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ORIGINAL ARTICLE

Exposure of meat products to nitrites as food additives in Poland

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Abstract

Introduction and Objective. Nitrites are commonly used as food additives E 249 and E 250 in the production of meat products, mainly to protect them from contamination with Clostridium botulinum bacteria. However, the intake of nitrites should be limited as it can have a potentially negative effect on health (suspected to be carcinogenic to humans). The aim of the study was the assessment of nitrite intake (expressed as sodium nitrite) in the diets of 4,134 persons, aged 1–96, in Poland.

Materials and Method. The data on sodium nitrite intake were based on the daily consumption of food products and meals, and the actual content of sodium nitrite in food products obtained from the analytical tests carried out by sanitary inspection laboratories in 2017 and 2018. Risk assessment was based on the sodium nitrite intake calculations of: mean (X), median (Me), 95th percentile (P95), and comparison with ADI. The data were analysed with respect to the total studied sample and the 'consumers only' group.

Results. The daily sodium nitrite intake expressed in mg/kg b.m./day, on average, 0.012 for all respondents, amounting to 12.1% ADI. The risk analysis shows that the Polish population was characterized by the average intake of sodium nitrite at a safe level (below ADI). However, certain cases of sodium nitrite intake (P95 level) were observed to exceed ADI. The most exposed group were children.

Conclusions. A balanced and varied diet, with limited consumption of meat products will help diminish the risk of excessive intake of nitrites by consumers in Poland.

Key words

exposure, nitrites, meat products

INTRODUCTION AND OBJECTIVE

Nitrogen compounds in the form of nitrate and nitrite ions can occur in food naturally (mainly in vegetables and drinking water) and as food additives. Studies show that vegetables, especially such leaf vegetables as arugula, spinach and lettuce, tend to have higher nitrate levels compared to seeds or tubers [1]. On the other hand, as food additives, nitrites (E249, E250) and nitrates (E251, E252) can be used in strictly defined amounts under the EU regulation on food additives [2]. These compounds are allowed for selected products in the meat category (nitrates and nitrites), ripened cheeses (nitrates), processed fish and fishery products, including molluscs and crustaceans (nitrates). According to the aforementioned regulation, the additives: sodium nitrite (E 250) and potassium nitrite (E 249) may be used in meat products up to 150 mg/kg (the amount introduced into the product), with the exception of sterilized meat products, in which the permitted dose of the above compounds is 100 mg/kg (amount introduced into the product expressed as sodium nitrite) [2]. The addition of nitrites is essential for maintaining the microbiological safety of meat products by inhibiting the growth of undesirable microorganisms (including *Clostridium botulinum*) [3]. Recently, some alternative meat preservation technologies have been developed which could reduce the use of nitrities, for example, the use of vegetable extracts or polyphenols. However, from the legal point of view, the use of substances that deliver a technological function in food to which they are added is deemed as their deliberate use as a food additive. Until such substances are authorized they cannot be used for meat preservation.

Sodium nitrite is a powerful oxidizing agent that causes hypotension and limits oxygen transport and delivery in the body through the formation of methemoglobin. Clinical manifestations can include cyanosis, hypoxia, altered consciousness, dysrhythmias – and death. [4]. Studies have shown a potential link between nitrite consumption and the occurrence of gastric cancer, as well as the consumption of nitrites and nitrates present in processed meats and colorectal cancer [3]. According to EFSA, 'meat and meat products' is the main food category contributing to the exposure for N-nitrosamines [5]. On the other hand, there are also known reports about the beneficial effects of nitrites on health. These compounds exhibit antimicrobial activity in the human stomach, while the products of their metabolism, such as nitric oxides, play an important role in regulating blood flow through blood vessels, preventing hypertension, arteriosclerosis and stroke [6].

The amounts of nitrites that can be ingested with food are determined on the basis of toxicological studies on animals and expressed by the ADI (Acceptable Daily Intake). The EFSA Expert Panel (ANS) set the ADI for nitrite from food at

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0.07 mg nitrite ions/kg b.w./day, equivalent to 0.1 mg sodium nitrite/kg b.w./day [3].

The aim of the study was to estimate the dietary intake of sodium nitrite and assess the risk of exposure of the Polish population to this compound, taking into account data on intake and actual amounts of sodium nitrite in processed meat products.

