Rocz Panstw Zakl Hig 2017;68(4):339-346

http://wydawnictwa.pzh.gov.pl/roczniki_pzh/

ORIGINAL ARTICLE

EXPOSURE ASSESSMENT OF THE POPULATION IN POLAND TO THE TOXIC EFFECTS OF ARSENIC COMPOUNDS PRESENT IN RICE AND RICE BASED PRODUCTS

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ABSTRACT

Background. Rice is a staple food for many people in the world and an important ingredient for production of food for infants and young children. According to European Food Safety Authority (EFSA), cereals, primarily rice and rice products, are an important source of human exposure to inorganic arsenic, which has been classified by the International Agency for Research on Cancer (IARC) as group I carcinogen. Arsenic is present in rice and rice products mainly as an inorganic form being more toxic than organic compounds.

Objectives. The aim of the study was to determine the total and inorganic arsenic content in rice, rice-based products including food for infants and young children available on the market in Poland and thus to estimate consumer exposure to inorganic arsenic from these groups of foodstuffs.

Materials and Methods. A total of 62 samples of rice and rice products from trade, including a group of rice products for infants and young children, were tested. Contents of total and inorganic arsenic were determined by using hydride generation atomic absorption spectrometry (HGAAS), after dry mineralization of samples and reduction of arsenic to arsenic hydride with sodium borohydride. To extract the inorganic arsenic forms, the samples were subjected to hydrolysis in concentrated HCl and then reduced in the presence of hydrobromic acid and hydrazine sulphate after which triple chloroform extractions and triple 1M HCl re-extractions were performed. Exposure of different groups of populations (adults and children), was estimated in relation to the Benchmark Dose Lower Confidence Limit ($BMDL_{05}$) as set by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) that resulted in a 0.5% increase in lung cancer (3.0 µg/kg body weight (b.w.) per day).

Results. Mean content of total and inorganic arsenic in investigated rice samples was 0.12 mg/kg (median: 0.09 mg/kg; 90th percentile 0.22 mg/kg) and 0.04 mg/kg (median: 0.03 mg/kg, 90th percentile 0.07 mg/kg). Brown rice was found to be more highly contaminated with both total and inorganic arsenic than white rice. Mean contamination of brown rice with total arsenic and inorganic arsenic was: 0.18 mg/kg (median: 0.12 mg/kg, 90th percentile: 0.32 mg/kg) and 0.05 mg/kg (median: 0.05 mg/kg, 90th percentile: 0.07 mg/kg). In turn for the white rice contamination was lower, mean total arsenic content: 0.10 mg/kg (median: 0.08 mg/kg, 90th percentile: 0.19 mg/kg) and mean inorganic arsenic: 0.03 mg/kg (median: 0.03 mg/kg, 90th percentile: 0.06 mg/kg). Contamination of rice-based products both total and inorganic arsenic was similar to those reported for rice, except rice wafers (mean: 0.24 mg/kg and 0.13 mg/kg). In the group of products for infants and young children obtained results were low – mean total arsenic content was 0.06 mg/kg and inorganic arsenic 0.02 mg/kg. The estimated average adult and children's exposure to inorganic arsenic with rice and rice products was less than 1% of the $BMDL_{05}$. Intake of inorganic arsenic by 12-month-old infants with rice-based products intended for this group of population was at 6% $BMDL_{05}$.

Conclusions. Based on the obtained results, it was found that the content of total and inorganic arsenic in investigated samples of rice and rice products did not pose a health risk even though contamination levels in some individual samples were significant.

Key words: *total arsenic, inorganic arsenic, rice, rice products, food for infant, food for young children, exposure assessment*

STRESZCZENIE

Wprowadzenie. Ryż stanowi podstawę wyżywienia wielu ludzi na świecie a ponadto jest ważnym składnikiem wykorzystywanym do produkcji żywności dla niemowląt i małych dzieci.

Według Europejskiego Urzędu ds. Bezpieczeństwa Żywności (EFSA) zboża, przede wszystkim ryż i produkty ryżowe są istotnym źródłem narażenia człowieka na arsen nieorganiczny, który został zaliczony przez Międzynarodową Agencję

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ds. Badań nad Rakiem (IARC) do grupy I substancji rakotwórczych dla człowieka. Arsen występuje w ryżu i produktach ryżowych głównie w postaci bardziej toksycznych nieorganicznych połączeń w porównaniu z organicznymi połączeniami charakteryzującymi się mniejszą toksycznością.

