Sodium and potassium content and their ratio in meatballs in tomato sauce produced with lower amounts of sodium

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Abstract. The goal of this study was to examine the possibility of partial replacement of sodium chloride with potassium chloride and ammonium chloride, with the target of achieving less sodium content in meatballs and tomato sauce as well as achieving a better Na:K ratio. The trial consisted of five groups. In the control group of meatballs and sauce, only sodium chloride was added. In group 1, half of the sodium chloride was replaced with potassium chloride related to control group while in group 2 one third of the sodium chloride was replaced with potassium chloride. In group 3, one third of the sodium chloride was replaced with ammonium chloride, and in group 4, sodium chloride was reduced to half the amount in the control group, and 1 g (0.25%) of ammonium chloride was also added. All products were acceptable according to sensory analyses. The largest reductions of sodium content were 44.64%, achieved in meatballs from group 1 and 50.62% in tomato sauce from group 4 in relation to meatballs and tomato sauce from control group. The highest Na:K ratio was calculated in meatballs and tomato sauce from control group, 2.88 and 4.39, respectively. The best Na:K ratio was in meatballs and tomato sauce from group 1, 0.60 and 0.92, respectively, in which half of sodium chloride was replaced with potassium chloride. However, in meatballs and tomato sauce from group 4, with only half the amount of sodium chloride related to control group, the Na:K ratio was worse because in these products, potassium chloride was not added.

1. Introduction
Excessive dietary sodium intake is linked with negative health influences, particularly with essential hypertension and consequential cardiovascular disorders. Intake of sodium via food, in many cases, exceeds the recommendation of the World Health Organization (WHO), and because of that, there are many directives issued from WHO concerning how to reduce sodium content in food. The meat industry is often a target of investigations connected with this topic. There are many studies about reducing sodium chloride and sodium content in meat products, which is done mostly by partial replacement of sodium chloride with other chloride salts. The meat industry is an important producer of ready-to-eat meals prepared or cooked in advance, with no further cooking or preparation required before being eaten. These ready-to-eat meals have become an important choice for modern consumers, with respect to the fast lifestyle of modern societies.
There are not much literature data on reducing the sodium content in ready-to-eat meals. Many investigations are focused on reducing sodium content in cooked meat products, but the real challenge is sodium reduction in meat products that are not thermally treated (dry fermented sausages, dry ham). Since it is the only salt with a clearly salty taste, in food, sodium chloride cannot be totally replaced with other salts. However, it can be partially replaced, and to this purpose, potassium chloride and less often, other chloride salts are used [1]. Besides potassium chloride, magnesium and calcium salts and ascorbates are most commonly used as replacers [2].

The need to reduce sodium in meat products and generally in food will be an aim of the food industry in the future; fast food chains will also have to address this issue, even if people think the amount of salt consumed via fast food is not so large [3]. Nonetheless, salt replacers present a difficult problem because of their degradation of desirable sensory characteristics, including texture and, of course, salty taste [4].

The WHO recommendation for dietary sodium intake is less than 2000 mg daily [5]. In the US, the recommendation is less than 2300 mg daily, but an adequate amount is 1500 mg daily [5]. The WHO guideline for dietary potassium intake is more than 3510 mg daily [6], but in the case of the US and Canada, this is set at 4700 mg daily for adults [7]. According to these recommendations, the Na:K ratio would be less than 0.49 (2300 mg Na daily and 4700 mg K daily) for healthy individuals.

Scientific data suggest that the dietary Na:K ratio is more associated with an increased risk of hypertension and cardiovascular diseases.

Accordingly, the goal of this study was to examine the possibility of partial replacement of sodium chloride with potassium chloride and ammonium chloride with the target of achieving less sodium content in meatballs and tomato sauce, as well as achieving a better Na:K ratio.

2. Materials and methods

The trial consisted of five groups. In the control group of meatballs and sauce, only sodium chloride was added. In group 1, half of the sodium chloride was replaced with potassium chloride while in group 2 one third of the sodium chloride was replaced with potassium chloride related to the control group. In group 3, one third of the sodium chloride was replaced with ammonium chloride and in group 4, sodium chloride was reduced by one half compared with the control, while 1 g (0.25%) of ammonium chloride was also added.

2.1. Meatball preparation

Meatballs were prepared from minced pork leg meat (grind plate 3 mm) purchased from a local market. Meat was well mixed with the ingredients presented in Table 1 to achieve optimal consistency to form into round shapes. Prepared meatballs were briefly fried in a thin layer of sunflower oil.

Table 1 Composition of meatballs, g

| Group | Minced pork (leg) | Sodium chloride | Potassium chloride | Ammonium chloride | Ground garlic |
|-------|-------------------|-----------------|-------------------|--------------------|--------------|
| Control | 400 | 6.00 | - | - | 2.00 |
| 1 | 400 | 3.00 | 3.00 | - | 2.00 |
| 2 | 400 | 4.00 | 2.00 | - | 2.00 |
| 3 | 400 | 4.00 | - | 2.00 | 2.00 |
| 4 | 400 | 3.00 | - | 1.00 | 2.00 |

2.2. Tomato sauce preparation

Sauces were prepared from tomato juice (Tomatino classic, Polimark, Serbia) and the ingredients presented in Table 2. A sauce was prepared from flour fried in sunflower oil for about 1 minute, and after that, water, tomato juice, salt/salt mixture and sugar were added. The sauces were simmered for 10 minutes.
Table 2 Composition of tomato sauce, g

| Group | Tomato juice | Water | Sunflower oil | Flour | Sugar | Sodium chloride | Potassium chloride | Ammonium chloride |
|-------|--------------|-------|---------------|-------|-------|-----------------|-------------------|-------------------|
| Control | 400 | 400 | 6.00 | 6.00 | 6.00 | 6.00 | - | - |
| 1 | 400 | 400 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | - |
| 2 | 400 | 400 | 4.00 | 4.00 | 4.00 | 4.00 | 2.00 | - |
| 3 | 400 | 400 | 4.00 | 4.00 | 4.00 | 4.00 | - | 2.00 |
| 4 | 400 | 400 | 3.00 | 3.00 | 3.00 | 3.00 | - | 1.00 |

2.3. Meal preparation
Meatballs were cooked in prepared tomato sauce for 45 minutes. Half an hour after cooking, the product was presented to sensory assessors for evaluation and sent to determine the sodium and potassium content.

