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COMPARATIVE STUDY OF SOME TRACE ELEMENTS AND MACROMINERALS IN PIG LEG DEPENDING ON THE COOKING METHOD

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Abstract

A comparative study of trace elements and macrominerals in pork can provide valuable information about how the safety and nutritional level of the meat is affected by the cooking method. This study aimed to assess the effects of three cooking methods (roasting, boiling, and microwaving) on the mineral composition of pig leg. In this study, minerals' concentration in raw and cooked pork samples were determined by ICP-OES. Roasting, boiling, and microwaving can lead to different effects on the minerals and the toxins present in the meat. The studied cooking methods influenced the mineral composition and nutritional value in cooked pig leg samples compared to raw ones, with impact on the minerals' intake. Generally, macromineral levels increased in cooked pork samples and trace elements decreased, with roasting improving the mineral nutritional value of pig leg.

Key words: *pig leg, trace elements, macrominerals, cooking method.*

INTRODUCTION

Meat plays a crucial role in providing the organism with essential minerals and nutrients (De Smet & Vossen, 2016). It is a significant dietary source that provides the body with vital minerals, such as iron, zinc, and selenium, essential in maintaining overall health and preventing various diseases. Meat can be a valuable part of a healthy diet when consumed in moderation and alongside a variety of other nutrient-rich foods. However, there are risks associated with excessive meat consumption (Giromini & Givens, 2022; Pereira & Vicente, 2013).

The quality of food has been negatively impacted by pollution, which has become a major source of exposure for people to harmful minerals (Chen et al., 2022; Wang et al., 2018). As a result, it is important to consider the accumulation of metallic pollutants in animal tissues, as well as the potential impact of toxic metals on essential metal levels in animals raised in industrialized areas (Chałabis-Mazurek et al., 2021; Shahjahan et al., 2022).

Some cooking methods can lead to the loss of nutrients, while others can increase the bioavailability of these nutrients. Overall, proper thermal preparation of meat is important for both food safety and nutritional quality (Rao et al., 2022; Suleman et al., 2020). The cooking method can affect the level of trace elements and macro-minerals in meat. The degree of mineral loss in cooked food is influenced by various factors such as cooking method and food type. Roasting is observed to result in less mineral loss compared to boiling, especially for foods of the same type. (Biel et al., 2019; Goran et al., 2016; Oz et al., 2016).

The pink meat of pork is a popular and widely consumed meat globally, providing essential nutrients such as protein, vitamins, and minerals (Biesalski, 2005).

The objective of this study is to investigate how the mineral levels of pork leg are affected by three distinct cooking methods, namely roasting, boiling, and microwaving. This study can provide valuable insights into how to prepare pork in a way that preserves its nutritional value and contributes to overall health and wellbeing.

MATERIALS AND METHODS

Samples of pork leg were obtained from the gluteus muscle of crossbred barrows farmed in

Romania. The barrows were between 6-8 months old and weighed approximately 100 kg. The meat samples were cut into similar square dimensions (approximately 2*2*2 cm pieces), weighed, labelled, and packed in temperature-resistant food plastic bags. Each bag contained four samples of 20 g ± 5% each. A total of 48 samples were divided into four groups: boiled, roasted, microwave irradiated, and raw. For each cooking method, the time for cooking was estimated after several tests to achieve edible samples. The bags were positioned in the centre of the electric/microwave oven tray/plate for roasting and microwave cooking, with no contact between the meat samples and oven tray/plate. The samples were then cooled for 5 hours at an ambient temperature of 20ºC, after which the liquid was discarded, and the samples were stored at 6ºC for 24 hours. Before grinding using the knife mill, raw and cooked samples at 6ºC were drained off.

0.5 g (wet weight - ww) was taken from each sample and digested using a Berghof Spedwave MWS-2 microwave oven as follows: Step 1: 120°C, 50% power; Step 2: 180°C, 75% power; Step 3: 100°C, 40% power.

The digested samples were diluted with ultrapure water to a volume of 25 mL and analyzed using a Thermo iCAP ICP-OES spectrometer (RF1100 W). The spectrometer had a reading time of 30 seconds and a washing time of 30 seconds, with a nebulizer gas flow of 0.5 L/min, an auxiliary gas flow of 0.5 L/min, and a sample injection pump flow of 50 rpm. Calibration curves were created using standard solutions of 0.001 ppm, 0.01 ppm, 0.1 ppm, 1 ppm, 5 ppm, 10 ppm, and 50 ppm, prepared by diluting a multi-element ICP MERCK standard that contained 1000 mL/L of Al, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Se, Sr, and Zn. The concentrations of minerals that were below the method detection limit are not reported in this study.

