# Arsenic in Rice: A Cause for Concern

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## ABSTRACT

Inorganic arsenic intake is likely to affect long-term health. High concentrations are found in some rice-based foods and drinks widely used in infants and young children. In order to reduce exposure, we recommend avoidance of rice drinks for infants and young children. For all of the rice products, strict regulation should be enforced regarding arsenic content. Moreover, infants and young children should consume a balanced diet including a variety of grains as carbohydrate sources. Although rice protein–based infant formulas are an option for infants with cows' milk protein allergy, the inorganic arsenic content should be declared and the potential risks should be considered when using these products.

**Key Words:** children, infants, rice drinks

(*JPGN* 2015;60: 142–145)

Arsenic is a ubiquitous metalloid that is found in nature in organic and inorganic forms. The harmful effects of arsenic are well established; however, toxicity depends on the form (inorganic or organic) and the oxidation state of arsenic compounds (1). It is generally accepted that inorganic arsenic is much more toxic than organic arsenic (2). The bioavailability of different forms of arsenic also varies. Most of the organic compounds are found in seafood, and when ingested, they undergo little biotransformation and are excreted almost unchanged (3). By contrast, inorganic arsenic, which is largely responsible for the toxic effects, is found mostly in water in specific geographic areas and in rice and rice products (2,4–6). Inorganic arsenic is considered a first-level carcinogen because long-term exposure is associated with an increased risk for various carcinomas including skin, bladder, lung, kidney, liver, and prostate (7). Furthermore, exposure is also associated with alterations in gastrointestinal, cardiovascular, hematological, pulmonary, neurological, immunological, and reproductive/developmental function (6). In greatly exposed children, inorganic arsenic exposure was reported to be related to the development of cancers and lung disease later in life (8–10). Exact mechanisms for the carcinogenicity of arsenic remain unclear but may include oxidative stress, inhibition of DNA repair, perturbation of signal transduction pathways, and chromosomal aberrations (11).

Most data in the literature report total arsenic. Quantification of inorganic arsenic is difficult, and efficient methods have only recently become available. Differentiation between total and inorganic arsenic is important because some foods such as fish and seafood with the highest total arsenic content have very low levels of the toxic inorganic form (2). In contrast, the concentration of inorganic arsenic is high in rice and can reach 90% of the total arsenic content. The concentration varies according to the soil where the rice was cultivated and the type of rice (12). The high arsenic concentration in rice compared with that in other grains reflects the anaerobic growing conditions of flooded rice paddies and the unique physiology of the plant that allows it to take up and sequester arsenic from the environment, accumulating it to a greater extent than the soil (13).

## REGULATION

The maximum tolerable level of total arsenic in drinking water defined by the World Health Organization (WHO) is 10 μg/L (14); however, there are no European Union (EU), US, or WHO limits for either total or inorganic arsenic in any food, including rice (15). The only country that regulates the level of inorganic arsenic in rice is China where the maximum contaminant level permitted is 0.15 mg/kg (16); however, because inorganic arsenic is considered a nonthreshold carcinogen, any exposure constitutes a risk and no tolerable intake level can be established (1).

The Joint Food and Agriculture Organization of the United Nations/WHO Expert Committee on Food Additives determined the lower limit of the benchmark dose confidence limit (BMDL) based on a 0.5% increase in the incidence of lung cancer to be 3.0 μg/kg body weight per day (6). The Contaminants in the Food Chain (CONTAM) Panel of the European Food Safety Authority (EFSA) determined the BMDL for a 1% extra risk for lung, skin, and bladder cancers and skin lesions to be in a range from 0.3 to 8 μg/kg body weight per day and recommended using this range

Received May 13, 2014; accepted July 7, 2014.

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The authors report no conflicts of interest.



DOI: 10.1097/MPG.0000000000000502

instead of a single reference point in the risk characterization for inorganic arsenic intake (2).

