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ORIGINAL ARTICLE

EXPOSURE TO NITRITES FROM MEAT PRODUCTS AS FOOD ADDITIVES AMONG ADOLESCENTS IN POLAND

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ABSTRACT

Background. Nitrites should be limited in the diet because their potential carcinogenic effects. However, the addition of nitrites is essential to maintain the microbiological safety of meat products, mainly to protect them from bacteria *Clostridium botulinum* and to preserve the pink colour of meat products and to give them desirable organoleptic properties. Acceptable Daily Intake (ADI) for nitrite (expressed as nitrite ion) established by EFSA is 0.07 mg per kilogram of body weight per day (mg kg^{-1} day^{-1}), equivalent to 0.1 mg kg^{-1} day^{-1} of sodium nitrite.

Objective. The aim of this study was the assessment of sodium nitrite intake in meat products and exposure to this compound in Polish adolescents.

Materials and Methods. The analysis of sodium nitrite intake with selected meat products by young Poles was based on consumption data of these products by adolescents aged 11-17 in 2019-2020 and analytical data on the actual content of sodium nitrite in meat products provided by laboratories of sanitary and epidemiological stations in 2017 and 2018 (4 voivodships).

Results. The intake of sodium nitrite by adolescents aged 11-17 years in total, both the mean (0.063 mg kg^{-1} day^{-1}) and the median (0.050 mg kg^{-1} day^{-1}) did not exceed ADI. On the other hand, the intake of sodium nitrite at the 95th percentile (P95) was 195% of the ADI, and the highest intake was found in young boys – 200% of the ADI.

Conclusions. The average intake of sodium nitrite from meat products by Polish adolescents was generally lower than ADI. However, there was observed potential risk of excessive intake for some boys and girls who had a high consumption of meat products.

Keywords: *nitrites, intake, meat products, adolescents*

INTRODUCTION

The food additives: nitrites (E 249, E 250) and nitrates (E 251, E 252) can be used in strictly defined amounts in accordance with the EU Food Additives Regulation [1], in the selected meat product categories (nitrates and nitrites), and also to ripened cheeses (nitrates), processed fish and fishery products including molluscs and crustaceans (nitrates). Sodium nitrite (E 250) and potassium nitrite (E 249) as additives may be used at a dose of up to 150 mg/kg in meat products. In sterilised meat products, the permitted dose of E 249 and E 250 is 100 mg/kg. The amounts of nitrites that can be added to food are determined on the basis of toxicological studies in animals. The EFSA Expert Panel (ANS) set the Acceptable Daily Intake (ADI) for nitrite (expressed as nitrite ion) as 0.07 mg kg^{-1} day^{-1}, equivalent to 0.1 mg kg^{-1} day^{-1} of sodium nitrite [2].

According to the database of the FAOSTAT website, the consumption of meat (according to the food balance method) in 2018 was 43.1 kg/person/year in the whole world, while in Poland it was 8.4 kg/person/year. The latest data (year 2022) showed that meat consumption in the world was 44.6 kg/person/year. The result for Poland in the same year was 81.6 kg/person/year [3].

The Polish Household Budget Surveys data on consumption of meat and meat products in 2000 and 2020 showed that the consumption of these products decreased from 5.47 kg/person/month in 2000 to 5.09 kg/person/month in 2020 [4, 5]. The consumption of processed meat in 2020 was 1.96 kg/person/month

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and almost 90% of which was red processed meat. Twenty years ago, it was 2.04 kg/person/month [6].

The level of nitrite intake from meat products in the Polish population has been monitored for many years. The present study estimates the dietary intake of sodium nitrite in meat products by Polish adolescents and assesses the risk of exposure to this compound, taking into account data on intake and actual amounts of sodium nitrite in meat products.

