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Original Scientific Paper

Daily consumption of sodium and nitrite from Serbian meat products: insights from principal component analysis

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ABSTRACT

Sodium chloride and nitrite play important roles in the meat processing industry, significantly influencing the safety, technological, and sensory properties of meat products, with nitrite classified as a food additive and sodium chloride as a food ingredient. Besides this important technological role, excessive intake can lead to human health disorders. Thus, the content of sodium chloride and nitrite in meat products on the Serbian market were analyzed using principal component analysis. A total of 64 meat products produced by the 18 most notable meat processors were collected from the Serbian retail market. The meat products collected belonged to four different groups: dry fermented sausages, finely comminuted cooked sausages, canned meat in pieces, and liver sausages and pates. Mean sodium chloride and nitrite contents for all analyzed meat products were 1.91 g/100g (the highest was for dry fermented sausages 3.67 g/100g; the lowest was for liver sausages and pates 1.19 g/100g) and 7.66 mg/kg (the highest was for chicken hot dogs 13.79 mg/kg; the lowest was for dry fermented sausages 2.17 mg/kg), respectively. The nitrite content in all analyzed meat products was in accordance with the European and Serbian legislation. Considering daily consumption of meat products and dried meat products in Serbia, and based on the obtained results, it can be concluded that consumers in Serbia exceed the recommended average daily consumption for sodium chloride. In conclusion, all possibilities for further reduction of sodium chloride consumption should be considered, especially because Serbia is a high risk country for cardiovascular diseases.

1. Introduction

Sodium chloride (salt) and nitrite are widely used in the meat processing industry due to their significant impact on the safety, technological, and sensory properties of meat products. Sodium chloride has historically been used in meat preservation due to its bacteriostatic effects. Moreover, it contributes to protein hydration and water-binding capacity, improves texture, and intensifies the aroma, flavor, and color of meat products (*Desmond*, 2006; *Haddad et al*., 2018; *Inguglia et al*., 2017; *Matthews & Strong*, 2005; *Pretorius & Schönfeldt*, 2018; *Rede & Petrović*, 1997;

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Ruusunen & Puolanne, 2005; *Wu et al*., 2015). Apart from its important role in the safety and quality of meat products, in the human body, sodium and chloride are essential for nerve and muscle function, fluid balance, and regulation of blood pH and pressure (*Catterall*, 2000; *Jentsch et al*., 2002).

Like salt, nitrite also influences the safety of meat products due to its ability to prevent and control the growth of pathogenic and undesirable microorganisms, especially *Clostridium botulinum* and *Listeria monocytogenes*. Furthermore, it has the ability to prevent lipid oxidation, and it improves the sensory properties of meat products by contributing to the development of their characteristic pink color, taste, and aroma (*Honikel*, 2008; *Parthasarathy & Bryan*, 2012; *Sebranek*, 2009).

Despite their technological benefits, excessive intake of salt and nitrite can adversely affect human health, which is why this topic has been receiving increasing public health attention. High sodium consumption increases the risk of hypertension, cardiovascular diseases, and other conditions (*Aburto et al*., 2013; *WHO*, 2010, 2016; *Wu et al*., 2015). Nitrites can form carcinogenic nitrosamines and contribute to toxic effects, such as methemoglobinemia and increased cancer risk (*Choi et al*., 2007; *EFSA*, 2010; *Gilchrist et al*., 2010; *Zhang et al*., 2018). These risks are particularly relevant in Serbia, where in 2024, 49.72% of deaths were due to cardiovascular diseases and 21.79% to cancer (*Statistical Office of the Republic of Serbia*, 2024). In response to these risks, regulatory frameworks limit nitrite content to 150 mg/kg (100 mg/kg for sterilized canned meats), with exceptions for traditional products (*European Commission*, 2011; *Serbian Regulation*, 2008). In contrast, the sodium chloride content in foods is not strictly regulated at the EU level, although international health authorities have issued recommendations for reduced intake, typically less than 5–6 g of salt (2–2.4 g of sodium) per day (*EFSA*, 2019; *WHO*, 2012; *WHO*, 2023; *FSA*, 2024; *Desmond*, 2006; *Matthews & Strong*, 2005). Instead, the EU Salt Reduction Framework has established non-binding, category-specific targets for sodium reduction, while some countries have introduced their own mandatory national benchmarks. For instance, Norway has defined precise targets for salt in meat products (sausages 1.6 g/100 g, pâté 1.5 g/100 g, dried sausages up to 5.0 g/100 g), whereas Bulgaria has implemented compulsory limits on salt content in processed meat products, such as up to 2 g/100 g for general meat products and up to 3.5 g/100 g for cured sausages. (*World Action on Salt, Sugar & Health*, 2025*; Norwegian Directorate of Health*, 2016; *European Commission; European Public Health Alliance*, 2021).

