24 h	40	85
IV Experimental group	Drying	14 - 15	2 h	50	86 - 88
	Smoking	15	3 h	40	86
	Aeration	15	20	100	86
	Rippening	14	15	50	86
	Smoking	14	2 h	40	85
	Aeration	14	10	100	85
	Rippening	14	24 h	40	85
Groups	**Boiling process parameters**				
	Process	**T (°C)**	**Time (min)**	**Air circulation %**	**Relative humidity (%)**
I Experimental group	I drying	65	20	7.1	74 - 76
	I smoking	70	5	-	-
	II drying	72	30		
	Baking	75	10		
	II smoking	70	15	-	-
II Experimental group	I drying	65	20	9.7	78 - 82
	I smoking	65	5	-	-
	II drying	72	35		
	Baking	75	10		
	II smoking	65	20	-	-
III Experimental group	I drying	65	20	9.7	78 - 82
	I smoking	60	5	-	-
	II drying	72	40		
	Baking	75	10		
	II smoking	60	25	-	-
IV Experimental group	I drying	65	20	12.7	82 - 86
	I smoking	55	5	-	-
	II drying	72	42		
	Baking	75	10		
	II smoking	55	30	-	-

3. Results and Discussion

Mineral matter content in four experimental groups of boiled and four experimental groups of dried sheep meat manufactured in industrial conditions, by changing different parameters (temperature, time, relative humidity) is presented in Table 2.

There was no statistical difference in mineral matter content of all fresh boiled and dried sheep meat and it was lower than in heat treated samples. Concentration of all mineral matter in boiled sheep meat was higher than in dried sheep meat samples.

The concentrations of four toxic metals being very negligible in most of the samples, which indicates that these foodstuffs are reasonably safe from metal toxicity. Sources of heavy metals in meat samples are due to the farming, use of fertilizer, pesticide and herbicide. As a consequence of environmental pollution, the contaminants may enter the food chain.

During the boiling and drying process, the content of the elements changed depending on the experimental group. In boiled meat samples lowest concentration of all elements analyzed was obtained in fourth experimental group. Third experimental group had the highest concentration of Na, while the content of K, Ca, Mg, Fe, Mn, P, Zn, Cu, Se, Cd, Pb, Mo, and Ni was the highest in the first experimental group. During the drying process the content of the individual elements also changed depending on the experimental group. Thus, the content of all the elements (Na, K, Ca, Mg, Fe, Mn, P, Zn, Cu, Se, Cd, Pb, Mo, and Ni) tested was highest in the second experimental group until the lowest content in the third experimental group was obtained.

Principal component analysis was conducted on the basis of a correlation matrix involving the mean values of 14 quantitative chemical parameters for eight control groups, and four combinations of boiled and dried sheep meat modalities and resulted in the creation of 14 synthetic variables [17]. The first five constructed synthetic variables were analyzed in more detail through their inherent values and the share that these variables had in total variance. Principal component analysis over the correlation matrix with 14 chemical elements, the first five major components contained 99.79% of the total variance with specific properties over 0.03 (Table 3).

Analyzing the obtained vectors, the most characteristic properties were identified and determined the contribution to the total chemical variability of dried and boiled sheep meat. The variables with the most distinctive vectors in each of the main components are as follows (Table 4):

- PC1: Na, K, Mg, Cd, Pb, and Se;
- PC2: P and Ni;
- PC3: Ca;
- PC4: Mo;
- PC5: Fe, Mn, Cu and Zn.

Table 2. Mineral matter content in boiled (BO I-IV) and dried (SO I-IV) sheep meat (mg/kg)

Elements	*BO I*	*BO II*	*BO III*	*BO IV*	*SO I*	*SO II*	*SO III*	*SO IV*
Na	82.37	79.16	85.78	78.34	78.11	79.79	75.34	77.34
K	449.5	409.59	438.78	405.41	401.93	411.67	379.89	400.13
Ca	15.47	13.61	15.25	13.4	12.89	13.9	12.43	12.76
Mg	39.69	35.11	38.96	34.23	33.72	36.31	31.76	32.89
Fe	4.87	3.99	4.79	3.85	3.71	4.12	3.41	3.72
Mn	0.04	0.027	0.036	0.026	0.026	0.028	0.024	0.025
P	435.45	422.14	432.7	418.7	417.1	425.19	410.5	413.32
Zn	4.51	4.19	4.47	4.11	4.11	4.21	3.84	4.09
Cu	0.252	0.24	0.25	0.24	0.235	0.242	0.226	0.233
Se	18.45	16.89	18.12	16.35	16.17	17.31	15.26	15.59
Cd	0.2	0.11	0.19	0.1	0.09	0.14	0.08	0.08
Pb	2.11	1.56	1.92	1.43	1.31	1.74	1.16	1.21
Mo	1.98	1.42	1.85	1.34	1.27	1.56	1.22	1.23
Ni	0.46	0	0.42	0	0	0	0	0

Table3. Characteristic value, variance and cumulative variation associated with the first five main components (PCs), estimated from the correlation matrix with 14 chemical parameters for eight control groups and four combinations of boiled and four combinations of dried sheep meat

Variables	PC1	PC2	PC3	PC4	PC5
Value	12.39	1.17	0.30	0.08	0.03
Variance (%)	88.47	8.37	2.18	0.54	0.23
Cumulative variance (%)	88.47	96.84	99.02	99.56	99.79

Table 4. Contribution of each of the 14 chemical parameters for eight control groups and four combinations of boiled and four combinations of dried sheep meat