MATERIAL AND METHODS

Dietary data were obtained from the Nationwide Dietary Cross-Sectional Survey in Poland, conducted from July 2019 to February 2020, among a nationally representative sample of adolescents (aged 11-17 years), according to the European Food Safety Authority (EFSA) guidelines on the EU Menu Methodology [7, 8]. The sodium nitrite content in the diets of 527 adolescents aged 11-17 years (265 boys and 262 girls) was estimated by age and sex, taking into account the weight of the respondents. Random sampling was used. Exclusion factors were: vegetarian diet, hospitalization and/or with an enteral and parenteral nutrition, mental condition which made impossible to obtain reliable information (neurodegenerative diseases, drunkenness, state after taking drugs and other substances stimulating) [9]. The dietary survey was conducted using the Album of Photographs of Food and Dishes [10]. The respondents were asked about food intake over the previous 24 hours. Both interviews were conducted during visits to the respondent's home and covered two non-consecutive days. The interval between the two interviews was at least seven days. The study was approved by the Bioethics Committee at the Institute of Food and Nutrition in Warsaw, Poland at 4 June 2018. A health risk assessment was based on the ADI as 0.07 mg kg^{-1} day^{-1} for nitrite ions, equivalent to 0.1 mg kg^{-1} day^{-1} of sodium nitrite [2]. The approach presented in the manuscript follows the methodology recommended by EFSA, for the creating of food additive intake data [7, 8]. This approach allows comparison of the results with other studies.

The data on sodium nitrite levels in food were obtained from chemical analyses of meat products (cold cuts, sausages, canned meat), ready-to-eat meals containing meat. These analyses were carried out in 2017 and 2018 by accredited laboratories of sanitary and epidemiological stations in 4 voivodships of Poland (Dolnośląskie, Lubelskie, Mazowieckie, Wielkopolskie). The content of nitrite in meat products was determined by spectrophotometric and HPLC method depending on laboratories [11]. The average content of sodium nitrite ($NaNO_2$) in the meat products was as follows: pork ham – 120 mg/kg, pork sausages – 7.5 mg/kg, poultry meat products – 15.6 mg/kg.

The Statistica(®) software was used for the statistical analyses. The distribution of sodium nitrite intake was checked with the use of Shapiro-Wilk test. The $p < 0.05$ statistical significance coefficient was adopted. The analysis of significance of differences in sodium nitrite intake between male and female respondents in the adult group was based on the nonparametric Mann-Whitney U test.

RESULTS

The analysis of consumption of meat products by 265 young boys and 262 young girls aged 11-17 years and the actual content of sodium nitrite in meat products showed that the overall sodium nitrite intake by adolescents was 0.063 mg kg^{-1} day^{-1} (0.066 mg kg^{-1} day^{-1} for boys and 0.059 mg kg^{-1} day^{-1} for girls) (Table 1). The above described parameters

Table 1. Sodium nitrite (E 250) content (mg kg^{-1} day^{-1}) in the diets of adolescents aged 11-17 years studied in 2019-2020 and the percentage of ADI

Gender	N	X	Me	Range	SD	P95	p (U-Mann-Whitney test)*
Daily intake (E 250) (mg kg^{-1} day^{-1})							
Boys	265	0.066	0.052	0-0.305	0.064	0.2	> 0.1
Girls	262	0.059	0.046	0-0.313	0.063	0.186	
Total	527	0.063	0.05	0-0.313	0.064	0.195	
% of ADI							
Boys	265	66.1	51.7	0-305	63.8	200	> 0.1
Girls	262	59.4	45.6	0-313	63.5	186	
Total	527	62.8	49.6	0-313	63.7	195	

N – number of respondents; X – mean; Me – median; SD – standard deviation; P95 – 95 percentile; * – statistically significance coefficient, $p < 0.05$; ADI – 0.1 mg kg^{-1} day^{-1}

Table 2. Sodium nitrite (E 250) content (mg kg^{-1} day^{-1}) in the diets of the studied adolescents aged 11-17 consuming meat products ("consumers only")

