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Original Scientific Paper

Chlorine content in meat products

Slobodan Lilić[1], Branka Borović[1], Danijela Vranić[1], Jelena Babić Milijašević[1], Tamara Gerić[1], Milan Milijašević[1] and Dunja Videnović[1]*

[1] *Institute of Meat Hygiene and Technology, 11000 Belgrade, Kaćanskog 13, Serbia*

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ABSTRACT

Chlorine is a halogen element that appears in the human body as a free anion, and it plays important role in physiological processes. The main source of chlorine in food is sodium chloride. Data regarding the salt content in meat products were collected from the nutrition labels of 339 meat product from retail markets. The study encompassed 39 pates, 71 cooked sausages (41 finely minced and 30 coarsely minced), 66 pasteurized hams, 42 smoked meat products, 60 dry fermented sausages, 41 dry meats and 20 samples of bacon. The highest average chlorine contents were determined in dry fermented sausages and dry meat (2.30 g/100 g and 2.69 g/100 g, respectively) in accordance with their highest salt contents among the studied meat products. Due to table salt having a major role in meat processing, it can be concluded that meat products are important source of chlorine in consumers.

1. Introduction

Chlorine is a halogen element and has two stable isotopes, ^{35}Cl and ^{37}Cl. It appears in human body as a monoatomic free anion, and in the combination with cations of sodium, calcium and magnesium, it has important roles in physiological processes. After sodium, chloride is the second most abundant ion in the human body (*Wang et al.*, 2017), making up 70% of all anions in extracellular fluid (*Berend et al.*, 2012).

Chloride is transported through several chloride channels, such as channels dependent on voltage (the chloride channel (ClC) family), the cystic fibrosis transmembrane conductance regulator (CFTR), Ca^{2+} activated chloride channels, anion channels that are volume regulated and ligand-regulated channels (*Berend et al.*, 2012, *Kondratskyi et al.*, 2014). These channels maintain and regulate membrane polarity and osmotic and acid-base balance between intracellular departments and the cytoplasm as well as between the cytoplasm and extracellular fluid (*Berend et al.*, 2012). Also, they contribute to the generation of electric signals in muscles and nerves as well as to secretion and reabsorption of fluids, particularly in the lungs (*Hollenhorst et al.*, 2011). Water secretion in lungs and exocrine organs is dependent on chloride that make mucus more wet and fluid, regulated by CFTR channels, defects in which cause cystic fibrosis (*Johnson et al.*, 2006). The channel for exchange of Cl^-/HCO^{3-} ions enables oxygen intake and the release of CO_2 in the lung, but converse exchange in peripheric tissues. This channel releases the CO_2 that is taken in as bicarbonate and enables the intake of chloride

***Corresponding author:** Slobodan Lilić, slobodan.lilic@inmes.rs

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ions, which increases haemoglobin affinity to oxygen (*Fischer et al*., 2007). Chloride secretion from gastric cells is a main factor in the secretion of HCl (*Berend et al*., 2012). In general, human food is low in chlorine, so the most significant source of chlorine is table salt (NaCl).

Since table salt is the most common ingredient in meat processing, this study aimed to investigate the chlorine content derived from meat products

2. Materials and methods

Data on the salt content in meat products were collected from the nutrition labels of 339 meat products from retail markets. The study encompassed 39 pates, 71 cooked sausages (41 finely minced and 30 coarsely minced), 66 pasteurized hams, 42 smoked meat products, 60 dry fermented sausages, 41 dry meats and 20 samples of bacon. Salt content is mandatorily declared on the label, along with protein content, carbohydrate and sugar content, fat and saturated fatty acid content and energy value per 100 g or 100 mL of food, according to Serbian legislation. Label data are also expressed with reference to a requirement for 2000 kcal of energy per day and a salt intake of 6 g/day. Labels can also contain data about monounsaturated fats, polyunsaturated fats, polyols, starch, fibre, vitamins and minerals. Sodium and chlorine contents were calculated from their atomic masses in the declared sodium chloride content of the products examined.

3. Results

The declared sodium chloride contents of the meat products are shown in Table 1, while the calculated sodium and chlorine contents are presented in Table 2. Therefore, the sodium and chlorine contents were directly dependent on the salt content.