MATERIALS AND METHOD

Nitrites content in processed meat products. Data on the actual content of sodium nitrite in food products were obtained from studies of processed meat products (cold cuts, canned meats), ready to eat meals containing meat, and delicatessen products. The analyses were carried out in 2017 and 2018 by accredited laboratories of sanitary and epidemiological stations in 4 Polish provinces: Dolnośląskie, Lubelskie, Mazowieckie and Wielkopolskie. The nitrite content of meat products was determined by the spectrophotometric method.

A total of 88 products obtained on the market were tested, with the same assortment being tested in some cases in the individual provinces (e.g. honey sirloin was tested in 2017 and 2018). 10 samples received < LOD (not detected), 13 samples received < LOQ (not quantified), and a value of 0 mg/1 kg of product was assumed for these results.

Dietary survey. The sodium nitrite content in the diets of 4134 respondents was estimated by age and gender, taking into account the weight of the respondents. The data was obtained from representative survey carried out in 2000 as part of the FAO project 'Household Food Consumption and Anthropometric Survey' [7]. The dietary survey was conducted by interviewing people about their food intake over the past 24 hours, using the 'Food and Meals Photo Album' developed at the Institute of Food and Nutrition in Warsaw.

Estimated nitrites intake. To calculate the sodium nitrite content in the diet, a database was prepared which included a list of products with sodium nitrite content obtained in laboratory tests, and data on products consumption in the daily diets of respondents.

Sodium nitrite intake was calulated for the entire population and the population of people who consume products containing the tested additives – the 'consumers only' group. The exposure to sodium nitrite took into account the age- and gender-specific counts given below with the average body weight per age group (Tab. 1). It should be noted that body weight measurements were taken in only 4,041 people, and that in the study group, both the total group and the 'consumers only' group, the number of people with measured body weight was smaller than the entire study group. The results of the study differ because, in the total group, the nitrite intake refers to all test subjects, while in the 'consumers only' group, the $NaNO_2$ intake considered only those consuming meat products with nitrites.

The approach presented in the study is in line with the methodology for compiling data on the intake of additives recommended by the European Food Safety Authority (EFSA). This approach allows the results to be compared with other studies.

Calculation method. The analysis of the significance of differences in sodium nitrite intake between male and female respondents in the adult group was based on the non-parametric Mann–Whitney U test.

Table 1. Number of respondents in each age group, taking into account body weight

Age (years)	Gender	No. of respondents	% of respondents	Mean body weight (kg)
1–3 years	boys	66	60.0	14.0
	girls	44	40.0	13.1
4–10 years	boys	219	48.6	27.4
	girls	232	51.4	26.0
11–17 years	boys	286	50.0	54.1
	girls	286	50.0	49.2
18–74 years	men	1,247	44.7	79.6
	women	1,543	55.3	67.0
>74 years	men	45	38.1	71.5
	women	73	61.9	66.2
In total (1–96 years)	male	1,863	46.1	67.0
	female	2,178	53.9	59.2
	male and female	4,041		62.8

The health risk assessment was based on the Acceptable Daily Intake (ADI) of 0.07 mg/kg b.w./day for nitrite ions, equivalent to 0.1 mg/kg b.w./day for sodium nitrite.

RESULTS

Intake of sodium nitrite in the studied general population group. The estimated average daily intake of sodium nitrite in the general population, calculated on the basis of consumption data and laboratory results of the actual $NaNO_2$ content in individual products, was 0.71 mg/person/day. In all age groups studied, the average intake of sodium nitrite did not exceed the ADI and ranged from 7.5% ADI (women over 74 years) to 25.0% ADI among boys aged 1–3. Sodium nitrite intake at P95 in most of the study groups did not exceed the ADI, excluding the youngest children. Boys and girls aged 1–3 years were the most exposed group to nitrites intake from meat products (intake at P95 was 158.1% and 137.5% of the ADI). Statistical analysis showed significant differences in sodium nitrite intake between male and female respondents for those aged 18–74 (Tab. 2).

Intake of sodium nitrite in 'consumers only' group. Estimates of exposure to sodium nitrite were also made for the 'consumers only' group who on the day of the study consumed products containing $NaNO_2$ (Tab. 3).