Considering the importance of monitoring sodium chloride and nitrite intake, this study analyzed their content in 64 meat products from four categories most commonly consumed in the Serbian diet. All samples were produced by the most prominent meat processors on the national market. Principal component analysis (PCA) was applied to provide a representative overview and support potential strategies for improving public health through informed regulatory measures.

2. Materials and methods

2.1. Meat products

A total of 64 meat products, produced by the 18 preeminent meat processors (P1-P18) were collected from the Serbian retail market. The meat products belonged to four different groups, defined by the Regulation on the Quality of Minced Meat, Semi-finished Meat Products, and Meat Products (*Serbian Regulation*, 2023) widely consumed in Serbian diet. The first group comprised dry fermented sausages (n=10) of the product type called "čajna kobasica" (PC). The second group was finely comminuted cooked sausages (n=21), of which 11 were chicken hot dogs (PPV) and 10 pork hot dogs (PSV). The third group consisted of canned meat in pieces (n=20), of which 11 were made of chicken meat called "pileća prsa" (PP) and 9 were pork products called "pizza šunka" (PS). Finally, the fourth group was liver sausages and pâtés (n=13), and all were the liver pâté called "jetrena pašteta" (PJ). After collection, the meat products were homogenized and stored at -18°C until analysis. All determinations were conducted in triplicate.

2.2. Sodium chloride and sodium nitrite content determination

The sodium content was determined using the FINSLab-5.4-3M-037 method for the determination of Na, K, Mg, Ca, and Mn in food by atomic absorption spectrophotometry, in accordance with the Rulebook on Food Declaration, Labeling and Advertising (*Serbian Regulation*, 2024). Based on the determined sodium content, the sodium chloride content was calculated in accordance with the Rulebook on Food

Declaration, Labelling and Advertising (*Serbian Regulation*, 2024) and expressed as grams of sodium chloride per 100 grams of sample. Residual nitrite content was determined according to the international standard (*ISO*, 1975) and expressed as mg nitrite/kg sample (*Peulić et al.*, 2020).

2.3. Statistical analysis

PCA was carried out using Statistica 13.5.0.17 software (TIBCO, Palo Alto, United States). PCA was performed to visualize differences between meat products groups and between samples in sodium chloride and nitrite content.

3. Results

The results of the PCA are presented in Figure 1. Figure 1a displays the PCA loading plot, which illustrates the contribution of individual variables—sodium chloride and nitrite—to the separation of the analyzed meat products. As evident from the plot, both variables significantly influenced the distribution of the meat products within the PCA space. Moreover, the two variables were not correlated, indicating that a higher nitrite content in a sample did not necessarily correspond to a lower sodium chloride content, and vice versa. Most meat products clustered closely around the origin of the PCA score plot (Figure 1b), suggesting a high degree of similarity in sodium and nitrite content across the majority of analyzed products. Only a limited number of meat products deviated significantly from this cluster, reflecting potential product-specific formulation practices or technological differences in processing.