Non parametric statistical analysis was performed for the obtained data using SPSS software. The Kruskal-Wallis test by ranks was used to determine whether there were significant differences between the levels of all analyzed mineral concentrations based on the cooking method. The difference between groups was considered to be statistically significant when P value was below 0.05, and it was highly significant when P value was below 0.001.

RESULTS AND DISCUSSIONS

Table 1 presents the average mineral levels of both raw and cooked pork leg. Among the 20 elements tested (Al, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Se, Sr, and Zn), only Al, Ba, Ca, Cu, Fe, K, Li, Mg, Na, Sr, and Zn were detected at levels above the limit of detection, and significant differences were observed between the various cooking methods for K, Fe, and Zn. The primary macro-minerals present in both raw and cooked meat were K (with average levels ranging from 267.115-370.431 ppm), followed by Na (with average levels ranging from 27.035-44.848 ppm), and Mg (with average levels ranging from 22.064-27.187 ppm).

Table 1. Total mineral levels* (ppm ww) in pork leg samples after different cooking method preparation

Element	Cooking method	Mean	Std Dev	Std Err Mean	*p*-value
Al	Raw	0.425	0.1313	0.0758	0.668
	Boiled	0.424	0.2574	0.1486	
	Roasted	0.559	0.0866	0.0500	
	Microwaved	0.467	0.0689	0.0398	
Ba	Raw	0.194	0.1033	0.0596	0.117
	Boiled	0.346	-	-	
	Roasted	0.049	0.0354	0.0251	
	Microwaved	-	-	-	
Ca	Raw	5.026	0.7488	0.4323	0.121
	Boiled	5.911	0.4473	0.2582	
	Roasted	6.573	0.7554	0.4361	
	Microwaved	6.530	0.7621	0.4400	

Cu	Raw	0.191	0.1068	0.0617	0.536
	Boiled	0.240	0.3393	0.2399	
	Roasted	0.144	0.0842	0.0486	
	Microwaved	0.064	0.0410	0.0236	
Fe	Raw	4.126 [a]	3.0095	1.7375	**0.022**
	Boiled	1.136 [b]	0.3985	0.2301	
	Roasted	1.751	0.2568	0.1483	
	Microwaved	1.446 [b]	0.0573	0.0331	
K	Raw	267.115 [a]	32.7415	18.9033	**0.049**
	Boiled	305.780	11.5961	6.6950	
	Roasted	370.431 [b]	55.2186	31.8805	
	Microwaved	293.281	14.7102	8.4929	
Li	Raw	0.518	0.0876	0.0506	0.183
	Boiled	0.459	0.2819	0.1627	
	Roasted	0.341	0.0718	0.0415	
	Microwaved	0.272	0.0562	0.0325	
Mg	Raw	22.064	3.1389	1.8122	0.369
	Boiled	23.507	1.1136	0.6429	
	Roasted	27.187	3.8062	2.1975	
	Microwaved	23.420	1.0497	0.6060	
Na	Raw	27.035	2.4004	1.3858	0.094
	Boiled	36.130	2.8528	1.6470	
	Roasted	44.848	10.6204	6.1317	
	Microwaved	33.666	4.2989	2.4820	
Sr	Raw	0.245	0.0560	0.0323	0.101
	Boiled	0.470	-	-	
	Roasted	0.221	0.0867	0.0500	
	Microwaved	0.095	0.0758	0.0437	
Zn	Raw	1.068 [a]	0.0387	0.0224	**0.050**
	Boiled	1.679	0.2964	0.1711	
	Roasted	1.864	0.1277	0.0737	
	Microwaved	1.994 [b]	0.2305	0.1331	

*Levels connected by different letters are significantly different. Comparison can't be made between different elements levels.

The mineral composition is influenced by various factors, including but not limited to species, breed, gender, age, muscle type, diet, genetics, and cooking method (Goran et al., 2016; Lebret & Čandek-Potokar, 2022; Tornberg, 2005; Wereńska et al., 2022).

Cooking of meat typically leads to higher macro-mineral levels compared to raw samples due to water loss during cooking. The extent of mineral loss depends on the cooking method and the solubility of the minerals. On the other hand, levels of Zn and Al were generally lower in raw samples than in cooked meat, independent of the cooking method.

The statistical analysis of the minerals' concentrations of the pork cooked by different methods showed no significant influence on the overall pork leg nutritional value (Table 1). However, the level of Zn was found to be significantly higher in microwaved meat compared to the raw samples.