	PC 1	PC 2	PC 3	PC 4	PC 5
Na	**0.2768**	-0.1900	0.1365	0.1310	-0.0678
K	**0.2758**	-0.1971	0.1841	0.1073	-0.0820
Ca	0.2610	0.1116	**-0.6722**	0.0428	0.1177
Mg	**0.2836**	-0.0152	-0.03944	-0.1620	0.0734
Fe	0.2797	0.1280	-0.1289	-0.1531	**0.2828**
Mn	0.2544	0.3602	-0.2713	0.2790	**-0.7228**
P	0.2663	**-0.3082**	0.1418	0.1207	-0.1538
Cu	0.2725	-0.1979	-0.2597	0.2607	**0.3240**
Zn	0.2780	-0.1714	-0.0460	0.1174	**0.3048**
Cd	**0.2799**	0.0139	0.2757	-0.1871	-0.0569
Pb	**0.2771**	-0.1639	0.2164	-0.1558	-0.1592
Se	**0.2792**	-0.1590	0.0682	-0.1163	-0.1682
Mo	0.2475	0.4169	0.0316	**-0.6587**	0.0470
Ni	0.1970	**0.6137**	0.4311	0.4888	0.2940

All observed features are present with high value in one of the top five major components. Since more than 96% of the total variability of the experiment is stored in the first two components, the same will be analyzed in detail. The most important properties in the first major component, which carry 88.47% of the total variability of the experiment, are Na, K, Mg, Cd, Pb, Se. The value of 8.37% of the total variability of the experiment, which is contained in the second main component, was mostly contributed by the P and Ni. Principal component approach (PC1 and PC2) as spatial dimensions (or x and y), constructed a set of two-dimensional graphs showing the interrelations of original quantitative properties, as well as spatial distributions of all analyzed combinations of the sample factors modalities

Meat is an important source of mineral matter. Average values of all the elements analyzed in this paper in all experimental groups and treatments of fresh samples are not significantly different (as can be seen in Figure 1). Values of mineral matter in fresh meat samples were lower than those obtained in samples subjected to boiling and drying treatments.

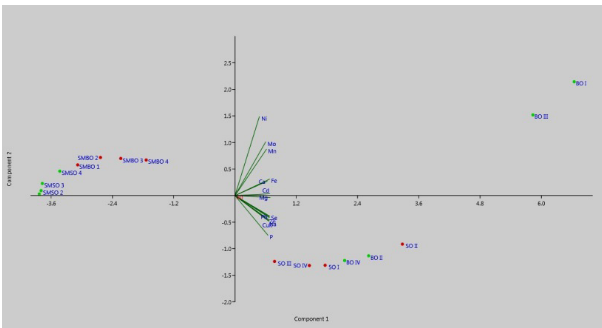

Figure 1. Separation of the set of four groups and combination of dried and boiled sheep meat on the basis of all analyzed properties using principal component analysis

As stated in the data analysis, the most important properties in the first major component, which carry 88.47% of the total variability of the assays, are Na, K, Mg, Cd, Pb, and Se. During the boiling process Na was only isolated because its maximum value was in the III experimental group (smoking temperature 60 ^{0}C, smoking time 30 min. and drying 65 - 72 ^{0}C, 60 min., relative humidity 78 - 82%) but the maximum values of all other elements was obtained in the I experimental group, with higher temperature, but smaller smoking time and relative humidity. Segregation of the elements: K, Mg, Cd, Pb, Se and P can be explained by the fact that in all the experimental groups of boiling process their concentrations were higher than in the drying process, except in the second experimental group where the values for these elements were also higher. Ni was not detected in neither drying experimental group, or in second and third experimental boiling group, and it's not in correlation with other analyzed elements.

The obtained average values of mineral matter in fresh samples tend to be higher than those obtained in studies of Vnučec and coworkers [18] on mineral matter of fresh Istrian lambs. Also, mineral matter concentration in Balouchi lamb was found to be lower in studies of Norouzian and Ghiasi, [19], in comparison with our results.

Obtained results values for the trace elements Fe, Zn, Cu, Mn, Se during the boiling and drying process were similar to the values obtained by Lucarini *et al.*, [20], who analyzed the Italian ham, and Ivanovic *et al.*, [21] who investigated samples of goat meat.

Lower concentrations of trace elements were observed in comparison to the values reported by Jimémez-Colmenero, *et al.*, [22], for Liberian prosciutto.

Mean concentration of K and Na in raw samples was higher than in the study of Valentin Goran and coworkers [23] in raw beef. On the other hand lower concentration of K and Na were described in other study of beef meat [24, 25]. Under the influence of thermal treatment mineral matter concentration has increased especially in boiled meat samples, probably due to water evaporation causing concentration of water minerals [26].

As Tomović and coworkers [10] previously highlighted, temperature and cooking time have a significant impact on the mineral content of meat. The statement was also confirmed in this study, where the values for all elements in boiled meat samples were higher than the mineral values in dried meat samples.

4. Conclusions

- The study reveals that analyzed meat products are the good sources of macro and micro nutrients and also contain the toxic elements within consumable limits.

- Despite the observed differences in the concentration of certain mineral substances, there was no significant difference between the experimental groups within the boiling and drying process. Finally, the analysis has shown that the meat samples subjected to the boiling process have a higher concentration of mineral matter compared to the dried meat samples. From the dietary point of view, various meat processing methods have influenced the content of essential mineral nutrients.

- Thermal treatment affected the concentration of all elements whose content was higher than their content in fresh samples.

- These data may be a recommendation to manufacturers to choose the most efficient way of processing meat to maintain or improve its nutritional quality.

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