The proportion of those consuming the meat products analysed in this study amounted to almost 50% of the total number of respondents. The average daily intake of total $NaNO_2$ in the 'consumers only' group was 1.45 mg/person/day (24.6% ADI). The highest average value 2.0 mg/person/day) was found in the group of men aged 18–74. Boys and girls aged 1–3 years were the most vulnerable group. For this population group, the average intake was found to be 55.1% and 49.9% of ADI, with the 95th percentile value exceeding acceptable levels at 174% and 188% of ADI, respectively. The group of boys and girls aged 4–10 also had a high intake at P95, which constituted 104% and 96.1% of the ADI. Statistical analysis in the 'consumers only' group showed significant

Table 2. Sodium nitrite intake in general studied population group and % ADI

Age (years)	Gender	N*	X	Me	SD	P 95	p (t-U-Mann-Whitney)**
Daily intake mg/person/day							
1–3 years	boys	70	0.35	0.00	0.66	1.96	>0.1
	girls	48	0.29	0.00	0.57	2.06	
4–10 years	boys	222	0.41	0.00	0.81	1.92	>0.1
	girls	233	0.40	0.00	0.72	1.92	
11–17 years	boys	295	0.77	0.00	1.45	3.67	>0.1
	girls	286	0.61	0.00	1.31	2.91	
18–74 years	men	1,278	1.09	0.00	1.90	4.96	<0.001
	women	1,578	0.55	0.00	1.06	2.91	
>74 years	men	46	0.59	0.00	1.34	4.01	>0.1
	women	78	0.48	0.00	0.78	2.89	
Total (1–96 years)	male	1,911	0.92	0.00	1.71	4.37	<0.001
	female	2,223	0.53	0.00	1.05	2.88	
	male and female	4,134	0.71	0.00	1.41	3.60	
Daily intake mg/kg b.w./day							
1–3 years	boys	66	0.025	0.000	0.047	0.158	>0.1
	girls	44	0.022	0.000	0.046	0.138	
4–10 years	boys	219	0.015	0.000	0.029	0.084	>0.1
	girls	232	0.015	0.000	0.028	0.090	
11–17 years	boys	286	0.015	0.000	0.027	0.072	>0.1
	girls	286	0.013	0.000	0.030	0.067	
18–74 years	men	1,247	0.014	0.001	0.025	0.063	<0.001
	women	1,543	0.008	0.000	0.017	0.045	
>74 years	men	45	0.008	0.000	0.017	0.056	>0.1
	women	73	0.008	0.000	0.012	0.039	
Total (1–96 years)	male	1,863	0.015	0.000	0.027	0.069	<0.001
	female	2,178	0.010	0.000	0.021	0.051	
	male and female	4,041	0.012	0.000	0.024	0.060	
% ADI							
1–3 years	boys	66	25.0	0.0	47.2	158.1	>0.1
	girls	44	21.6	0.0	45.6	137.5	
4–10 years	boys	219	15.1	0.0	28.7	83.6	>0.1
	girls	232	15.4	0.0	28.0	90.5	
11–17 years	boys	286	14.6	0.0	26.6	72.4	>0.1
	girls	286	13.3	0.0	30.4	66.5	
18–74 years	men	1,247	14.1	1.0	24.9	62.8	<0.001
	women	1,543	8.5	0.0	16.9	44.5	
>74 years	men	45	7.8	0.0	16.8	56.4	>0.1
	women	73	7.5	0.0	12.2	39.0	
In total (1–96 years)	male	1,863	14.5	0.0	26.6	68.5	<0.001
	female	2,178	10.1	0.0	21.5	51.1	
	male and female	4,041	12.1	0.0	24.1	59.7	

N – number of respondents; X – mean; Me – median; SD – standard deviation; P95;
* The number of people with measured body weight is lower than the total number of respondents
** Statistically significant differences p <0.05 ADI = 0.1 mg/kg b.w./day

differences in sodium nitrite intake between male and female respondents for those aged 11–74, similar to the general population.

