MINERAL COMPOSITION OF MEAT FROM DIFFERENT SPECIES OF ANIMALS FROM SERBIA*

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Abstract

This study aimed to provide information on levels of magnesium (Mg), potassium (K), calcium (Ca), copper (Cu) and zinc (Zn) in 154 meat samples from six species of animals. Samples (chicken, turkey, pork, lamb, equine and beef meat) were gathered from different meat processing facilities in Serbia during 2023. The levels of macro- (Mg, K, Ca) and micro- (Cu, Zn) elements were determined by inductively coupled plasma mass spectrometry (ICP-MS). The highest significant mean content ($p < 0.05$) of Mg was measured in chicken meat. The highest values of K and Ca were found in pork and equine meat, respectively, and there were no significant differences between other meat species. Equine meat had the highest significant mean levels of Cu while the significantly highest Zn levels were determined in beef meat. The distribution of the elements in meat samples was examined by applying principal component analysis (PCA).

Keywords: *macro- elements; micro-elements; meat; species of animals*

INTRODUCTION

Being known as rich and suitable sources of nutrients, which are vital for the normal functioning of almost all biochemical and enzymatic processes in the body (Geiker *et al.,* 2021), meat and meat products represent a valuable part of human nutrition. For this reason, meat takes leading position among the food of animal origin (Nikolic, 2018). On the other hand, meat is probably controversial food today and is subject to the greatest number of ethical and moral, health, environmental and economic dilemmas (Font-i-Furnols & Guerrero, 2022).

Global meat production has been rising. According to Food and Agriculture Organization of the United Nations (FAO, 2023) 357 million tonnes of meat were produced in 2021, 53% more than in 2000, with chicken meat representing more than

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half the increase. According to the EFSA (European Food Safety Authority) (https://www.efsa.europa.eu/en/data-report/food-consumption-data) Comprehensive European Food Consumption Database, the average amount (kg) of fresh and frozen meat, consumed per capita per year, for Serbian population is following: beef – 8.78, pork - 14.98, poultry - 18.61, turkey – 0.18 and ovine – 0.82. With respect to the significant meat consumption pattern in Serbia, modern consumers have shown an increasing interest in meat quality and safety, especially in relation to their health.

Nowadays, authentic scientific information on the content of macro- and micro-elements in meat from different animal species from Serbia are limited (Nikolic *et al.,* 2015; Djinovic-Stojanovic *et al.*, 2017; Nikolic *et al.,* 2017). Levels of these elements in meat vary according to geographical origin, sex, animal category, their breeding and production system etc. (Nikolic, 2018; Dehelean *et al.*, 2023; Hoffman *et al.*, 2024). Therefore, this study aimed to comparatively examine meats in terms of mineral composition originating from turkey, chicken, pork, beef, lamb, and equine consumed in Serbia. Moreover, such data could be useful for future studies on the total dietary intake of these elements by the Serbian population. Principal component analysis (PCA) was used to assess the effect of species of animals on mineral composition of muscle.

MATERIALS AND METHODS

Sample collection

In total, 154 red meat samples (thigh muscles) from different species of animals (19 chicken, 8 turkey, 73 pork, 10 lamb, 10 equine and 34 beef meat) were collected in different meat processing facilities in Serbia during 2023. After the collection had been carried out, the samples were homogenized, labeled and stored in polyethylene bags and frozen at -18 °C prior to analysis.

Sample preparation and reagents

Frozen meat samples were thawed at 4 °C and homogenized, then approximately 0.5 g (wet weight) of sample was mineralized by adding 5 mL of nitric acid (67-70%, TraceMetal grade, Fisher Chemical, Belgium) and 5 mL deionized water, purity of 0.067 μS/cm, produced by a Purelab DV35 water purification system (ELGA, Buckinghamshire, UK). Microwave assisted digestion was performed in a MARS 6 iWawe Microwave Digestion System (CEM Technology, USA). After cooling at room temperature, the digests were quantitatively transferred into polypropylene volumetric flasks and diluted to 100 mL with deionized water.

