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THE CONTENTS OF NITRATES (III) AND (V), ADDED POLYPHOSPHATES AND TOTAL LEVELS OF PHOSPHORUS, CALCIUM, MAGNESIUM, IRON AND ZINC IN SOME CURED MEAT PRODUCTS

ZAWARTOŚĆ AZOTANÓW (III) I (V), DODANYCH POLIFOSFORANÓW ORAZ FOSFORU CAŁKOWITEGO, WAPNIA, MAGNEZU, ŻELAZA I CYNKU W WĘDLINACH

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The aim of the study was to determine the contents of nitrates (III) and (V), the originally added and total phosphorus as well as levels of calcium, magnesium, iron and zinc in selected Polish cured poultry and pork products. Also, the degree to which such products satisfy recommended dietary requirements for the above minerals in adults was assessed.

INTRODUCTION

During processing of cured meat products different food additives, including polyphosphates and nitrates (III) and (V), are used because they are necessary for technological and economic reasons and to improve sensory parameters. Polyphosphates added to cured meat products exercise a variety of actions. They stabilize pH, regulate acidity, have ion-complexing power, bind water and have emulsifying, condensing and anti-oxidant effects [13, 17, 19, 20]. However, their dietary excess may lead to disorders of absorption and metabolism of other elements, especially calcium and magnesium. Nitrates (III) and (V) on the other hand are used as preservatives and anti-oxidants. They are bacteriostatic and bactericidal (e.g. against of a neurotoxin by the growth of *Clostridium botulinum*), lower the thermal resistance of the spores and inhibit their development during heat treatment. Nitrates improve the organoleptic features of most cured meat products (bright red colour of meat, improved taste and smell). It has been established that cured meat products are a source of 85% of dietary nitrates (III) and 10% of nitrates (V) [1, 2, 5, 6, 10, 12]. Too large doses of dietary nitrates (III) and (V) are harmful for humans and animals [3, 9, 18, 25, 28]. That is why, to preserve good quality of food, nitrates used in cured meat have been limited to a necessary minimum by a Regulation of the Ministry of Health [14].

The aim of the study was to determine nitrate (III) and (V) levels in selected cured meat products available on the market and compare the results with the official standards in order to confirm that indeed they were safe. Also, both quantitative and qualitative determinations of polyphosphates and relationships between added and total phosphorus, calcium, magnesium, iron and zinc were carried out in order to assess to what degree cured meat products provide these elements as shown in recommended dietary allowances for adults.

MATERIAL AND METHODS

The study was performed on 34 samples of different brands of cured meat products (11 poultry products and 23 pork products). All the samples were purchased on the local market in Warsaw. The meat samples used for analysis were homogenised and a representative mass (2,0 g) was weight into the crucible and the concentrated nitric acid (5 ml) was added. The test samples of meat products underwent wet mineralization in a closed system in a microwave mineralizer (Plazmatronika). In the next step, samples were diluted with redistilled water and made up to 10 ml in volumetric flasks. The phosphorus content was measured by the spectrophotometric method (molybdenum blue method) according to *Scheele* [11, 22]. The protein content was determined by the method of *Kjeldahl* [11, 21]. Next, the physiological phosphorus levels were measured assuming that the natural phosphorus occurring in the muscle tissue is correlated with the amount of protein constituting 1% of its content [7, 22]. The amount of added phosphorus was calculated as the difference between total and physiological phosphorus. Polyphosphates added to the meat products were identified by thin-layer chromatography [22]. Mineral elements, such as calcium, magnesium, iron and zinc were measured in the digested samples by flame atomic absorption in the conditions specified by the manufacturer's instruction [29]. All analysis were performed in triplicate.

Nitrates (III) and (V) were determined by spectrophotometry with *Griess* reagents, according to the Polish standard [23, 26]. The method consists of qualitative determination of nitrates (III) and of nitrates (V) after reduction to nitrates (III) by measuring the absorbance of coloured complexes of dizocompounds of nitrates (III) with sulphanilamide (*Griess* reagent I) and N-(1-naphthyl) ethylenediamine dihydrochloride (*Griess* reagent II) in hydrochloric acid. Reduction of nitrates (V) to nitrates (III) was performed using powdered cadmium.