The mean level of Fe showed significant differences after cooking ($p < 0.05$). Pork is known as one of the main sources of heme Fe, which is the form of Fe with the highest bioavailability (Menezes et al., 2018). Previous studies have indicated that the levels of soluble heme Fe generally decrease from raw meat to cooked meat, depending on the increasing cooking temperature (Goran et al., 2016; Purchas et al., 2004). Similarly, in the present study, the Fe levels in pork showed statistically significant decreases after cooking, regardless of the cooking type. This may be due to the difference between the heme Fe levels of haemoglobin and myoglobin origin, which are soluble and insoluble heme Fe, respectively (Cabrera et al., 2010).

The mean Zn values significantly increased ($p < 0.05$) in cooked pork samples compared to raw meat. Moreover, the different cooking methods used for pork showed significant differences ($p < 0.05$), with microwaved pork samples having the highest average level of Zn. These significant differences in Zn mean level in cooked pork samples were likely due to an increase in the insoluble Zn fraction in denatured proteins in pork leg (Goran et al., 2016; Menezes et al., 2018).

The K level increased significantly ($p < 0.05$) after roasting, which may be attributed to the reduction of K leaching into the cooking water, potentially induced by the use of temperature-resistant plastic bag cooking. Previous research has indicated that dry cooking methods can result in increased mineral level due to water evaporation (Borela et al., 2022; Goran et al., 2016; Omojola et al., 2015). The average levels of the other studied macro-minerals Ca, Mg, and Na were higher in roasted pork, but not significantly different compared to raw pork samples, results which are consistent to their lower leach into lost cooking liquids.

Al, Ba, Cu, Li, and Sr levels in pork cooked samples, did not register statistically significant differences between raw and cooked samples. The average levels of Al in roasted pork were higher than in raw pork samples, but the difference was not statistically significant. Ba level in microwaved samples could not be observed due to average levels below analysis method detection limits.

The mean levels of Cu and Sr in cooked pork samples showed an increase in boiled samples, but the differences were not significant. The mean level of both trace minerals in the other cooked pork samples decreased, but not significantly when compared to the average levels found in raw meat samples. A higher level of Sr was observed in boiled pork samples, while it decreased in the other cooked samples. This trend was inversely related to the lower levels of Ca in boiled samples, which increased in the other cooked samples. This is likely because Sr shares similar properties with Ca (Goran et al., 2016; Zhao et al., 2016). There were no significant ($p > 0.05$) differences observed in the average Li levels in cooked pork samples, with the highest levels being found in raw pork samples and the lowest levels in the microwaved pork samples.

CONCLUSIONS

The chemical composition and nutritional value of pork can be influenced by different cooking methods, which in turn can impact the intake of essential mineral nutrients. Thermal preparation has been shown to affect the levels of Fe, K, and Zn in cooked pork samples compared to raw ones, with significant differences observed in boiled and microwaved samples for Fe levels, and in microwaved samples for Zn levels. Regarding macro-elements, only roasted samples showed significant differences, specifically for K. Roasting appears to be the most effective pork cooking method for improving the mineral nutritional value of the meat. This information can serve as a recommendation for consumers to choose the most effective cooking method for maintaining or improving the nutritional quality of pork.

REFERENCES

Biel, W., E, C.-P., & A, K. (2019). Offal Chemical Composition from Veal, Beef, and Lamb Maintained in Organic Production Systems. *Animals (Basel), 9*(8), 489. doi:10.3390/ani9080489

Biesalski, H. (2005). Meat as a component of a healthy diet – are there any risks or benefits if meat is avoided in the diet? *Meat Science, 70*(3), 509–524. doi:10.1016/j.meatsci.2004.07.017

Borela, V., de Alencar, E., Mendonça, M., Han, H., Raposo, A., Ariza-Montes, A., . . . Zandonadi, R. (2022). Influence of Different Cooking Methods on Fillet Steak Physicochemical Characteristics. *Int. J. Environ. Res. Public Health, 19*, 606. doi:10.3390/ijerph19010606

Cabrera, M., Ramos, A., Saadoun, A., & Brito, G. (2010). Selenium, copper, zinc, iron and manganese level of seven meat cuts from Hereford and Braford steers fed pasture in Uruguay. *Meat Science, 84*(3), 518–528. doi:10.1016/j.meatsci.2009.10.007

Chałabis-Mazurek, A., Valverde Piedra, J., Muszyński, S., Tomaszewska, E., Szymańczyk, S., Kowalik, S., . . . Schwarz, T. (2021). The Concentration of Selected Heavy Metals in Muscles, Liver and Kidneys of Pigs Fed Standard Diets and Diets Containing 60% of New Rye Varieties. *Animals (Basel), 11*(5), 1377. doi:10.3390/ani11051377

Chen, L., Zhou, M., Wang, J., Zhang, Z., Duan, C., Wang, X., . . . Fang, L. (2022). A global meta-analysis of heavy metal(loid)s pollution in soils near copper mines: Evaluation of pollution level and probabilistic health risks. *Sci Total Environ, 835*, 155441. doi:10.1016/j.scitotenv.2022.155441

De Smet, S., & Vossen, E. (2016). Meat: The balance between nutrition and health. A review,. *Meat Science, 120*, 145-156. doi:10.1016/j.meatsci.2016.04.008.