Cel. Celem badań było oznaczenie zawartości arsenu całkowitego i nieorganicznego w ryżu, produktach ryżowych, w tym żywności dla niemowląt i małych dzieci dostępnych w obrocie handlowym w Polsce oraz ocena narażenia konsumentów na pobranie arsenu nieorganicznego z tymi grupami środków spożywczych.

Materiał i metody. Zbadano łącznie 62 próbki ryżu oraz produktów ryżowych pochodzących z obrotu handlowego, w tym grupę produktów ryżowych przeznaczonych dla niemowląt i małych dzieci. Zawartości arsenu całkowitego i nieorganicznego oznaczono po suchej mineralizacji próbek metodą absorpcyjnej spektrometrii atomowej z wykorzystaniem generacji wodorków (HGAAS), po uprzedniej redukcji arsenu do arsenowodoru za pomocą borowodorku sodu. W celu wydzielenia nieorganicznych form arsenu próbki przed mineralizacją poddano hydrolizie w środowisku stężonego HCl, a następnie redukcji w obecności kwasu bromowodorowego i siarczanu hydrazyny oraz 3-krotnej ekstrakcji chloroformem i reekstrakcji 1M HCl. Oszacowane narażenie w odniesieniu do różnych grup populacji porównano z wartością najniższej dawki wyznaczającej (Benchmark Dose Lower Confidence Limit) $BMDL_{05}$ ustaloną przez the Joint FAO/WHO Expert Committee on Food Additives (JECFA) powodującą 0,5% wzrost zachorowań na raka płuc (3,0 µg/kg m.c./dzień).

Wyniki. Średnia zawartość arsenu całkowitego i nieorganicznego w badanych próbkach ryżu wyniosła 0,12 mg/kg (mediana: 0,09 mg/kg; 90-ty percentyl: 0,22 mg/kg) oraz 0,04 mg/kg (mediana: 0,03 mg/kg, 90-ty percentyl: 0,07 mg/kg). Zanieczyszczenie ryżu brązowego zarówno arsenem całkowitym jak i nieorganicznym było wyższe w porównaniu z ryżem białym. Średnia zawartość arsenu całkowitego w badanych próbkach ryżu brązowego wyniosła 0,18 mg/kg (mediana: 0,12 mg/kg, 90-ty percentyl: 0,32 mg/kg), natomiast arsenu nieorganicznego 0,05 mg/kg, (mediana: 0,05 mg/kg, 90-ty percentyl: 0,07 mg/kg). Zanieczyszczenie ryżu białego arsenem całkowitym i nieorganicznym było niższe, średnia odpowiednio: 0,10 mg/kg (mediana 0,08 mg/kg; 90-ty percentyl 0,19 mg/kg) oraz 0,03 mg/kg (mediana 0,03 mg/kg; 90-ty percentyl 0,06 mg/kg). Zanieczyszczenie produktów ryżowych zarówno arsenem całkowitym jak i nieorganicznym było podobne do stwierdzanego w ryżu z wyjątkiem wafli ryżowych (średnia: 0,24 mg/kg i 0,13 mg/kg). W grupie produktów dla niemowląt uzyskane wyniki były niskie – średnia zawartość arsenu całkowitego wyniosła 0,06 mg/kg, nieorganicznego zaś 0,02 mg/kg. W odniesieniu do dorosłych i dzieci oszacowane średnie narażenie na arsen nieorganiczny dla ryżu i produktów ryżowych wyniosło poniżej 1% najniższej dawki wyznaczającej $BMDL_{05.}$ Pobranie arsenu nieorganicznego przez 12-miesięczne niemowlęta z produktami na bazie ryżu przeznaczonymi dla tej grupy populacji wyniosło 6% $BMDL_{05.}$

Wnioski. Na podstawie uzyskanych wyników stwierdzono, że zawartość arsenu całkowitego i nieorganicznego w zbadanych próbkach ryżu i produktów ryżowych nie stanowi zagrożenia dla zdrowia, pomimo iż zanieczyszczenie pojedynczych próbek było istotne.