The EFSA report stated that inorganic arsenic exposure from food and water ranges from 0.13 to 0.56 μg/kg body weight per day for average consumers in 19 European countries (2). This estimated dietary exposure is within the range of the proposed BMDL values, indicating that the risk of toxicity cannot be excluded (2).

Regulation of maximum levels for heavy metals in foods for infants and young children is generally lacking; in the EU, maximum levels have been established only for lead in infant formula and follow-on formula, and for inorganic tin in canned baby foods and processed cereal–based foods for infants and young children (17). At present, there is no upper limit for what constitutes a safe inorganic arsenic intake in infants and children, even though they may be more susceptible to toxic effects, with higher exposure reported to be associated with increased infant morbidity and mortality (8–10) and impaired development (18).

## ARSENIC IN RICE

The arsenic content of raw rice varies from 0.1 to 0.4 mg of inorganic arsenic/kg of dry mass (2,4,5,12,19,20). Rice has a much higher arsenic level than that in other grains such as wheat and barley, for which the reported total arsenic content is 0.03 to 0.08 mg/kg (21). Moreover, the quantity of inorganic arsenic in cereals based on grains other than rice was less than detection levels (22).

The arsenic content in rice varies depending on the type of the rice cultivar, the place where it was cultivated, and how it was processed; brown rice contains higher concentrations than white rice (12,19,23). Moreover, changes in arsenic content may occur during the preparation of food in which cooking water seems to be of special importance; cooking rice in uncontaminated water can reduce the arsenic content of the rice (24,25).

Most of the inorganic arsenic in rice is concentrated in the bran layers that contain 10 to 20 times higher concentrations than whole grain (4,26). Therefore, the risk from consumption of products made from rice bran such as rice drinks is much higher than that from raw, but polished (white) rice (27). Moreover, rice bran is often added to products such as rice crackers or rice cereals to increase the fiber content or used directly as a health food supplement (28). As stated in the EFSA report, ''rice grains'' and ''rice-based products'' in the EU market contain very high mean levels of total arsenic, ranging from 0.14 and 0.17 mg/kg (2).

## RICE AND INORGANIC ARSENIC CONSUMPTION IN INFANTS AND CHILDREN

Rice consumption differs between ethnic groups. Traditionally in European adults, an average of 9 g of rice is consumed per day, leading to an additional exposure to inorganic arsenic of 0.015 μg/kg body weight (2), whereas in the Asian diet, rice consumption is approximately 300 g per day leading to an extra exposure of 0.5 μg/kg body weight (2); however, the risk of exposure to inorganic arsenic from rice is not limited to Asian communities; infants and young children have 2 to 3 times higher inorganic arsenic exposure than adults (2,16,27).

It has been reported that infants fed with breast milk consume the lowest levels of arsenic; Sternowsky et al found that arsenic could not be detected in more than 80% of breast milk samples and the highest concentration was 0.0028 mg/L (29). Moreover, a recently published Swedish study evaluated the content of metals in human milk; the mean total arsenic content was 0.55 μg/L, but none of the samples contained inorganic arsenic (30). Regarding arsenic in cows' milk–based infant formulas, EFSA reported that 60% of samples were less than the limit for quantification, and when inorganic arsenic was detectable, the measured levels were on average only 0.0009 mg/kg. Based on these results, it was estimated that infants who are fed with cows' milk formula ingest approximately 0.11 μg/kg per day of inorganic arsenic, which is more than 3 times higher than the estimated intake from breast milk (2). Results for recently introduced rice protein–based infant formula are lacking (31,32). One study (31) reported that inorganic arsenic in rice protein–based infant formula was 7.3 times lower than the amount reported by EFSA for infant rice–based products, which was 0.11 mg/kg (2). This would equate to 0.015 mg/kg of product, which is more than 15 times higher than in regular cows' milk–based formula; however, exact amounts of inorganic arsenic in rice protein–based infant formulas have not been independently studied.