Analysis of the following five elements, Mg, K, Ca, Cu and Zn, was performed by inductively coupled plasma mass spectrometry (ICP-MS) (iCap Q mass spectrometer, Thermo Scientific, Bremen, Germany). The most abundant isotopes were used for quantification. Operating conditions of the ICP-MS system were: RF power (1550 W); cooling gas flow (14 L min^{-1}); nebulizer flow (1 L min^{-1}); collision gas flow (1 mL min^{-1}); operating mode (Kinetic Energy Discrimination); dwell time (10 ms).

Standards

Standard stock solutions of each element (Mg, K, Ca, Cu and Zn) were obtained from CPA Chem (Stara Zagora, Bulgaria). The purity of the starting material in standards was 99.999% for each element. For quantitative analysis of the samples, a five-point calibration curve (including zero) was constructed for the ^{24}Mg, ^{39}K, ^{44}Ca, ^{63}Cu and ^{66}Zn isotopes.

Statistical analysis

Statistical analysis of experimental data was performed using software Statistica 10.0 (StatSoft Inc., Tulsa, OK, USA). For testing the differences in elements levels between different meat and between total group results one-way analysis of variance (ANOVA) and Tukey's HSD were applied. Statistically significant differences were expressed at the probability level of 0.05. PCA was used to group the observed samples and to discover any possible correlations among the element levels.

RESULTS AND DISCUSSION

The contents of five elements (Mg, K, Ca, Cu and Zn) in chicken, turkey, pork, lamb, equine and beef meat, expressed in terms of mean and standard deviation (SD) are presented in Table 1.

Table 1. Levels (mg/kg) of five selected elements (Mg, K, Ca, Cu and Zn) in meat from six animal species

	Element levels (mg/kg)				
Animal species	Mg	K	Ca	Cu	Zn
Beef, n=34					
Mean	218.76 [a]	3913.62 [a]	44.00 [a]	0.70 [b]	47.43 [d]
SD	34.32	506.69	18.89	0.30	16.20
Equine, n=10					
Mean	230.78 [a, b]	3605.53 [a]	62.51 [a]	1.37 [c]	33.12 [c]
SD	43.06	498.54	19.19	0.53	14.47
Lamb, n=10					
Mean	235.52 [a, b]	3720.47 [a]	38.53 [a]	0.77 [b]	29.95 [b, c]
SD	41.23	413.53	25.00	0.23	6.99
Pork, n=73					
Mean	255.55 [a, b]	4120.41 [a]	51.56 [a]	0.55 [a, b]	20.60 [a, b]
SD	46.12	471.33	27.98	0.27	9.34
Turkey, n=8					
Mean	269.59 [b, c]	3955.08 [a]	56.76 [a]	0.49 [a, b]	24.01 [b, c]
SD	39.15	428.40	19.86	0.26	14.75
Chicken, n=19					
Mean	307.15 [c]	3820.04 [a]	51.67 [a]	0.30 [a]	11.16 [a]

SD	49.05	495.24	13.65	0.13	4.47

[a–d] Values within the same column with different superscripts are significantly different ($p < 0.05$).

The mean levels (mg/kg) of elements were in the range of 218.76-307.15 (Mg), 3605.53-4120.41 (K), 38.53-62.51 (Ca), 0.30-1.37 (Cu) and 11.16-47.43 (Zn). Some significant differences in the levels of Mg, Cu and Zn ($p<0.05$) were found between meat from different animal species, while K and Ca levels were not significantly different.

The highest mean level of Mg was determined in chicken meat (307.15 mg/kg). It was significantly higher than Mg mean levels measured in all other analysed meat while the mean Mg level in turkey meat was only significantly higher than the Mg level in beef meat. The mean Mg levels in the current study were in line with the data reported by the Frida Food Data (2024).