Słowa kluczowe: *arsen całkowity, aren nieorganiczny, ryż, produkty ryżowe, żywność dla niemowląt, żywność dla małych dzieci, ocena narażenia*

INTRODUCTION

Arsenic is an element characterized by a very large difference in the toxicity of individual specimens [12, 16, 33, 37]. More toxic are inorganic arsenic compounds, which have been classified by the International Agency for Research on Cancer (IARC) as group I carcinogenic [5, 22, 23, 37, 38]. Inorganic compounds of this element can cause lung, bladder, skin, kidney and liver cancer.

In 2009, the European Food Safety Authority (EFSA) established a range of benchmark dose lower confidence limit ($BMDL_{01}$) values between 0.3 and 8.0 µg/kg b.w. per day for cancers of the lung, skin and bladder, as well as skin lesions [20, 23, 37].

In 2010, the Joint FAO/WHO Expert Committee on Food Additives (JECFA), based on the epidemiological studies computed the Benchmark Dose Lower Confidence Limit ($BMDL_{05}$) at 3.0 µg/kg b.w./day causing a 0.5% increase in lung cancer [49]. The Committee withdrew the previous provisional tolerable weekly intake (PTWI) which was at 15 µg/kg b.w./day [48].

The main source of inorganic arsenic in human diet are primarily cereal grains, cereal based products, rice grains and rice based products, food for special dietary uses, drinking water, bottled water, coffee, beer, fish and vegetables [5, 24, 27, 30, 37, 38]. Rice has higher arsenic levels than other cereals because characterized of more efficient accumulation of this element form the soil and water [5, 26, 28, 34, 39, 40]. The content of arsenic in rice can be even 10 times higher than in other cereals [11, 21, 53]. It is estimated that about 50 % of arsenic is present in rice in more toxic inorganic form, however this value can vary from 10 to 90% depending on rice cultivar, locality and growing conditions [11,18, 25, 29, 53].

Consumption of rice varies between 12.7 g per person per day in Europe to 381.3 g per day in the Far East [43]. Rice is a staple food of over three billion people in the world and is a basic cereal for production of food for infants and young children [3, 17, 29, 35, 50]. Rice-based infant food has a low allergen potential and higher nutritional value in comparison with other cereals [5, 16, 26, 39]. The absence of gluten makes rice a basic cereal for infants with celiac disease [5]. Children under three years

of age are the most exposed to inorganic arsenic which is directly related to the intake of rice based-products [5, 37, 45, 46]. Other important factor is that infants and young children have higher food consumption rates on body weight basis than adults [39]. Dietary exposure to inorganic arsenic for children under three years old, including from rice-based foods, is in general estimated to be about 2 to 3-fold that of adults and ranges from 0.50 to 2.66 µg/kg b.w. per day. High consumers of rice in Europe, such as certain ethnic groups, are estimated to have a daily dietary exposure of inorganic arsenic of about 1 µg/kg b.w. per day [37]. According to EFSA the average arsenic intake in EU countries ranges from 0.936 µg/kg b.w. per day to 1.224 µg/kg b.w. per day [38]. Currently, maximum permissible levels of inorganic arsenic in some group of foodstuffs are set in Commission Regulation (EU) 2015/1006 of 25 June 2015 amending Regulation (EC) No 1881/2006. These only concern rice, rice products such as rice wafers, rice crackers and rice cakes as well as rice destined for the production of food for infants and young children and are set in the range of 0.10 mg/kg ÷ 0.30 mg/kg [9]. The maximum level for polished rice - 0.2 mg/kg complies with the limit set by the Codex Committee on Contaminants in Foods but limit for husked rice set in EU 0.25 mg/kg is much lower from the maximum level adopted by Codex - 0.35 mg/kg for this product [15]. Requirements for other groups of foodstuffs at the EU and national level as well as stipulated by the Codex Alimentarius standards of FAO/WHO, deal with total arsenic only [8, 15, 31, 32, 36].

In 2015 the European Commission adopted recommendation concerning monitoring of arsenic in food – (EU) 2015/1381. According to this recommendation, Member States are obligated to monitor the levels of arsenic in wide variety groups of foodstuffs during the years 2016-2018 [7]. The main aim of this recommendation is to enable an accurate estimation of exposure and to complete requirements in legislation in the future.