Giromini, C., & Givens, D. (2022). Benefits and Risks Associated with Meat Consumption during Key Life Processes and in Relation to the Risk of Chronic Diseases. *Foods, 11*(14), 2063. doi:10.3390/foods11142063

Goran, G., Tudoreanu, L., Rotaru, E., & Crivineanu, V. (2016). Comparative study of mineral composition of beef steak and pork chops depending on the thermal preparation method. *Meat Science, 118*, 117-121. doi:10.1016/j.meatsci.2016.03.031

Lebret, B., & Čandek-Potokar, M. (2022). Review: Pork quality attributes from farm to fork. Part I. Carcass and fresh meat. *Animal, 16*(Supplement 1), 100402. doi:10.1016/j.animal.2021.100402

Menezes, E., Oliveira, A., França, C., Souza, G., & Nogueira, A. (2018). Bioaccessibility of Ca, Cu, Fe, Mg, Zn, and crude protein in beef, pork and chicken after thermal processing. *Food Chem, 240*, 75-83. doi:10.1016/j.foodchem.2017.07.090

Omojola, A., Ahmed, S., Attoh-Kotoku, V., & Wogar, G. (2015). Effect of cooking methods on cholesterol, mineral composition and formation of total heterocyclic aromatic amines in Muscovy drake meat. *J Sci Food Agric., 95*(1), 98-102. doi:10.1002/jsfa.6687

Oz, F., Aksu, M., & Turan, M. (2016). The Effects of Different Cooking Methods on Some Quality Criteria and Mineral Composition of Beef Steaks. *Journal of Food Processing and Preservation, 41*(4), e13008. doi:10.1111/jfpp.13008

Pereira, P., & Vicente, A. (2013). Meat nutritional composition and nutritive role in the human diet. *Meat Science, 93*(3), 586-592. doi:10.1016/j.meatsci.2012.09.018

Purchas, R., Rutherfurd, S., Pearce, P., Vather, R., & Wilkinson, B. (2004). Cooking temperature effects on the forms of iron and levels of several compounds in beef semitendinosus muscle. *Meat Science, 68*, 201–207.

Rao, J., Meng, F., Li, Y., Chen, W., Liu, D., & Zhang, J. (2022). Effect of cooking methods on the edible, nutritive qualities and volatile flavor compounds of rabbit meat. *J Sci Food Agric., 102*(10), 4218-4228. doi:10.1002/jsfa.11773

Shahjahan, M., Taslima, K., Rahman, M., Al-Emran, M., Alam, S., & Faggio, C. (2022). Effects of heavy metals on fish physiology - A review. *Chemosphere, 300*, 134519. doi:10.1016/j.chemosphere.2022.134519

Suleman, R., Wang, Z., Aadil, R., Hui, T., Hopkins, D., & Zhang, D. (2020). Effect of cooking on the nutritive quality, sensory properties and safety of lamb meat: Current challenges and future prospects. *Meat Science, 167*, 108172. doi:10.1016/j.meatsci.2020.108172

Tornberg, E. (2005). Effects of heat on meat proteins – Implications on structure and quality of meat products. *Meat Science, 70*(3), 493–508. doi:10.1016/j.meatsci.2004.11.021

Wang, M., Zhang, R., He, K., & Chen, L. (2018). Concentrations and health risks of heavy metals in vegetables from typical farmland in the Pearl River Delta, South China. *Ecotoxicology and Environmental Safety, 147*, 548-556. doi:10.1016/j.ecoenv.2017.09.029

Wereńska, M., Haraf, G., Okruszek, A., Marcinkowska, W., & Wołoszyn, J. (2022). The Effects of Sous Vide, Microwave Cooking, and Stewing on Some Quality Criteria of Goose Meat. *Foods, 12*(1), 129. doi:10.3390/foods12010129

Zhao, Y., Wang, D., & Yang, S. (2016). Effect of organic and conventional rearing system on the mineral level of pork. *Meat Science, 118*, 103-107. doi:10.1016/j.meatsci.2016.03.030