Table 3. Sodium nitrite intake in studied 'consumers only' group and % ADI

Age (years)	Gender	N*	% general studied group	X	Me	SD	P 95	p (t-U-Mann-Whitney)**
Daily intake mg/person/day								
1–3 years	boys	31	44.3	0.80	0.55	0.79	2.50	>0.1
	girls	21	43.8	0.66	0.36	0.72	2.06	
4–10 years	boys	109	49.1	0.83	0.54	0.99	2.34	>0.1
	girls	121	51.9	0.77	0.54	0.85	2.42	
11–17 years	boys	143	48.5	1.59	1.09	1.75	5.10	0.007
	girls	148	51.7	1.18	0.73	1.62	4.02	
18–74 years	men	697	54.5	2.00	1.39	2.19	6.06	<0.001
	women	702	44.5	1.24	0.89	1.30	3.75	
>74 years	men	18	39.1	1.50	0.70	1.81	6.44	>0.1
	women	38	48.7	0.98	0.73	0.87	2.96	
In total (1–96 years)	male	998	52.2	1.77	1.09	2.03	5.78	<0.001
	female	1,030	46.3	1.15	0.73	1.29	3.64	
	male and female	2,028	49.1	1.45	0.91	1.72	4.69	
Daily intake mg/kg b.w./day								
1–3 years	boys	30	45.5	0.055	0.039	0.057	0.174	>0.1
	girls	19	43.2	0.050	0.028	0.059	0.188	
4–10 years	boys	107	48.9	0.031	0.018	0.035	0.104	>0.1
	girls	121	52.2	0.030	0.019	0.033	0.096	
11–17 years	boys	140	49.0	0.030	0.023	0.032	0.090	0.038
	girls	148	51.7	0.026	0.015	0.038	0.075	
18–74 years	men	686	55.0	0.026	0.016	0.029	0.082	<0.001
	women	686	44.5	0.019	0.013	0.021	0.060	
>74 years	men	18	40.0	0.020	0.009	0.022	0.069	>0.1
	women	36	49.3	0.015	0.011	0.014	0.048	
Total (1–96 years)	male	981	52.7	0.028	0.017	0.031	0.087	<0.001
	female	1,010	46.4	0.022	0.014	0.027	0.071	
	male and female	1,991	49.3	0.025	0.015	0.029	0.082	
% ADI								
1–3 years	boys	30	45.5	55.1	38.5	57.3	174	>0.1
	girls	19	43.2	49.9	28.0	58.9	188	
4–10 years	boys	107	48.9	30.8	17.7	34.7	104	>0.1
	girls	121	52.2	29.6	19.4	32.9	96.1	
11–17 years	boys	140	49.0	29.9	22.9	31.5	90.0	0.038
	girls	148	51.7	25.8	14.9	38.3	75.3	
18–74 years	men	686	55.0	25.6	16.4	28.8	82.0	<0.001
	women	686	44.5	19.0	12.9	21.0	59.7	
>74 years	men	18	40.0	19.6	8.6	22.0	69.1	>0.1
	women	36	49.3	15.3	11.5	13.6	48.3	
Total (1–96 years)	male	981	52.7	27.6	17.3	31.4	87.3	<0.001
	female	1,010	46.4	21.7	13.9	27.2	71.1	
	male and female	1,991	49.3	24.6	15.2	29.5	82.0	

N – number of respondents; X – mean; Me – median; SD – standard deviation; P95;
* Number of people with measured body weight is lower than the number of "consumers only" respondents
** Statistically significant differences p <0.05 ADI = 0.1 mg/kg b.w./day

Food products as a source of sodium nitrite in the diet. In the course of the evaluation of $NaNO_2$ intake, the groups of meat foodstuffs that are sources of sodium nitrite in the diets of the whole study group were analysed (Fig. 1). The data presented shows that 54% of the sodium nitrite present in the diets of the respondents came from pork products – pork cold cuts (hams, sirloins and sausages).

There is a need to limit the consumption of these types of products, which can help reduce the risk of excessive nitrite intake.