Performance criteria for the methods of analysis inorganic arsenic in food as well as sampling plans were described in Commission Regulation (EU) 2016/582 of 15 April 2016 amending Regulation (EC) No 333/2007 [10].

The aim of the study was to determine total and inorganic arsenic in various types of rice and rice products including food for infants and young children available on the market in Poland, and to assess consumer exposure to more toxic inorganic arsenic found in these products.

MATERIALS AND METHODS

Samples

62 samples of rice and rice products including food for infants and small children that are available on the Polish market were tested for total and inorganic arsenic content. The products under analysis were: (1) 24 rice samples of different kind and origin (white, brown, jasmine, basmati, parboiled); (2) 20 samples of rice-based products for infants (rice gruel with fruits, rice gruel with milk and fruits); (3) 8 ready-to-eat pureed infant foods with addition of rice containing also other ingredients such as: meat, vegetable, fruits and milk; (4) 10 samples of rice products such as: rice wafers, crackers, flakes, noodles and rice paper.

Instruments & Equipment

The Philips Pye Unicam model 9200 Atomic Absorption Spectrometer with a PU 9360 continuous hydride vapour generation system was used for determination of total and inorganic arsenic. Further equipment included a Vortex Multi Reax shaker (Heidolph, Germany), centrifuge (Eppendorf HG, Germany), Ceran 500 hotplate (Harry Gestigkeit GmbH, Germany), Mileston Pyro TC microwave oven (Italy), hydrophobic filters (Syringe type, Millipore, 0.45 µM pore diameter), class A laboratory glassware and FALCON test tubes made of polypropylene (PP).

Reagents

Nitric acid (65% Merck), Hydrochloric acid (35 – 38% Avantor), hydrobromic acid (≥48% Sigma-Aldrich), hydrazine sulphate (Fluka), chloroform (99 – 99.4%, Sigma-Aldrich), magnesium nitrate hexahydrate (Merck), magnesium oxide (Chempur), sodium hydroxide (Merck), sodium borohydride (Merck), potassium iodide (Avantor), ascorbic acid (Avantor), a primary standard solution of arsenic (V) 1 g/L (Merck) and deionized water. All reagents used were on an appropriately high degree of purity.

Sample preparation procedure for determination of total arsenic

Approximately 1.0 g samples were placed into a quartz vaporizer and 10 mL of ashing aid was added (20% w/v $MgNO_3$ * $6H_2O$, 2% m/v MgO) followed by 5 ml of 50% v/v nitric acid. After evaporating to dryness on the hotplate, the residues were digested in a microwave oven using the manufacturer's recommended program to achieve mineralization; with the final ashing temperature not exceeding 400ºC. The resulting ash was dissolved in 5 ml 6M HCl, filtered and transferred to a flask and filled to 50 ml with 6M hydrochloric acid. Suitable blanks were prepared under the same conditions [4].

Sample preparation procedure for determination of inorganic arsenic

Samples (0.5 g) were placed into polypropylene centrifuge tubes and 1 mL of deionised water was added followed by thorough shaking to ensure complete

wetting. Concentrated HCL (20 mL) was then added and the mixture was left to stand overnight (12 – 15 hours). Next reduction was performed with 2 mL of hydrobromic acid and 1ml hydrazine sulphate (1.5% m/m) followed by manual shaking for 30 seconds. The mixture was three times extracted with chloroform (10 mL; with vortex-shaking for 3 minutes at 1400 revolutions/min (rpm) and centrifuged for 20 minutes at 4000 rpm after which the organic layer was transferred into clean polypropylene centrifuge tubes; this latter stage was repeated twice more. The combined organic layers underwent purification by being passed through hydrophobic membrane filters. Purified filtrate was extracted twice with 10 mL of 1M HCl, mixture was shaken for 3 minutes and centrifuged for 20 minutes at 4000 rpm.

The filtrates were transferred into flasks. The same procedure was used for sample blanks. Filtrates were then evaporated to dryness on a heating block and then incinerated to ash in a microwave oven using progressively increasing the temperature to 400ºC at the rate of 50ºC/h. When 400ºC was achieved, the ash samples were maintained at this temperature for 8 hours after which a white ash was obtained. The remaining ash was moistened with water, dissolved in 6M HCl and transferred into 25 mL flasks.