According to technological use and sensory characteristics of products, the lowest mean salt contents were determined in pate and finely minced cooked sausages, while salt contents were higher in coarsely minced cooked sausages, pasteurized ham

Table 1. Sodium chloride content in meat products, g/100 g

Thermally treated products	**Mean ± SD**
Pate (n = 39)	1.17±0.06 (1.10-1.30)
Finely minced cooked sausages (n = 41)	1.90±0.35 (1.40-2.60)
Coarsely minced cooked sausages (n = 30)	2.26±0.40 (1.70-3.30)
Pasteurized ham (n = 66)	2.10±0.38 (1.20-2.85)
Smoked meat products (n = 42)	2.68±0.53 (1.70-3.30)
Thermally untreated products	
Dry fermented sausages (n = 60)	3.78±0.37 (3.10-4.50)
Dry meat (n = 41)	4.40±1.21 (2.60-6.40)
Bacon (n = 20)	2.80±0.83 (2.00-5.10)

Table 2. Sodium and chlorine content in meat products, g/100 g

Thermally treated products	**Sodium (range)**	**Chlorine (range)**
Pate (n = 39)	0.47 (0.44-0.52)	0.72 (0.67-0.79)
Finely minced cooked sausages (n = 41)	0.76 (0.56-1.04)	1.16 (0.85-1.58)
Coarsely minced cooked sausages (n = 30)	0.91 (0.68-1.32)	1.38 (1.03-2.01)
Pasteurized ham (n = 66)	0.84 (0.48-1.14)	1.28 (0.73-1.73)
Smoked meat products (n = 42)	1.07 (0.68-1.32)	1.63 (1.03-2.01)
Thermally untreated products		
Dry fermented sausages (n = 60)	1.51 (1.24-1.80)	2.30 (1.89-2.74)
Dry meat (n = 41)	1.76 (1.04-2.56)	2.69 (1.58-3.90)
Bacon (n = 20)	1.11 (0.80-2.04)	1.69 (1.22-3.10)

and smoked meat products. The highest salt contents were, according to the labels, in dry fermented sausages and dry meat.

4. Discussion

Deficiency of chloride rarely occurs and is defined as a low chloride level in the blood, mostly 97-107 mmol/L. It can be caused by gastrointestine and kidney losses and inherited and acquired metabolic disorders (*Berend et al*., 2012). One study cited that deficiency occurs in infants that are fed breast milk with a naturally low chloride concentration (*Hill and Bowie*, 1983) and in infants fed with milk replacers. It can occur in children and adults fed on fluid foods with low chloride content (*Miyahara et al*., 2009). Hypochloridaemia in infants is linked to growth retardation, lethargy, toughness, anorexia, gastrointestinal symptoms, weakness, loss of potassium, metabolic alkalosis and haematuria (*Grossman et al*., 1980).

Excessive chloride intake through food is not common. A chloride concentration in serum above 107 mmol/L, hyperchloremia, mainly appears due to loss of bicarbonates through faeces, for example in the case of severe diarrhoea that causes metabolic acidosis. It can appear as a consequence of all conditions that cause loss of fluid through skin and kidneys, and is also seen if there is a reduced volume of extracellular fluid, an increased tubular chloride reabsorption, an excessive intake of chloride salt, particularly NaCl, and as a consequence of therapy with corticosteroids and acetazolamide. A chlorine level in drinking water up to 4 mg/L is considered as safe and unlikely to cause health problems, according to the US Center for Disease Control and Prevention (CDC), while the World Health Organization (*World Health Organization*, 2013) recommends the guideline value of 5 mg/L for long-term human consumption of drinking water.

In 2005, the European Food Safety Authority (EFSA) still had not set a tolerable upper intake level for chloride, then only recommending that salt consumption be limited to 6 g daily. However, in 2019, EFSA set safe and adequate daily intake levels for chloride: For infants aged 7–11 months 0.3 g per day, for toddlers of 1–3-years 1.7 g per day, for children of 4–6 years 2 g per day, for children of 7–10 years 2.6 g per day, and for people aged 11 years and more 3.1 g per day.

EFSA considers that 5 g of table salt per day is adequate intake in adults. Extrapolated adequate intakes for sodium are 0.2 g/day for infants (0–6 months) and for infants (7–12 months), 1.1 g/day for children from 1–3 years and 1.3 g/day for children from 4–6 years, 1.7 g/day for children aged 7–10 years and 2 g/day for children 11–17 years old, just as for adults (*EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA)*, 2019; *Turck et al*., 2019). However, the estimated mean adult salt intake (g/day) in some countries was: China 10.9 g, Montenegro 10.7 g, Portugal 10.5 g, Benin 9.9 g, Italy 9.7 g, India 9.1 g, Australia 9.0 g, the United States 9.0 g, New Zealand 8.5 g, Canada 8.3 g, England 8.1 g, Samoa 7.3 g, and Barbados 6.6 g (*Armstrong*, 2019). *Rybicka and Nunes* (2022) reported on salt intake in European countries. The average daily salt intake was: 6–7 g in Germany and Latvia; 7–8 g in Bulgaria; 8–9 g in the United Kingdom, France, Switzerland, Austria, Slovakia, the Netherlands, Denmark, Norway, Finland and Lithuania; 9–10 g in Ireland, Spain and Italy; 10–11 g in Belgium, Sweden and Estonia; 11–12 g in Poland and Romania; 12–13 g in Slovenia and Portugal; 13–14 g in the Czech Republic, 14–15 g in Hungary (*Rybicka and Nunes*, 2022) and; in Serbia 10.01 g/day (*Kwong et al.*, 2022).