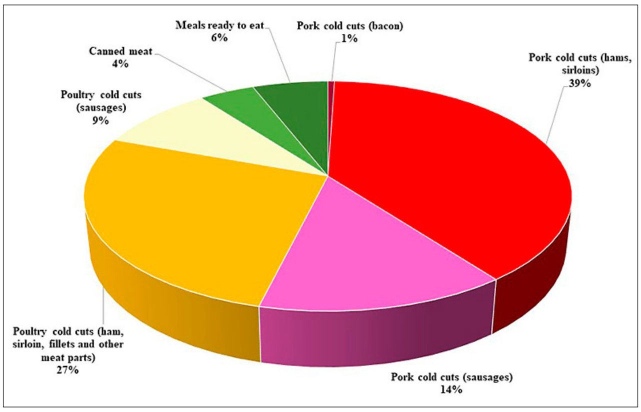

Figure 1. Share of individual product groups as a source of sodium nitrite in the diets of respondents (%)

DISCUSSION

The authors compared the data on actual dietary intake of sodium nitrite (E250) to the previous analyses basing on the same 2000 Polish population intake data, considering the same groups of people [8] which were made with the use of the worst case scenario, where the maximum level in food products was used to calculate the nitrites intake [2]. In 2009, an assessment was carried out of the exposure of the Polish population to nitrites originating mostly (over 98%) from cured meat products. When analysing the data, the maximum permissible amounts of E250 that can be used by the producer during the production of meat products were assumed (worst case scenario). The value of the average intake of sodium nitrite from food by the general public was 9.3 mg/person/day, which was 156% of the ADI [8].

On the other hand, analysing the intake of E 250 from meat products on the basis of the actual content of this compound showed that it was significantly lower at 0.7 mg/person/day, which corresponds to nearly 12.1% of the ADI. In all analysed groups of people, a decrease in the amount of actual nitrite intake from cured meat products was observed compared to the assumptions of the worst case scenario. Assessment of consumer exposure to nitrites in meat products, based on the results of laboratory tests for residues of sodium nitrite in meat products, indicate a lower intake of nitrites than in the worst case scenario. This is understandable given the fact that the actual nitrite content (expressed as sodium nitrite) found in meat products is usually lower than the Maximum Permitted Level of these compounds set by legislation [9, 10, 11]. A 2003 opinion from the European Food Safety Authority (EFSA) indicated that a direct correlation between the amount of nitrite entering a product and the residue of these compounds cannot be established [12]. The content of nitrates and nitrites in the final product depends on many factors, such as the type of heat treatment, the pH of the product, storage conditions and time, and the addition of ascorbic or isoascorbic acid salts.

Comparing the results of the current with results from other countries, it was found that in groups of adolescents the intake of sodium nitrite with meat products varies across the countries of the European Union. In France, the intake of nitrites along with meat products by the same age group (people over 15 years) accounted for 16.7% of the ADI [13]. In Poland, sodium nitrite intake was lower in the 11–17 age group, at 14% of ADI. In Denmark, the intake of nitrite for people aged over 15 years was lower than in Poland – 7% of the ADI for men and 3% of the ADI for women [14]. This low intake of nitrite in Denmark is likely due to the fact that at the time of the study, Denmark had national regulations allowing the use of nitrite in meat products at lower levels than provided for in the European Parliament and Council Regulation [2]. Denmark has maintained stricter regulations on the use of nitrite in food, i.e. a maximum of 60 mg/kg, and up until the present day, only in certain meat products a maximum of 100 mg/kg or 150 mg/kg [15]. The producers should use the lowest possible levels of nitrite in meat products to minimise consumer exposure.

The main challenge now for the meat industry is to look for effective ways to reduce nitrite residues in cured meat, and to find better substitutes for nitrite in meat products. New technologies, such as High Hydrostatic Pressure (HHP) treatment and several plant extracts, microflora and organic acids could be effectively used in processed meat products as nitrite alternatives [16]. However, there is no single substitute for nitrite that can simultaneously provide all its functions. Therefore, the most effective approach is to use combined technologies in the meat curing process, in which low levels of sodium nitrite are used in combination with other compounds and/or with other processing technologies that show inhibitory effects against the most prevalent pathogenic microorganisms (primarily *Clostridium botulinum)* and better sensory properties. Further research is needed to confirm the safety of these compounds as well as the technology in terms of human health before implementation in the food industry [17].