Determination of total and inorganic arsenic

The analytical method used was an in-house one developed at the Department of Food Safety of the National Institute of Public Health-National Institute of Hygiene (NIZP-PZH).

The sample for total arsenic content was prepared by taking appropriate volumes (10 – 20 ml) of the mineralised solutions and reducing in the presence of 6M HCl and a mixture of potassium iodide (5% m/v solution and 5% m/v solution of ascorbic acid, where the 6M HCl was used to make up the reaction mixture to a fixed volume. Where inorganic arsenic was to be determined, the entire volume of mineralised solutions was used for the aforementioned reduction reaction. The final analyses of total arsenic and inorganic arsenic were performed by HGAAS before which the samples had been subjected again to reduction; this time with 1% sodium borohydride. Conditions used were optimized according to the instrument manufacturer's recommendations.

Quality Assurance

Validated analytical methods accredited according to EN/ISO/IEC 17025:2005 were applied. The method has been validated and tested with positive results in international proficiency testing organized by Joint Research Centre - Institute for Reference Materials and Measurements, Belgium and UK Central Science Laboratory (FAPAS).

Interlaboratory quality control was performed using certified reference material 1568b (NIST) with a certified total and inorganic arsenic content.

RESULTS

The results of total and inorganic arsenic determined in 62 samples of rice, rice products, including rice-based-food for infants and young children that are available on the Polish market are presented in Figure 1. Average content of total arsenic in investigated rice samples was 0.12 mg/kg (median: 0.09 mg/kg; 90th percentile 0.22 mg/kg). In the half of rice samples total content of arsenic exceeded 0.10 mg/kg and in three samples 0.20 mg/kg. The content of total arsenic in white rice samples was lower - mean: 0.10 mg/kg (median: 0.08 mg/kg, 90th percentile: 0.19 mg/kg), than for brown rice - mean: 0.18 mg/kg (median: 0.12 mg/kg, 90th percentile: 0.32 mg/kg). The proportions of inorganic arsenic to total arsenic in investigated samples are shown in Figure 2.

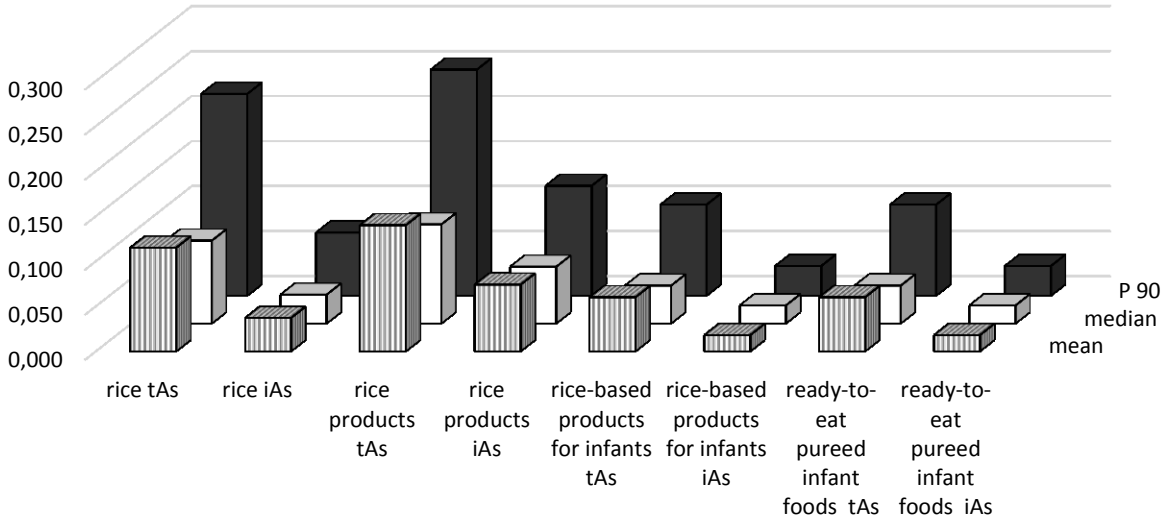

Figure 1. Total (tAs) and inorganic arsenic (iAs) contents in tested samples; mg/kg