RESULTS AND DISCUSSION

In Poland, the maximum limit of phosphates (expressed as P_2O_5) added to meat products is 5 g/kg product while sodium nitrate (III) may be used exclusively as a uniform mixture with table salt where the $NaNO_2$ content must not exceed 0.5-0.6%. The permissible limit of nitrates (III+V) in cured meat products, smoked meat products and in canned meats is 125 mg/kg product, expressed as $NaNO_2$ [14].

According to our findings, in cured pork products nitrates (III) ranged from 0.6 mg to 53.8 mg $NaNO_2$/kg (mean 8.5 mg/kg) while in cured poultry product the range was 1.0 to 33.5 mg $NaNO_2$/kg (mean 9.2 mg/kg). The mean content in all tested cured meat products was 8.7 mg $NaNO_2$/kg product (Tab. I).

The mean nitrates (V) content for all tested cured meat products was 17.7 mg $NaNO_3$/kg product (Tab. II). In cured pork products nitrate (V) ranged from 9.2 mg to 58.7 mg $NaNO_3$/kg (mean 20.4 mg/kg) while in cured poultry product the range was 5.5 mg to 20.1 mg $NaNO_3$/kg (mean 11.9 mg/kg). These findings are in agreement with the literature data [4, 8, 27] which report nitrates (III) residues of approximately 10 mg/kg and nitrates (V) residues of

Table I. Content of sodium nitrate (III) in tested products (mg/kg)
Zawartość azotanu sodu (III) w badanych produktach (mg/kg)

Products	n	$\bar{x}$ ± SD	min	max
Cured pork products	23	8.5 ± 13.3	0.6	53.8
Cured poultry products	11	9.2 ± 12.2	1.0	33.5
Total	34	8.7 ± 12.8	0.6	53.8

$\bar{x}$ – geometrical mean
SD – standard deviation

Table II. Content of sodium nitrate (V) in tested products (mg/kg)
Zawartość azotanu sodu (V) w badanych produktach (mg/kg)

Products	n	$\bar{x}$ ± SD	min	max
Cured pork products	23	20.4 ± 12.3	9.2	58.7
Cured poultry products	11	11.9 ± 4.7	5.5	20.1
Total	34	17.7 ± 11.1	5.5	58.7

$\bar{x}$ – geometrical mean
SD – standard deviation

10-50 mg/kg. All cured meat products showed lower concentrations of nitrates (III) than nitrates (V), which indicates absence of an advanced reduction process. The mean level of nitrates (III) in cured poultry products (9.2 mg/kg) was very close to the mean nitrate (V) content (11.9 mg/kg) in contrast to cured pork products where nitrates (V) predominated (Tab. I, II).

Determinations of nitrates (III+V) did not establish levels exceeding the permissible limits described in the Polish Standards (Tab. III). In cured pork products nitrates (III+V) ranged from 8.3 mg to 77.9 mg $NaNO_2$/kg (mean 25.2 mg/kg) while in cured poultry product the range was 5.8 to 40.6 mg $NaNO_2$/kg (mean 19.4 mg/kg) (Tab. III). It should be noted that cured pork products contained much higher maximum nitrates (III+V) levels than cured poultry products although mean nitrates (III+V) levels were similar. The mean nitrates (III+V) content of cured pork and poultry products was 23.3 mg $NaNO_2$/kg product (Tab. III). Interestingly, 18% of all cured meat products showed nitrates (III+V) levels below 10 mg $NaNO_2$/kg product and above 40 mg/$NaNO_2$/kg product. When historical studies of residual nitrates (III+V) in cured meat products in Poland over a period of 10 years [4] are compared with new studies a significant decrease in nitrate content of meat products can be seen (Tab. IV). This reduction has been achieved by lowering the amount of added nitrates (III), increased content of ascorbic acid, improved quality control of processing and improved recipes for cured meat products (less fat, less new additives). A search for preservatives which might replace nitrates (III) continues, but no single universal and multifunctional compound has been found. Alternative preservatives include lactic acid, antioxidants