The mean sodium chloride content across all analyzed meat products was 1.91 g/100 g. As shown in the PCA score plot (Figure 1b), samples of čajna kobasica (a dry fermented sausage) were positioned in the negative quadrant of the first principal component (F1), with their distribution strongly influenced by sodium chloride content. This group exhibited the highest mean sodium chloride concentration (3.67 g/100 g), with a particularly elevated level observed in the product produced by manufacturer no. 4. These results are consistent with previously reported data for traditional Serbian dry fermented sausages (*Ikonić et al*., 2020), and exceed levels recorded by *Vranić et al*. (2009) for similar products on the domestic market. In contrast, liver sausages and pâtés exhibited the lowest sodium chloride levels, averaging 1.19 g/100 g. Notably, three meat products from this group (PJ4, PJ11, and PJ18) had sodium chloride contents below 1.00 g/100 g and were located in the positive region of F1, showing a clear difference from the dry fermented sausages. Finely comminuted cooked sausages contained, on average, 2.10 g/100 g (chicken hot dogs) and 1.95 g/100 g (pork hot dogs) of sodium chloride, while canned meat products ranged from 1.35 g/100 g in pileća prsa to 1.41 g/100 g of sodium chloride in pizza šunka.

On average, 183.47 g of meat and meat products are consumed daily in Serbia. Among these, meat products are the third most commonly consumed group, after poultry and pork, contributing 38.06 g per day, whereas dried meat products rank fifth, with 12.9 g consumed daily. The mean sodium chloride content in the studied meat products was 1.91 g/100g, and in dried meat products, obtained by *Vranić et al*., (2009), was 5.09 g/100g, which means that the average consumer in Serbia would intake 0.73 and 0.66 g of sodium chloride daily from meat products and dried meat products, respectively. In many countries, meat and meat products are the second largest contributors to dietary salt intake, after baked goods, and the meats contribute around 20% of the sodium intake (*Desmond*, 2006). From these data, it is clear that the average daily intake of sodium chloride from meat products and dried meat products, added together, is 1.39 g. Moreover, the mean sodium chloride content in meat products observed in this study (1.91 g/100 g) exceeds the WHO global sodium benchmarks for liver sausages (525 mg Na/100 g, equivalent to 1.33 g/100 g of salt), hot dogs (540 mg Na/100 g, equivalent to 1.37 g/100 g of salt), and cured meat (950 mg Na/100 g, equivalent to 2.41 g/100 g of salt), highlighting the need for effective sodium reduction strategies in Serbian meat products.

According to the PCA loading plot (Figure 1a), nitrite content—represented in the positive quadrant of F1—significantly contributed to the separation of five meat products (PPV10, PPV4, PP7, PPV2, and PS9), each exhibiting nitrite concentrations exceeding 19 mg/kg (ranging from 19.16 to 39.12 mg/kg). Group-wise means were as follows: 4.59 mg/kg for liver sausages and pâtés, 7.02 mg/kg for pork hot dogs, and 9.27 mg/kg and 9.41 mg/kg for chicken and pork canned meats, respectively.

Based on the mean nitrite content of 7.66 mg/kg for meat products and 10.7 mg/kg for dried meat products (*Bajčić et al*., 2018), and using the same consumption figures as above (38.06 g and 12.9 g/day), the estimated nitrite intake is 0.29 mg/day from

meat products and 0.10 mg/day from dried meat products, resulting in total nitrite intake of 0.39 mg/day. The acceptable daily intakes (ADIs) for nitrite, as set by the former Scientific Committee for Food (*SCF*, 1997) and the Joint FAO/WHO Expert Committee on Food Additives (*JECFA*, 2002), are 0.06 and 0.07 mg/kg body weight/day, respectively (*SCF*, 1997; *JECFA*, 2002). For an adult weighing 65 kg, the maximum permitted daily intake ranges from 3.9 to 4.55 mg/day. The calculated intake of 0.39 mg/day is therefore well below the established safety thresholds. All measured nitrite levels in this study complied with the maximum levels permitted by European legislation (*European Commission*, 2011) and Serbian national regulations (*Serbian Regulation*, 2018). The results are also consistent with findings from the German market (*Andrée et al.*, 2010; *Honikel*, 2008), indicating that Serbian meat processors generally operate within legally acceptable limits of nitrite additives.