Gender	N	% in relation to total respondents	X	Me	Range	SD	P95	p (U-Mann-Whitney test)*
Daily intake (E 250) (mg kg^{-1} day^{-1})								
Boys	217	81.9	0.081	0.071	0-0.305	0.062	0.223	> 0.1
Girls	203	77.5	0.077	0.065	0-0.313	0.062	0.209	
Total	420	79.7	0.079	0.067	0-0.313	0.062	0.211	
% of ADI								
Boys	217	81.9	80.7	70.9	0-305	61.6	223	> 0.1
Girls	203	77.5	76.7	65	0-313	62.2	209	
Total	420	79.7	78.8	66.9	0-313	61.9	211	

N – number of respondents; X – mean; Me – median; SD – standard deviation; P95 – 95 percentile; * – statistically significance coefficient, $p < 0.05$; ADI – 0.1 mg kg^{-1} day^{-1}

did not exceed the ADI. The mean sodium nitrite intake was 66.1% of the ADI in the group of boys and 59.4% of the ADI in the group of girls. However, sodium nitrite intake at the P95 was 195% of the ADI for all subjects. The highest intake was found in boys – 200% of the ADI.

The data from the group of young people consuming meat products ("consumer only" group – 420 persons: 217 boys and 203 girls) was almost 80% of the total studied subjects (Table 2). The average intake of sodium nitrite was 0.079 mg kg^{-1} day^{-1} (0.081 mg kg^{-1} day^{-1} for boys and 0.077 mg kg^{-1} day^{-1} for girls), which represented an average of 78.8% of the ADI for all adolescents (80.7% of the ADI for boys and 76.7% of the ADI for girls).

In the assessment of intake and risk of exposure to $NaNO_2$, there were specified the groups of food products that are sources of sodium nitrite in the diet. Figure 1 shows the percentage of food groups that are

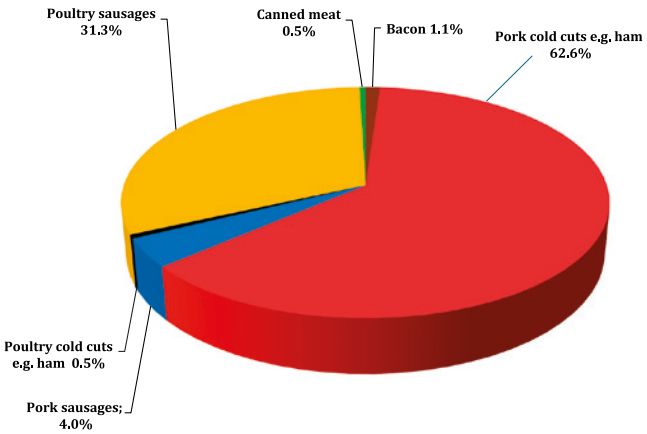

Figure 1. Percentage share of meat product groups as a source of sodium nitrite in the diets of the young respondents (11-17 years)

sources of E 250 in the diets of young Poles. The data show that more than half (62.6%) of the sodium nitrite in the diet of the Polish adolescents came from cured products – pork cold cuts, e.g. ham, and 31.3% from poultry sausages.

DISCUSSION

Considering the data on nitrite intake from meat products by young consumers (11-17 years) in Poland (total group), it should be noted that in the years 2019-2020 the exposure to sodium nitrite was 0.066 mg kg^{-1} day^{-1} for boys and 0.059 mg kg^{-1} day^{-1} for girls. In the same group of young Poles (11-17 years) in 2000, exposure was 0.015 mg kg^{-1} day^{-1} for boys and 0.013 mg kg^{-1} day^{-1} for girls [12]. This indicates that consumption of meat products has increased over this years. It should also be added that the assortment of meat products containing nitrites has increased during these years. Also the surveys in 2019-2020 shows a large percentage of adolescents consumed meat products (81.9% of boys and 77.5% of girls), then in the 2000, where percentage of adolescents consumed meat products was 49% in group of boys and 51.7% in the group of girls [12]. Czech-Załubska et al. [13] reported that the dietary exposure to sodium nitrite in adolescents (12-17 years) in 2023 was 0.038 mg kg^{-1} day^{-1} (tier 3). However, it should be noted that these data include the actual concentrations of nitrites in cured meat products reported in the literature, together with their frequency of occurrence [13]. In our study, the nitrite content of meat products was obtained from laboratory tests as part of food inspection by laboratories of sanitary and epidemiological stations in 2017-2018.