Table III. Content of nitrates (III) and (V) in tested products (mg $NaNO_2$/kg)
Zawartość azotanów (III) i (V) w badanych produktach (mg $NaNO_2$/kg)

Products	n	$\bar{x} \pm SD$	min	max	No of samples exceeding limit 125 mg $NaNO_2$/kg*
Cured pork products	23	25.2 ± 19.8	8.3	77.9	0
Cured poultry products	11	19.4 ± 13.7	5.8	40.6	0
Total	34	23.3 ± 18.1	5.8	77.9	0

* – according to Regulation of the Polish Ministry of Health of 23.04.2004 [14]
$\bar{x}$ – geometrical mean
SD – standard deviation

Table IV. Comparison of nitrates (III) and (V) content in meat products (mg $NaNO_2$/kg) [4]
Porównanie zawartość azotanów (III) i (V) w produktach mięsnych (mg $NaNO_2$/kg)) [4]

Products	Years	n	$\bar{x} \pm SD$	min	max	No of samples exceeding limit 125 mg $NaNO_2$/kg*
Cured meat products	1994[a]	41	61.4 ± 24.4	25.5	120.9	0
	1995[a]	46	48.8 ± 21.0	21.8	127.9	1
	1996[a]	74	38.3 ± 40.4	9.9	342.3	1
	1997[a]	75	33.0 ± 19.3	8.5	98.2	0
	1998[a]	125	32.5 ± 17.1	7.8	111.9	0
	1999[a]	115	32.4 ± 18.5	6.1	89.0	0
	This study	34	23.3 ± 18.1	5.8	77.9	0

* – according to Regulation of the Polish Ministry of Health of 23.04.2004 [14]
[a] according to *Kłossowska* [4]
$\bar{x}$– geometrical mean
SD – standard deviation

(ascorbic acid, citric acid, α-tocopherol), nicotinates, fumarates, sodium hypophosphite or bacterial species producing lactic acid [14, 27].

The contents of polyphosphates added to the investigated products ranged from 0 to 372.9 mg P_2O_5/100 g product (mean 140.4 mg P_2O_5/100 g) in cured pork products and from 0 to 280.4 mg P_2O_5/100 g (mean 104.3 mg P_2O_5/100 g) in cured poultry products. The mean value for all cured meat products tested was 124.6 mg P_2O_5/100 g product (Tab. V). No polyphosphates were found in 9% of the products while in 25% their concentrations exceeded 200 mg P_2O_5/100 g product. Comparing the results of studies conducted over

Table V. Content of added phosphate in tested products (mg P_2O_5/100 g)
Zawartość dodanych fosforanów w badanych produktach (mg P_2O_5/100 g)

Products	n	$\bar{x} \pm SD$	min	max	No of samples exceeding limit 500 mg/100 g*
Cured pork products	23	140.4 ± 83.4	0	372.9	0
Cured poultry products	11	104.3 ± 112.7	0	280.4	0
Total	34	124.6 ± 95.2	0	372.9	0

* – according to Regulation of the Polish Ministry of Health of 23.04.2004 [14]
$\bar{x}$– geometrical mean
SD – standard deviation

a period of 10 years, one may see that polyphosphate levels just like nitrates (III+V) levels tended to fall till 1999 [4]. In recent years, these levels have dangerously increased by 100% compared to 1999.

It may be accounted for by the fact that regulations limiting the maximum amount of polyphosphates added to meat products changed. The limit increased from 150 mg P_2O_5/100 g product (pork and poultry products) and 300 mg P_2O_5/100 g product (beef products) to as much as 500 mg P_2O_5/100 g product. According to the Regulation of the Polish Ministry of Health [14] – orthophosphates, diphosphates, triphosphates and polyphosphates may be added to processed meat products. No such compounds were found in the meat products investigated. As mentioned earlier, addition of polyphosphates improves processing, sensory properties and output of meat products. On the other hand, there have been reports of their unfavourable effects on calcium metabolism and concentrations of other elements, such as magnesium, iron and zinc in the body [16, 24]. The optimum concentration of polyphosphates in food products has been a subject of numerous debates. This issue concerns mainly to meat products, processed cheese, powdered soup mixes, confectionery and beverages [15, 16]. It must be remembered that some food products also contain natural phosphorus, the amount of which ranges from several to several hundred milligrams per 100 g of products. According to reports, the amount of phosphorus increases by 20 to 30% when food is industrially processed [30]. Phosphorus contained in food occurs mostly in combination with lipids or proteins. It can be absorbed from these complexes only after their decomposition by suitable digestive enzymes. Additionally, in the legumes and cereals some of the phosphorus is present as poorly soluble divalent-metal salts of inosito-6-phosphpric acid (phytic acid) which is also poorly absorbable [30]. On the other hand, inorganic phosphates, used as additives, easily undergo hydrolysis in the alimentary tract and their proportion in total phosphorus is larger than that of the phosphorus naturally occurring in foods [16, 30].