2.4. Determination of Na and K
Aliquots of approximately 0.3 g were transferred into Teflon vessels and 5 mL nitric acid (p.a. Sigma-Aldrich, St. Louis, MA, USA) and 1.5 mL hydrogen peroxide (30%, p.a., Merck & Co., Whitehouse Station, New Jersey, USA) were added. The sample solutions were quantitatively transferred into disposable flasks and diluted, then digested using a microwave program that consisted of three steps as follows: 5 min from room temperature to 180°C, 10 min hold 180°C, 20 min vent. After cooling at room temperature, digests were diluted to 100 mL with deionized water (ELGA).

The analysis was performed by inductively-coupled plasma mass spectrometry (ICP-MS). Measurements were performed using the instrument “iCap Q” (Thermo Scientific, Bremen, Germany), equipped with collision cell and operating in kinetic energy discrimination (KED) mode. The following isotopes were measured: $^{39}$K and $^{23}$Na.

Torch position, ion optics and detector settings were adjusted daily using tuning solution (Thermo Scientific Tune B), in order to optimize measurements and minimize possible interferences. For the qualitative analysis of the samples, a five-point calibration curve (including zero) was constructed for each isotope in the concentration range of 0.1 – 2.0 mg/L. An additional line of the peristaltic pump was used for on-line introduction of multi-element internal standard ($^6$Li, $^{45}$Sc – 10 ng/mL; $^{71}$Ga, $^{89}$Y, $^{209}$Bi – 2 ng/mL) covering wide mass range. Concentrations of each measured isotope were corrected for response factors of both higher and lower mass internal standard using interpolation method.

The quality of the analytical process was controlled by the analysis of the standard reference material (NIST SRM 1577c). Measured concentrations were within the range of the certified values for all isotopes.

3. Results and discussion
All samples of meatballs and tomato sauce as well as whole meals were sensorially acceptable [6].

Results of sodium and potassium content in meatballs and tomato sauce are presented in Table 3. Sodium content in meatballs and tomato sauce was directly influenced by added sodium chloride. The highest sodium content was determined in meatballs and tomato sauce from control group (8537.13 mg/kg and 12750.89 mg/kg) and the lowest was in meatballs and tomato sauce from group 4 (4901.47 mg/kg and 6296.02 mg/kg). The highest sodium content in tomato sauce from the control group was also the result of high sodium content in tomato juice, which was found to be 5410.03 mg/kg. The largest reductions of sodium content were 44.64% achieved in meatballs from group 1 and 50.62% in tomato sauce from group 4 (in the relation to meatballs and tomato sauce from control group). The smallest reduction of sodium was in group 3 meatballs as well as in tomato sauce (26.71% and 24.29%, respectively), in which only one third of sodium chloride was replaced with ammonium chloride.
Table 3. Sodium and potassium content in meatballs and tomato sauce, mg/kg

| Group | Meatballs Sodium | Potassium | Tomato sauce Sodium | Potassium |
|-------|-----------------|-----------|---------------------|----------|
| Control | 8537.13 | 2960.59 | 12750.89 | 2902.90 |
| 1 | 4726.03 | 7866.11 | 7470.57 | 8156.76 |
| 2 | 5908.05 | 5654.13 | 8384.73 | 6363.66 |
| 3 | 6256.80 | 3319.82 | 9653.45 | 2725.61 |
| 4 | 4901.47 | 3120.96 | 6296.02 | 2102.97 |

Sodium:potassium ratios (Na:K) of the meatballs and tomato sauce are presented in Table 4. The largest ratio was calculated in meatballs and tomato sauce from control group, 2.88 and 4.39, respectively. The best Na:K ratio was in meatballs and tomato sauce from group 1, 0.60 and 0.92, respectively, in which one half of sodium chloride was replaced with potassium chloride. However, in meatballs and tomato sauce from group 4, with one half the amount of sodium chloride related to control group, the Na:K ratio was worse because in these products, potassium chloride was not added.

Table 4. Sodium:potassium (Na:K) ratios in meatballs and tomato sauce

| Group | Meatballs | Tomato sauce |
|-------|-----------|--------------|
| Control | 2.88 | 4.39 |
| 1 | 0.60 | 0.92 |
| 2 | 1.04 | 1.32 |
| 3 | 1.88 | 3.54 |
| 4 | 1.57 | 2.99 |

4. Conclusion
All the prepared meatballs and tomato sauce as well as whole meals were sensorially acceptable. The lowest sodium content was in meatballs and tomato sauce from group 4 (4901.47 mg/kg and 6296.02 mg/kg).

The largest reductions of sodium content were 44.64% achieved in meatballs from group 1 and 50.62% in tomato sauce from group 4, in relation to meatballs and tomato sauce from control group.

The best Na:K ratio was in meatballs and tomato sauce from group 1, 0.60 and 0.92, respectively, in which one half of the sodium chloride was replaced with potassium chloride.

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