The highest mean levels of K (4120.41 mg/kg) and Ca (62.51 mg/kg) were measured in pork and equine meat, respectively, but there were no significant differences between meat species. Lower levels of K were found by Bilandzic et al. (2021) in beef and pork than in this study (Table 1). The mean K level in chicken meat was close to the data reported by Bilandzic *et al*. (2021) while the data from USDA Food database Central (2024) showed lower concentration of K in beef, turkey and chicken meat than in this study. The mean Ca levels in all analysed meat species (Table 1.) were lower while the mean K levels were higher than those published by Frida Food Data (2024).

The mean level of Cu in equine meat (1.37 mg/kg) was significantly higher than Cu mean level measured in all other analysed meat. Also, the mean levels of Cu in lamb and beef meat were significantly higher than measured Cu mean level in chicken meat. The mean Cu levels in meat from six animal species were similar to concentrations reported by Lombardi-Boccia *et al*. (2005), ((mg/kg): Beef: 0.3-0.9; lamb: 1.0; horse: 1.2; pork: 0.4-0.7; chicken: 0.4-1.1; turkey: 0.3-1.2). Considerable higher levels of Cu in sheep and horse (8.53 and 8.45 mg/kg) were found by Bilandzic et al. (2010).

The mean level of Zn in beef meat (47.43 mg/kg) was significantly higher than Zn mean level measured in all other analysed meat and was in line with the data for raw beef meat (39.4-47.5 mg/kg) from Italian markets (Lombardi-Boccia *et al*., 2005). The obtained mean levels of Zn in equine, lamb and turkey meats were significantly higher than Zn mean level measured in chicken meat (11.16 mg/kg), which was similar with those found in our previously investigation (chicken cuts – drumstick: 14.1 mg/kg) (Djinovic-Stojanovic *et al*., 2017).

Principal component analysis (PCA)

PCA was applied to the correlation matrix, which included the five parameters for the meat from six animal species (Hammer *et al*., 2001). PCA was applied to group the observed the possible correlations among the measured Mg, K, Ca, Cu and Zn levels and the animal species (chicken, turkey, pork, lamp, equine and beef meat) (Figure 1). The first two components (PC1 and PC2) resulting from the examination of the levels

of micro- and macro-elements in meat from different animal species accounted for 82.48% of the total variance (PC1 53.37%, PC2 29.11%). In the case of PC1, the levels of Cu and Zn (significant positive correlations) as well as the Mg level (significant negative correlation) contributed the most to the variability of the meat samples. In the case of PC2, significant positive correlation was established for Ca level, while a significant negative correlation was established for the K level. For the third principal component (PC3), the level of K achieved a strong positive correlation, while the Mg level produced a strong negative correlation. For the fourth principal component (PC4), the level of Zn achieved strong positive correlations, while the Cu level produced a strong negative correlation. Figure 1 shows the Cu and Zn levels, as well as the Mg and K levels were highly positively correlated. However, the Mg and Zn levels, as well as the Cu and K levels were highly negatively correlated.