According to our study, the mean total phosphorus (i.e. natural and added) in the cured meat products was 226.1 mg/100 g (28% RDA) (Tab. VII). The mean contents of other elements per 100 g of product were as follows: calcium – 9.1 mg (1% RDA), magnesium – 17.5 mg (5% RDA), iron – 0.8 mg (5% RDA) and zinc – 1.4 mg (10% RDA). The highest

Table VI. Comparison of added phosphate content in meat products (mg P_2O_5/100 g) [4]
Porównanie zawartość dodanych fosforanów w produktach mięsnych (mg P_2O_5/100 g) [4]

Products	Years	N	$\bar{x}$ ± SD	min	max	No of samples exceeding limit 500 mg/100 g*
Cured meat products	1994[a]	41	145 ± 55	30	250	14
	1995[a]	46	103 ± 48	0	220	4
	1996[a]	74	92 ± 52	0	230	4
	1997[a]	75	89 ± 45	0	150	0
	1998[a]	125	88 ± 39	20	190	5
	1999[a]	115	65 ± 54	0	180	4
	This study	34	124.6 ± 95	0	373	0

* – according to Regulation of the Polish Ministry of Health of 23.04.2004 r. [14]
[a] – according to *Kłossowska*[4]
$\bar{x}$ – geometrical mean
SD – standard deviation

Table VII. Content of Ca, Mg, Fe, Zn and P in tested products [mg/100 g] [n=34]
Zawartość Ca, Mg, Fe, Zn i P w badanych produktach [mg/100 g] [n=34]

Cured pork and poultry products	$\bar{x}$ ± SD	min	max	RDA	Ratio
Ca	9.1 ± 4.9	3.4	29.4	1%	P:Ca - 25:1
Mg	17.5 ± 3.6	12.1	27.4	5%	P:Mg - 13:1
Fe	0.8 ± 0.3	0.4	2.4	5%	P:Fe - 255:1
Zn	1.4 ± 0.6	0.4	3.4	10%	P:Zn - 151:1
P	226.1 ± 48.4	112.6	338.2	28%	–

$\bar{x}$ – geometrical mean
SD – standard deviation

levels of zinc and iron were found in pork products. Because the metabolism of calcium and phosphorus in the human body is closely interrelated, dietary intake of phosphorus and calcium should remain at the same level, i.e. the calcium : phosphorus ratio in daily diet should be 1 mol : 1 mol or 40 g calcium : 30.9 g phosphorus. In breast milk, the ratio is 1.5:1 and it may be assumed that these values should be considered a standard in infant nutrition [15, 24, 30]. Our study demonstrated that in meat products the P : Ca ratio was 25:1; P : Mg – 13:1; P : Fe – 255:1; P : Zn – 151:1 (Tab. VII). Such excess of phosphorus may impair the absorption of other minerals as poorly soluble salts form in the alimentary tract.

CONCLUSIONS

Summing up, in none of the cured meat products investigated, the regulatory limit of nitrates (III) and (V) was exceeded. The amount of polyphosphates added to the meat products we have investigated also remained below the limit established by the Polish regulations. Also, no polyphosphates which are not allowed has been detected. As meat products are very popular, even when their daily consumption is 100 g, they may become a rich source of phosphorus and less important as sources of zinc, magnesium and iron, but will supply virtually no calcium. Additionally, a very unfavourable ratio of phosphorus to the remaining elements, especially calcium may significantly impair their absorption.