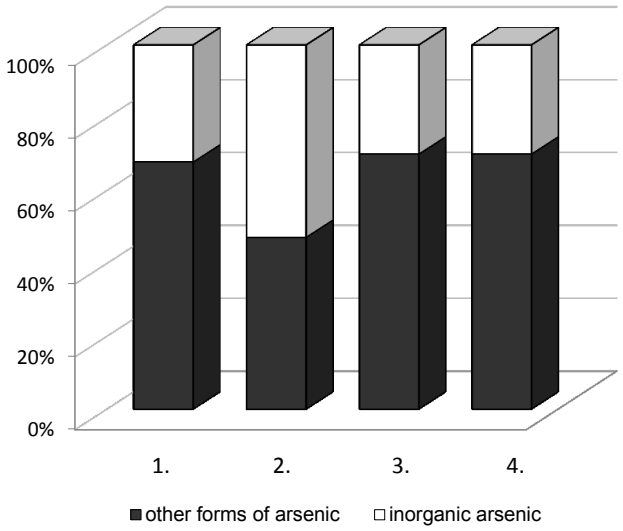

Figure 2. Proportions of inorganic arsenic to other forms of arsenic measured in tested samples

DISCUSSION

Total arsenic contamination of rice samples in Poland was similar to that reported in other EU countries mean: 0.1362 - 0.1424 mg/kg [37]. However, reported arsenic levels of rice in the present studies were higher than those obtained in monitoring studies conducted in Poland in the years 2004-2008 [42, 51]. The study conducted in UK and France also showed lower contamination of rice with arsenic [1, 2, 14]. Some other studies indicate high contamination of rice from US with total arsenic. The mean arsenic content in US rice ranged from 0.2 mg/kg to 0.3 mg/kg [25].

The content of inorganic arsenic for about one third of the tested rice samples did not exceed limit of detection of the method used – 0.025 mg/kg. Average content was 0.04 mg/kg, median: 0.03 mg/kg, 90th percentile: 0.07 mg/kg, and was much lower than reported by other EU member states countries - mean: 0.0925-0.1099 mg/kg [38].

Mean contamination of brown rice with inorganic arsenic was 0.05 mg/kg (median: 0.05 mg/kg, 90th percentile: 0.07 mg/kg) and for the white rice contamination of inorganic arsenic was just slightly lower, mean: 0.03 mg/kg (median: 0.03 mg/kg, 90th percentile: 0.06 mg/kg). Even lower contamination of white rice with inorganic arsenic was found by other authors [52].

The survey conducted in Sweden indicates similar contamination of white rice samples both total and inorganic arsenic to that reported in our study, mean values: 0.10 mg/kg and 0.07 mg/kg respectively. Results obtained for brown rice were significantly lower compared with results obtained in Swedish investigations, mean 0.14 - 0.17 mg/kg [17]. In the US inorganic arsenic content in brown and white rice was 0.072 - 0.1913 mg/kg and 0.0576 - 0.1119 mg/kg respectively [47], which is higher than reported in our study.

Reported in the present study results for inorganic arsenic in rice samples were also significantly lower than the permitted maximum level 0.20 mg/kg set by Commission Regulation (EU) 2015/1006. The content of inorganic arsenic in tested samples ranged from 30 to 50% of total arsenic, and was similar for white and brown rice - Figure 2. The results of studies conducted by other authors indicate a similar ratio [26]. There were no significant differences in total and inorganic arsenic contents for rice samples from different regions. However, the survey conducted in Italy indicates great differences in total and inorganic arsenic content for rice depending on geographical origin. Total arsenic concentration in rice samples depending on origin was in the range 0.11mg/kg - 0.28 mg/kg. These values for inorganic arsenic were in the range: 0.06 mg/kg – 0.10 mg/kg [41].

