The intake of phosphorus through meat products: a health risk assessment

D Milicevic¹D Vranic¹ V Koricanac¹ Z Petrovic¹ A Bajic¹ N Betic¹ and S Zagorac²

¹ Institute of Meat Hygiene and Technology, Kaćanskog 13, 11040 Belgrade, Republic of Serbia
² Delikos d.o.o., Partizanski put 515a, 11450 Sopot, Republic of Serbia

E-mail: dragan.milicevic@inmes.rs

Abstract. The aim of this study was to assess the dietary exposure of phosphorus in the Serbian adult population by combining individual consumption data with available data for analysed meat products. During a three years period of investigation (2018 to 2020), a total of 682 samples consisting of 425 cooked sausages and 257 smoked meat products were collected from different local retail markets across the Serbia to examine phosphorus concentrations. The mean phosphorus concentration, expressed as P2O5, varied from 4.68±0.88 g/kg to 6.05±1.30 g/kg in finely minced cooked sausages and smoked meat products, respectively. The average estimated daily dietary intake (exposure) (EDI) of phosphorus ranged from 1.115 mg/kg BW (body weight)/day (finely minced cooked sausages) to 1.441 mg/kg BW/day (smoked meat products). Phosphorus dietary intake (exposure) averaged 3.08% of the acceptable daily intake (ADI: 40 mg/kg BW/day). According to our results, the average phosphorus exposure in the Serbian adult population from consumption of these meat products is far below the European ADI.

1. Introduction
Phosphorus, an essential nutrient, performs vital functions in skeletal and non-skeletal tissues and is pivotal for energy production. Phosphorus is involved in many physiological processes, such as in the cell’s energy cycle, in signalling pathways in the form of cyclic monophosphates, in cellular regulation through phosphorylation, and in the mineralization of bones and teeth [1]. About 85% of the body’s phosphorus is in bones and teeth, while 14 % is in soft tissues, including muscle, liver, heart and kidney, and only 1 % is present in extracellular fluids [2]. The major dietary contributors to phosphorus intake are foods of animal origin, i.e. milk and dairy products, followed by meat, poultry and fish, grain products and legumes [3]. Inorganic phosphates are derived mainly from food additives. Phosphorus additives (E 338-341; E 343; E 450-452) are increasingly being used in processed and fast foods, especially in the meat industry, cheeses, baked products and beverages for several technological purposes. They increase water holding capacity (WHC), preserve moisture or colour, emulsify ingredients and enhance flavour, as well as stabilize foods. It has been estimated that 50% of daily phosphorous intake in the Western world is from food additives [3,4]. Phosphorus in food additives is rapidly and almost completely absorbed, whereas the natural constituent of protein-bound phosphorus is more slowly and less efficiently absorbed (60%) [5]. An association between high serum phosphate levels and cardiovascular morbidity and mortality in patients with chronic kidney disease and bone
health complications has long been known [6]. Therefore, high phosphorus intakes from additives should be taken into account as a potential public health concern. These additives were evaluated by the Scientific Committee for Food [7], which derived a group acceptable daily intake (ADI) for phosphates expressed as phosphorus of 40 mg/kg body weight (BW) per day and concluded that this ADI is protective for the human population. Also, European Directives on food additives [8] require that Member States monitor intakes to ensure that consumers do not have an excessive intake of each given food additive, which could lead to a health hazard. The Serbian standard maximum limit for total phosphates, expressed as P$_2$O$_5$, in meat products is $<8$ g/kg [9] or $\leq 5$ g/kg of added phosphorus [10].

Chronic non-communicable diseases such as cardiovascular diseases are a national public health problem affecting as much as 51.7% of the general adult population. In Serbia, they constitute the major contributor to the burden of disease in terms of disability-adjusted life years (DALYs) or mortality [11]. Despite the lack of systematic national surveys of assessment of total dietary phosphorus intake, studying the nutritional status as well as lifestyle of the population is fundamental to design national guidelines and public policies. Therefore, the objective of this study was to determine phosphorus content in processed meat products. Based on the analysis results, dietary exposure of the Serbian adult population to phosphorus was then estimated and discussed.

2. Materials and Methods
2.1. Sample Collection and Preparation
A total of 682 samples consisting of 425 cooked sausages and 257 smoked meat products were randomly collected over three years (2018, 2019 and 2020). Samples included domestic and imported products from different local retail markets across the Serbia. Further description of the analytical procedure and equipment for determining phosphorus content in the sampled food commodities can be found in previous work conducted by Koricanac et al. [2].