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Summary

The aim of the study was to determine the contents of nitrates (III) and (V), the originally added and total phosphorus as well as levels of calcium, magnesium, iron and zinc in selected Polish cured poultry and pork products. Also, the degree to which such products satisfy recommended dietary requirements for the above minerals in adults was assessed. The nitrates (III) and (V) and polyphosphate levels in the meat products tested were found to vary although they never exceeded the limits imposed by relevant regulations. The mean combined content of nitrates (III+V) in the cured meat products was 23.3 mg $NaNO_2$/kg, i.e. 19% of the maximum allowable dose which is 125 mg/kg product. It should be emphasised that the mean maximum levels of nitrates (III), nitrites (V) and nitrates (III+V) were much

higher in pork products than in poultry products. The mean content of polyphosphates added to the meat products was 124.6 mg P_2O_5/100 g product, i.e. 25% of the maximum allowable dose which is 500 mg/100 g product. Cured pork products demonstrated higher maximum levels of added phosphates than cured poultry products. No polyphosphates which are not allowed were found in the meat products which were investigated. The levels of minerals per 100 g of product were as follows: total phosphorus (natural and added) – 226.1 mg, calcium – 9.1 mg, magnesium – 17.5 mg, iron – 0.8 mg and zinc – 1.4 mg. Consumption of 100 g of the meat products investigated provided 28% of daily dietary requirements (RDA) for phosphorus, 1% for calcium, 10% for zinc, 5% for magnesium and iron. The highest levels of zinc and iron were found in pork products. Our study demonstrated that in meat products the P:Ca ratio was 25:1; P:Mg – 13:1.

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ZAWARTOŚĆ AZOTANÓW (III) I (V), DODANYCH POLIFOSFORANÓW ORAZ FOSFORU CAŁKOWITEGO, WAPNIA, MAGNEZU, ŻELAZA I CYNKU W WĘDLINACH

Celem pracy było oznaczenie zawartości azotanów (III) i (V), fosforanów dodanych oraz fosforu całkowitego oraz wapnia, magnezu, żelaza i cynku w wybranych wędlinach wieprzowych i drobiowych. Określono również w jakim stopniu 100 g badanych produktów pokrywa średnie dzienne zapotrzebowanie na w/w składniki mineralne u osób dorosłych. W toku badań stwierdzono zróżnicowaną zawartość azotanów (III) i (V) oraz polifosforanów w analizowanych przetworach mięsnych. Jednakże w żadnym przypadku nie została przekroczona dopuszczona ilość, określona w stosownym rozporządzeniu. Średnia zawartość sumy azotanów (III + V) w wędlinach wynosiła 23,3 mg $NaNO_2$/kg, co stanowi 19% dopuszczonej dawki czyli 125 mg $NaNO_2$/kg produktu. Warto podkreślić, że najwyższe poziomy azotanów (III) i (V) oraz (III + V) stwierdzono w wędlinach wieprzowych. Średnia zawartość polifosforanów dodanych wynosiła 124,6 mg P_2O_5/100 g, co stanowi 25% dopuszczonej dawki czyli 500 mg/100 g produktu. Także w tym przypadku maksymalna wykryta ilość polifosforanów występowała w wędlinach wieprzowych. W żadnej z prób nie stwierdzono niedopuszczonych polifosforanów. Średnia zawartość składników mineralnych w 100 g produktu przedstawiała się następująco: fosfor całkowity (dodany i naturalny) – 226,1 mg; wapń – 9,1 mg; magnez – 17,5 mg; żelazo – 0,8 mg; cynk – 1,4 mg. Tak więc spożycie 100 g badanego produktu mięsnego pokrywa w 28% średnie dzienne zapotrzebowanie na fosfor; w 1% na wapń; w 10% na cynk i w 5% na magnez i żelazo. Wyższe poziomy cynku i żelaza stwierdzono w wędlinach wieprzowych w porównaniu do wędlin drobiowych. Zgodnie z wynikami badań można stwierdzić, że stosunek P:Ca wyniósł 25:1; P:Mg – 13:1.

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