The mean concentration of both total and inorganic arsenic in the investigated presently rice based products such as pasta and flakes samples did not exceeded values obtained for rice (mean 0,140 mg/kg and 0.074 mg/kg respectively) except rice wafers (mean: 0.24 mg/kg and 0.13 mg/kg). Reported results in the group of rice products were lower than maximum level 0.3 mg/kg set in legislation [9]. In the investigated group of products for infants included: rice gruel, rice gruel with fruits and rice gruel with milk and fruits, and other solid ready-to-eat meals for infants containing rice, meat, vegetable, milk and fruits. Obtained results for these products were low – mean total arsenic content was 0.06 mg/kg (median: 0.04 mg/kg; 90th percentile 0.10 mg/kg). Similar average total arsenic contamination was obtained for these products in the monitoring studies conducted in Poland in the years 2009-2013 by the sanitary-epidemiological stations and coordinated by the Department of Food Safety of the National Institute of Public Health-National Institute of Hygiene (NIPH-NIH) [24].

Mean content of inorganic arsenic was 0.02 mg/kg (median: 0.04 mg/kg; 90th percentile 0.03 mg/kg). In more than half of the tested samples the inorganic arsenic content was below limit of detection of the analytical method used. Still lower results for both total and inorganic arsenic were obtained for ready-to-eat meals containing rice in combination with other ingredients such as: meat, vegetable and fruits. Similar lower results were described by other authors: mean inorganic arsenic concentration for ready–to-eat meals containing meat was reported at 0.008 mg/kg and total arsenic at 0.013 mg/kg [5].

In a UK study, total arsenic concentrations in pure baby rice ranged from 0.12 to 0.47 mg/kg while inorganic arsenic levels ranged from 0.06 to 0.16 mg/kg. These results for total arsenic were confirmed earlier in monitoring studies for weaning foods and formulae for infants conducted by the Food Standards Agency. Mean concentration of total arsenic in baby rice was 0,183 mg/kg [13]. Also, several other studies have shown that rice-based infant food can contain elevated levels of inorganic arsenic [39].

Taking into account the data of the Central Statistical Office on consumption of rice - 0.17 kg/person/month, [6] dietary exposure of total and inorganic arsenic was estimated and compared to the respective benchmark dose lower confidence limit $BMDL_{05}$ resulting in a 0.5% increase in lung cancer established by JECFA at 3.0 µg/kg b.w. per day.

Intake of inorganic arsenic with rice by adults (70 kg) taking into account mean contamination of 0.1% $BMDL_{05}$ (90^{th} percentile 0.2%) and does not pose a health risk. Intake of inorganic arsenic at this level of contamination by children (20 kg) would be equivalent to 0.4% $BMDL_{05}$ (90^{th} percentile 0.6%). Considering total arsenic content without distinction of different forms only this gives an average value of 0.3% $BMDL_{05}$ and 1.1% $BMDL_{05,}$ respectively, which also does not pose a health threat.

Based on the data of WHO, GEMS/Food Consumption Cluster Diets [43], where a 2-fold higher consumption of rice in European countries has been reported at 12.7 g per person per day (0.38 kg/person/month) inorganic arsenic intake by adults in Poland at the average contamination of rice and rice based products available on the domestic market will also not exceed 1% $BMDL_{05.}$

Considering nutrition recommendation developed by the Mother and Child Institute [19] as well as manufacturer's consumption recommendation as labeled on the products, the consumption of rice products by 12-month-old infants at the average contamination of inorganic arsenic - 0.02 mg/kg will result in intake at the level of 6% $BMDL_{05.}$ Estimated exposure taking into account data from this study is lower than reported in other countries [38].

According to the EU's Rapid Alert System for Food and Feed (RASFF) only a few notifications referred to raised levels of inorganic arsenic in rice as compared to other foodstuffs. Most of the notifications registered since 2005 were related to the high content of total arsenic in such foods as: food supplements, fruits and vegetables, drinking water, natural mineral water and food additives [44].

CONCLUSIONS

1. Total and inorganic arsenic contamination of tested rice and rice based products does not pose a health risk.
2. Ratios of inorganic arsenic to total arsenic in investigated samples were in the range of 30 to 50%.
3. The obtained results of inorganic arsenic content in all tested samples were significantly lower than maximum levels set in EU legislation as well as in FAO/WHO standards for white and brown rice and their products.

Acknowledgement

The study was performed as a scientific project financed by the National Institute of Public Health-National Institute of Hygiene, Warsaw, Poland (No 4/ZŚ.1., 2012.)

Conflict of interest

The authors declare no conflict of interest.

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Received: 11.07.2017
Accepted: 06.10.2017