5. Conclusion

The lowest average salt contents were determined in pate and finely minced cooked sausages, while salt levels were higher in coarsely minced cooked sausages, pasteurized ham and smoked meat products. The highest salt contents were, according to the product labels, in dry fermented sausages and dry meat. Sodium and chlorine levels are directly linked to the salt content in the products. Meat products constitute a significant source of dietary chloride.

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References

Armstrong, M. (2019). China isn't alone in its salt consumption problem. Statista. Hamburg, Germany. https://www.statista.com/chart/18937/salt-consumption/

Berend, K., van Hulsteijn, L. H., & Gans, R. O. (2012). Chloride: The queen of electrolytes? *European Journal of Internal Medicine*, 23(3), 203–211. https://doi.org/10.1016/j.ejim.2011.11.013

EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA). (2019). Dietary reference values for chloride. *EFSA Journal*, 17(5), e05779. https://doi.org/10.2903/j.efsa.2019.5779

Turck, D., Castenmiller, J., de Henauw, S., Hirsch-Ernst, K. I., Kearney, J., Knutsen, H. K., Maciuk, A., Mangelsdorf, I., McArdle, H. J., et al. (2019). Dietary reference values for sodium. *EFSA Journal*, 17, e05778. https://doi.org/10.2903/j.efsa.2019.5778

Fischer, H., Illek, B., Finkbeiner, W. E., & Widdicombe, J. H. (2007). Basolateral Cl channels in primary airway epithelial cultures. *American Journal of Physiology - Lung Cellular and Molecular Physiology*, 292(6), L1432–L1443. https://doi.org/10.1152/ajplung.00425.2006

Grossman, H., Duggan, E., McCamman, S., Welchert, E., & Hellerstein, S. (1980). The dietary chloride deficiency syndrome. *Pediatrics*, 66(3), 366–374.

Hill, I. D., & Bowie, M. D. (1983). Chloride deficiency syndrome due to chloride-deficient breast milk. *Archives of Disease in Childhood*, 58(3), 224–226. https://doi.org/10.1136/adc.58.3.224

Hollenhorst, M. I., Richter, K., & Fronius, M. (2011). Ion transport by pulmonary epithelia. *Journal of Biomedicine and Biotechnology*, 2011, Article ID 174306. https://doi.org/10.1155/2011/174306

Johnson, M. D., Bao, H. F., Helms, M. N., Chen, X.-J., Tigue, Z., Jain, L., Dobbs, L. G., & Eaton, D. C. (2006). Functional ion channels in pulmonary alveolar type I cells support a role for type I cells in lung ion transport. Proceedings of the National Academy of Sciences, 103(14), 4964–4969. https://doi.org/10.1073/pnas.0510642103

Kondratskyi, A., Kondratska, K., Skryma, R., & Prevarskaya, N. (2015). Ion channels in the regulation of apoptosis. *Biochimica et Biophysica Acta (BBA) - Biomembranes*, 1848(10), 2532–2546. https://doi.org/10.1016/j.bbamem.2014.12.030

Kwong, E. J. L., Whiting, S., Bunge, A. C., Leven, Y., Breda, J., Rakovac, I., Cappuccio, F. P., & Wickramasinghe, K. (2022). Population level salt intake in the WHO European region in 2022: A systematic review. *Public Health Nutrition*, 1–14. Advance online publication. https://doi.org/10.1017/S1368980022001234

Miyahara, J., Aramaki, S., & Yokochi, K. (2009). Dietary chloride deficiency due to new liquid nutritional products. *Pediatrics International*, 51(2), 197–200. https://doi.org/10.1111/j.1442-200X.2008.02721.x

Rybicka, I., & Nunes, M. L. (2022). Benefit and risk assessment of replacing sodium chloride by other salt/substances in industrial seafood products. *EFSA Journal*, 20(6), e200420. https://doi.org/10.2903/j.efsa.2022.e200420

Wang, W., Zhang, X., Gao, Q., Lawas, M., Yu, L., Cheng, X., ... Dong, X. (2017). A voltage-dependent K (+) channel in the lysosome is required for refilling lysosomal Ca (2+) stores. *Journal of Cell Biology*, 216(6), 1715–1730. https://doi.org/10.1083/jcb.201612123

World Health Organization. (2013). Global action plan for the prevention and control of noncommunicable diseases 2013–2020. WHO. ISBN 9789241506236.

Authors info

Slobodan Lilić, https://orcid.org/0009-0004-9452-0361
Branka Borović, https://orcid.org/0000-0003-0371-0991
Danijela Vranić, https://orcid.org/0000-0002-7192-488X
Jelena Babić Milijašević, https://orcid.org/0009-0003-8923-7046
Tamara Gerić, https://orcid.org/0000-0002-9303-5231
Milan Milijašević, https://orcid.org/0000-0003-4269-236X
Dunja Videnović, https://orcid.org/0009-0008-2638-247X