Regarding children's nitrite intake (general studied population), it should be noted that in Poland it is comparable to selected European countries, e.g. Estonia [18]. Studies carried out in 2013–2014 showed that in Estonia, the average intake of nitrites from meat products by children aged 1–3 years was 22% of ADI (23.6% of ADI in Poland), and in the group of children aged 4–6 years and 7–9 years, the intake of these compounds in Estonia was recorded in amounts equivalent to 26% of ADI and 20% of ADI. In Poland, there was a lower intake in the 4–10 age group – 15.3% ADI. The intake of nitrites with meat products by children aged 3–14 in France [13] was 16.7% of the ADI. The average intake of nitrite from cured products in Sweden [19] was: 18.6% ADI for 4-year-olds, 14.3% ADI for 8–9-year-olds, and 10% ADI for 11–12-year-olds.

A Greek study, according to the results from the Hellenic National Nutrition and Health Survey (HNNHS), median exposure was estimated to be within safe levels for all population groups. However, 6.6% (n = 143) of the consumers exceeded ADI of nitrite (0.07 mg/kg bw/day), of which 20.3% were children aged 0–9 years. In total, pork meat was the major contributor (41.5%) [20]. According to the Polish results, the amount of the nitrite in the pork meat products was 54% in diet of the studied persons.

Danish analyses based on the Danish Diet, Cancer and Health Cohort, socio-demographic and lifestyle information was obtained from participants at enrolment (1993–1997). In a Danish cohort of 55,754 participants aged 50–65, the median Interquartile Range (IQR) intakes of dietary nitrate and nitrite were 58.13 (44.27–74.90) mg/d and 1.79 (1.43–2.21) mg/d, respectively [21]. The average nitrite intake of children aged 4–5 and 6–14 was 17% and 9% of the ADI, respectively, for boys, and 14% and 8% of the ADI, respectively, for girls [14]. In the opinion of the EFSA, the intake of nitrites as additives in European countries does not exceed the ADI, with a small exception for children aged 3–9 years consuming large amounts of foods containing these compounds (95th percentile of intake) [3].

Referring to children's nitrite intake in the 'consumer only' group, it should be noted that the average dietary intake of these compounds in Poland was higher than in Estonia [18]. Studies conducted in 2013–2014 showed that in Estonia, the average intake of nitrites by children aged 1–3 years consuming cured meat products was 24% ADI (55.1% ADI for boys and 49.9% ADI for girls in Poland), and for children aged 4–6 years and 7–9 years an intake of 28% ADI and 21% ADI was recorded (30.8% ADI for boys and 29.6% ADI for girls in 4–10 age group in Poland).

The results obtained in the current study concern consumer exposure in Poland to nitrites from cured meat products, where total consumer exposure to dietary nitrites may be higher because nitrites are also present in drinking water and other foods, such as grain products, including bread, and dairy products, including cheese. Consumer exposure to nitrites may be higher after taking into account the conversion of nitrates to nitrites in the human body (endogenous conversion). The conversion of nitrate to nitrite occurs mainly in the oral cavity, and it is estimated that 5–7% of the nitrate present in food is reduced to nitrite by oral bacteria [22, 23].

Recently, as part of the work of the European Commission, consideration has been given to lower the permissible doses of nitrites added to food as additives – this applies to meat products as well as ripened cheese. This will reduce the consumption of nitrate with food. Another way to reduce nitrite intake is to limit the consumption of cured meat products [18]. In July 2022, the French Agency for Health Safety (ANSES) recommended consuming no more than 150 grams of processed meat per week (ANSES). The American Institute for Cancer Research (AICR) indicates that there is convincing evidence that consumption of processed meat is a cause of colorectal cancer [24]. Published recommendations for a healthy diet in the EAT-Lancet Commission emphasize greater consumption of vegetables, fruits, whole grains, legumes, nuts, and unrefined fats, such as olive oil, a moderate consumption of seafood and poultry, and a limited consumption of red meat, products with added sugar, processed grain products, and vegetables containing higher amounts of starch [25].

CONCLUSIONS

The estimated average intake of sodium nitrite from meat products in the Polish population was found to be at a safe level (below the ADI value). However, there is an emerging potential risk for some consumers, especially children aged 1–3 years who have a high intake of processed meat products in relation to their body weight. There is a need to reduce the consumption of processed meat among children. Recommendations regarding the limitation of processed meat consumption can help reduce the risk of excessive nitrite intake by consumers in Poland, especially children.

It is necessary to disseminate recommendations regarding the knowledge that a balanced and varied diet, with limited consumption of processed meat, can help reduce the risk of excessive nitrite intake by consumers in Poland, especially children.

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