4. Conclusions

The results of this study demonstrate that both sodium chloride and nitrite contents significantly influenced the distribution of meat product samples within the PCA space. The mean sodium chloride and nitrite contents were 1.91 g/100 g and 7.66 mg/kg, respectively. Estimated daily intake of sodium chloride from meat and dried meat products in Serbia was 1.39 g, while nitrite intake was 0.39 mg. Although nitrite levels were well below the acceptable daily intake and within legislative limits, sodium chloride intake exceeded recommended levels. Given the high cardiovascular risk in Serbia, efforts to reduce salt intake should be prioritized. Future research should focus on the development and implementation of reformulation strategies, consumer education, and product innovation aimed at improving the nutritional profile of meat products without compromising food safety or quality.

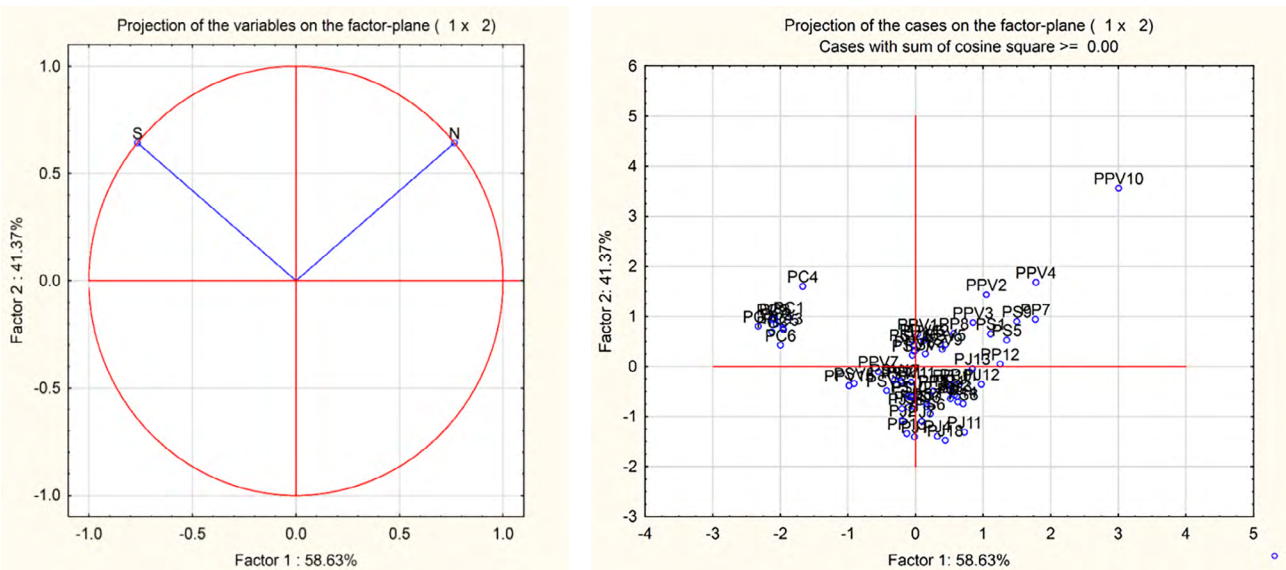

Figure 1 a). PCA loading plot in the plane of factors 1 and 2 – the labels correspond to sodium chloride (S) and nitrite (N) content. **b)** PCA score plot in the plane of factors 1 and 2 – the labels correspond to the meat products given in materials and methods.

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