Acceptable Daily Intake for this population group has changed over about 20 years. In 2000, the % of

ADI for young boys was 14.6% and for young girls 13.3% [12]. In our study using data from 2019-2020, % of ADI increased and was 66.1% (boys) and 59.4% (girls). The intake of sodium nitrite at the P95 level was doubled (200% of the ADI for young boys and 186% of the ADI for young girls). In 2000, P95 was 72.4% (boys) and 66.5% (girls) [12].

In the group "consumers only" (people consuming meat products) in 2019-2020 intake of sodium nitrites was 80.7% of the ADI (boys) and 76.7% of the ADI (girls). In 2000, the % of ADI in this group was 29.9% for boys and 25.8% for girls [12]. In this case, both studies assumed the same values for sodium nitrite in meat products (2017-2018 laboratory data), while using different consumption data, from 2000 [12] and from years 2019 and 2020.

Among the different types of meat products consumed by young Poles (11-17 years) more than 63% were smoked meat, including ham, and 35% were sausages. In the study by Czech-Załubska et al. [13] the data on meat product consumption were similar. Steamed smoked meats and wiener sausages and kabanos sausages were consumed the most.

It should also be added that the total dietary exposure of young people to nitrites may be higher because nitrites are also present in drinking water and other foods: cereal products (bread), dairy products including cheese. However, the levels of nitrite in the above-mentioned foods outside drinking water are often below the LOD (Limit of Detection) [14-17]. Similarly, Larson et al. [18] reports that consumer exposure to nitrite from drinking water is low and this source of nitrite often does not have a significant impact on estimated dietary nitrite intake.

Sodium nitrite is a compound that requires special attention in terms of risk assessment. $NaNO_2$ is added to meat as a nitrogen compound to maintain microbiological safety against the development of pathogenic bacteria such as *Clostridium botulinum* in meat products [2]. In recent years, some alternative meat preservation technologies have been developed that could reduce the use of nitrites (e.g. use of plant extracts or polyphenols in the production of meat products). However, until such substances are authorised, they cannot be used for meat preservation. According to the EFSA opinion, "meat and meat products" is the main food category contributing to the exposure to N-nitrosamines [19]. In an opinion of 2022, the French Agency for Health Safety (ANSES) recommended not to consume more than 150 g of meat products per week [20]. The American Institute for Cancer Research (AICR) and others experts recommend concluded that consumption of processed meat is a convincing cause of colorectal cancer [19-23]. Recently, as part of the work of the European Commission, consideration has been given to reducing the permitted doses of nitrites added to foods as additives – this applies to both meat products and ripened cheese. This will reduce these substances in food. Another way to reduce nitrite intake is to limit the consumption of cured meat products [24].

CONCLUSIONS

The average intake of sodium nitrite from meat products by Polish adolescents was 0.066 mg kg^{-1} day^{-1} for boys and 0.059 mg kg^{-1} day^{-1} for girls, which correspond to 66.1% and 59.4% of the ADI respectively.

Among some adolescents the high levels of sodium nitrite intake was observed at P95 (above ADI) in the group for boys and girls, as well.

Educational activities on balanced and varied diet with limited consumption of meat products can help to reduce the risk of excessive intake of nitrites.

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Conflict of interest

The authors declare no conflicts of interest.

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