Rice is a widely used carbohydrate source during weaning because of its availability, bland taste, nutritional value, and relatively low allergenic potential (27,33). Moreover, rice and derived products such as starch, flour, and syrup are used to fortify different infant foods, including drinks, commercial purees, and snacks (34). This could lead to high exposure of young children to inorganic arsenic (2,14). For specific groups of children with certain allergies or celiac disease, dependence on rice products is even higher (26,27).

Several studies evaluated the inorganic arsenic content in different rice-based infant products (26,27,34–38). In the US population, mean childhood (1–6 years of age) dietary intake of inorganic arsenic is 3.2 μg per day with a range of 1.6 to 6.2 μg per day (36). Meharg et al estimated that inorganic arsenic levels in the rice drink available in the United Kingdom are 0.007 to 0.021 mg/L (26) and in pure baby rice 0.06 to 0.16 mg/kg (27). Assuming consumption of a single 20-g portion per day, this equates to 0.45 and 0.75 μg/kg body weight for a 1-year-old child with a body weight of 9.25 kg (27). Similar results were reported for infant rice cereals in the United States where mean values were 0.10 mg/kg (39).

The maximum daily intake of inorganic arsenic is higher for infants who do not consume gluten. Infants with celiac disease consuming products without gluten had an arsenic exposure of 0.41 μg/kg per day compared with 0.26 μg/kg per day in healthy infants consuming products with gluten (37). The present report also found that the products with the highest content of arsenic were manufactured using organic brown rice, which is typically used by consumers seeking natural and/or ecological products. Consistent with this, Jackson et al reported that toddler formulas with added organic brown rice syrup have 20 times higher levels of inorganic arsenic than regular formulas (34).

Overall, EFSA stated that infants in the EU and Norway are exposed to a mean of 1.6 μg/kg per day of inorganic arsenic through rice-based infant food alone (2).

Although dietary exposure of children is higher than that of adults, the significance of this observation is uncertain because the toxic effects are caused by exposure for long periods (2). The exposure estimates in the EU and Norway are within the range of the BMDL values proposed by EFSA; however, they are much higher than the lowest level in the range (0.3 μg/kg per day) (2). Because of the uncertain minimum safe level, possible toxic effects, and the high content of inorganic arsenic in infant food, several national initiatives and authorities have advised against consumption of rice drinks for infants and toddlers (38). The UK Food Standards Agency does not recommend substitution of breast milk, infant formula, or cows' milk by rice drinks for toddlers and young children up to 4.5 years, whereas the Swedish National Food Agency recommends no rice-based drinks for children younger than 6 years and, in Denmark, children are advised against consuming rice drinks and biscuits (40–42).

## CONCLUSIONS AND RECOMMENDATIONS

Based on the available evidence at present, the ESPGHAN Committee on Nutrition concludes as follows:

1. Inorganic arsenic intake during childhood is likely to affect long-term health.
2. Rice, especially rice bran, contains high levels of inorganic arsenic.
3. Although there are data on inorganic arsenic in infant foods and rice drinks, there is a lack of published data on the amount in rice protein–based infant formula.

Recommendations are as follows:

1. Inorganic arsenic intake in infancy and childhood should be as low as possible.
2. The inorganic arsenic content of dietary products used by infants and children needs to be regulated.
3. Although rice protein–based infant formulas are an option for infants with cows' milk protein allergy, the inorganic arsenic content should be declared and the potential risks should be considered when using these products.
4. Rice drinks should not be used in infants and young children.
5. Inorganic arsenic exposure from food can be reduced by including a variety of grains such as oat, barley, wheat, maize, and rice.
6. In areas of the world where rice consumption is high in all ages, authorities should be prompted to declare which of the rice cultivars have the lowest arsenic content and are, therefore, the least harmful for use during infancy and childhood.
7. Globally, the arsenic content in rice should be monitored and rice with the lowest content should be used for the preparation of infant foods.

Research directions are as follows:

1. More data on the inorganic arsenic content of different foods and the impact of different levels on health later in life are required. These data will allow the development of evidence-based recommendations regarding the acceptable arsenic content in different foods for infants and children.

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