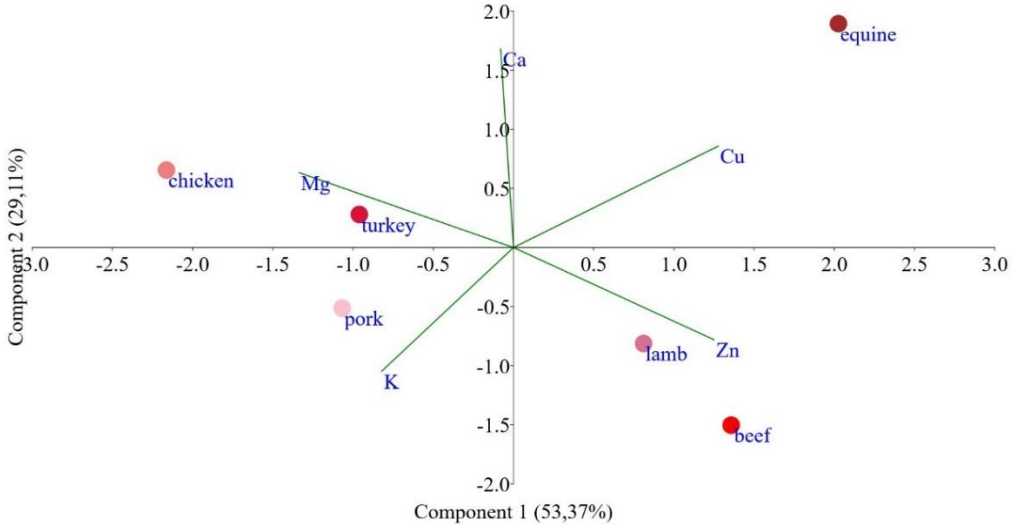

Figure 1. Bi-plot graphic of PCA of Mg, K, Ca, Cu and Zn levels in meat from different animal species.

The influence of different parameters, that described the examined meat samples, can be evaluated from Figure 1. Examined meat from different animal species are located on different sides of the graphic. Equine meat, in which the highest Ca and Cu levels were observed, was located on the upper right side of the graphic. The chicken and turkey meat were on the opposite side of the graphic (upper left), in which the highest Mg levels were observed in comparison with other meat. Chicken meat was located the furthest on that side, since chicken meat contained higher Mg levels than turkey meat. The pork meat samples, in which the highest K levels were observed, were located on the lower left side of the graphic. The lamb and beef meat samples were on the opposite side of the graphic (lower right) with regard to their high Zn levels. Beef meat was

located the furthest on that side, since beef meat contained highest Zn levels than other analysed meats.

CONCLUSIONS

Levels of Mg, K, Ca, Cu and Zn in chicken, turkey, pork, lamp, equine and beef meat were determined and estimated by comparing with levels found in similar meat samples from literature data. There is a variability in elements content in meat among studies. Our findings suggest some significant differences in Mg, Cu and Zn levels among meat from different animal species. The significantly highest Mg, Cu and Zn levels were determined in chicken, equine and beef meat, respectively. The highest K and Ca levels were determined in pork and equine meat, respectively. Considering the importance of meat as a source of needed minerals, our results can be useful for future studies on total dietary intake of human population. Having in mind the permanent breeding improvement of animals, further control of meat mineral composition is recommended.

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MINERALNI SASTAV MESA OD RAZLIČITIH VRSTA ŽIVOTINJA U SRBIJI

U ovom radu određen je sadržaj magnezijuma (Mg), kalijuma (K), kalcijuma (Ca), bakra (Cu) i cinka (Zn) u 154 uzoraka mesa koje potiču od šest vrsta životinja. Uzorci mesa (piletina, ćuretina, svinjetina, jagnjetina, junetina i konjsko meso) su uzeti iz različitih postrojenja za preradu mesa u Srbiji tokom 2023. godine. Sadržaji makro- (Mg, K, Ca) i mikro- (Cu, Zn) elemenata određeni su primenom induktivno kuplovane plazme sa masenom spektrometrijom (inductively coupled plasma mass spectrometry, ICP-MS). Najveći, statistički značajan ($p < 0.05$), sadržaj Mg utvrđen je u uzorcima pilećeg mesa. Svinjsko meso imalo je najveći sadržaj K, a konjsko meso najveći sadržaj Ca, ali se ti sadržaji nisu statistički razlikovali u odnosu na sadržaje tih elemenata u drugim analiziranim vrstama mesa. Statistički značajne razlike utvrđene su između sadržaja Cu, kao i između sadržaja Zn u analiziranim vrstama mesa. Konjsko meso je imalo najveći sadržaj Cu dok je u uzorcima junetine utvrđen najveći sadržaj Zn. Distribucija elemenata u uzorcima mesa analizirana je primenom PCA analize (principal component analysis, PCA).

Ključne riječi: *makroelementi, mikroelementi, meso, vrsta životinje*