2.2. Exposure Assessment and Risk Characterization
The dietary intake levels of phosphorus (mg/kg BW/day) from processed meat products was estimated on the basis of the concentrations of the phosphorus in examined samples and on the basis of average per capita consumption data obtained by Household Budget Survey [12]. Total phosphorus EDI was compared with the ADI proposed by EFSA [7].

2.3. Statistical Analysis
Data were analysed using Minitab 17 Ink statistical software. Phosphorus contents in groups of the studied samples of processed meat products were expressed in the form of descriptive statistics and their distributions.

3. Results and Discussion
The contents and distributions of phosphorus in each group of processed meat products are summarized in Table 1 and Figure 1. The EDI data for phosphorus in processed meat products are shown in Table 2.

Data obtained in this study indicate low phosphorus content in processed meat products. As shown in Table 1, the mean phosphorus (P$_2$O$_5$) content in finely minced cooked sausages was 4.68±0.88 with a range of 1.12 to 9.22 g/kg. According to national regulation, only two (0.5%) of the 425 finely minced cooked sausages were above regulatory limit (< 8 g/kg), reaching a content of 9.22 g/kg P$_2$O$_5$. Our results are in line with data obtained in previous studies [2, 13]. Regarding smoked meat products, phosphorus (P$_2$O$_5$) content ranged from 2.32 to 10.64 g/kg with a mean value of 6.05±1.30 g/kg. In our study, seven (2.72%) of the 257 smoked meat products was above the regulatory limit, reaching a content of 10.64 g/kg P$_2$O$_5$.

The average EDI of phosphorus for the Serbian adult population ranged from 1.115 to 1.441 mg/kg BW/day (Table 2). Our results showed that the processed meat products were a minor contributor to the dietary intake of phosphorus (3.08%). The ADI of 40 mg/kg BW/day corresponds to an intake of 2.8 grams of phosphorus per day for an average adult weighing 70 kg [7]. Hence, exposure to phosphates
from the meat products in our study is considered to be far below this ADI. The main contributor to the dietary intake of phosphorus could differ by region depending on the habitual diet of the study population. However, data for children’s exposure was not taken into consideration during the study period.

Table 1. Mean levels and ranges for phosphorus ($P_2O_5$) in processed meat samples

| Food Group                  | N   | Mean±SD (g/kg) | Min-Max (g/kg) | Above MPL N (%) |
|-----------------------------|-----|----------------|----------------|-----------------|
| Finely minced cooked sausages | 425 | 4.68±0.88     | 1.12-9.22       | 2 (0.5)         |
| Smoked meat products        | 257 | 6.05±1.30     | 2.32-10.64      | 7 (2.72)        |
| Total                       | 682 | 5.19±1.24     | 1.12-10.64      | 9 (1.32)        |

N – total number of analysed samples; MPL – maximum permitted level (< 8 g/kg) [9].

Table 2. Estimated dietary intake of phosphorus and risk characterization of phosphorus intake

| Food Group                  | Mean±SD (g/kg) | ADC (g/day) | EDI (mg/kg BW/day) | Contribution to ADI (%) | ADI (mg/kg BW/day) | AI (mg/day) |
|-----------------------------|----------------|-------------|--------------------|--------------------------|--------------------|-------------|
| Finely minced cooked sausages | 2.04±0.38     | 38.2        | 1.115              | 2.79                     | 40                 | 550         |
| Smoked meat products        | 2.64±0.57     | 1.441       | 2.79               | 2.79                     | 40                 | 550         |
| Total                       | 2.27±0.54     | 1.233       | 3.08               | 3.08                     |                    |             |

$P$ content (43.64% of $P_2O_5$); ADC – Average Daily Consumption of meat products [12]; EDI – Estimated Daily Intake; Default body weight value for adults was 70 kg [14]; ADI – acceptable daily intake [7]; AI – adequate intake [15].

Figure 1. Distribution of phosphorus content ($P_2O_5$) (g/kg) in finely minced cooked sausages (A) and smoked meat products (B).

4. Conclusion
The results presented in this paper indicate there is no health concern for phosphorus intake by adults in Serbia consuming meat-based products. This study highlights the need for additional total diet studies on the dietary intake of phosphorus in different population groups.
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