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Research Article

Arsenic concentrations in at home prepared cooked and fried rice

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Abstract

Rice is the most widely consumed food for a large part of the world containing a variety of essential nutrients, but can also be contaminated with toxics like arsenic. This study analyzes the effect of cooking and frying, processed in the consumer's kitchen, on arsenic concentrations

Firstly, arsenic concentrations were measured in a number of rice species from Thailand and Turkey, available in supermarkets. The effect of cooking was studied in both white and brown rice with time of cooking and rice: water ratio as recommended by the producer. Part of the cooked rice was fried together with other ingredients for the preparation of the popular dish nasi goreng. Arsenic concentrations were measured with instrumental neutron activation analysis.

Only one of the ten analyzed species contained an arsenic concentration beyond the European maximum limit of 0.3 mg/kg. Cooking of white rice resulted in a decrease of the arsenic concentration by 46%, while the concentration in brown rice was reduced by 27%. The preparation of the fried rice dish nasi goreng resulted in an additional reduction by 20% per weight unit, which should be attributed for the most part to a diluting effect by the addition of the other ingredients. Heating of rice without water reduced the arsenic concentration only by 10%.

Cooking and frying of rice according to recommendations by the producer, result in a significant reduction of the arsenic concentration.

Keywords: rice; arsenic; neutron activation analysis; cooked rice; fried rice

1. Introduction

For a large part of the population on earth rice is the most important food providing carbohydrates, proteins, B vitamins and minerals. However, because of the presence of toxic elements like arsenic, concerns are expressed at regular times on the consumption of rice products especially when the daily food intake mainly consists of rice. Some inorganic compounds of this metalloid like As_2O_3 can be extremely toxic. But even less toxic compounds can be harmful in case of chronic overexposure. Quite a large number of disorders have been associated with arsenic, such as skin and neurological diseases; furthermore arsenic is considered to be carcinogenic [1]. Arsenic is present almost everywhere on earth, but concentrations in soil and groundwater vary from country to country and even between regions in the same country [2]. In some parts of the world with high concentrations in the groundwater, such as in India and Bangladesh, this water is not only used for drinking but also to irrigate the paddy fields. Because the plant is mainly growing under water, it is continuously exposed to arsenic, while the element is also accumulating in the ground. Compared to many other crops, the plant extracts more arsenic from water and soil contributing to the relatively high concentrations in rice [3]. The presence of arsenic in drinking water as well as in food results in a serious health problem for millions especially living in south-east Asia [4].

The mean daily rice consumption in The Netherlands is 11 grams per individual, which is in sharp contrast to a mean global consumption of 235 grams per day [5]. But even in The Netherlands and other west European countries consumers have been alarmed for an overconsumption of rice products. This concern is especially addressed to babies, toddlers and young children since rice is often present in products like porridge, wafers, and milk. Also dishes from other cultures have become more and more popular and in many of them rice is the main ingredient, resulting in an increase of rice consumption in older children and adults. Exposure of the body to arsenic is not only determined by the concentration and the chemical speciation of arsenic present in the rice, but also by the way the food is processed. In the Dutch kitchen rice is mostly cooked or fried, as in the preparation of popular dishes like nasi goreng and paella. This study focuses on the effect of these methods of preparation, as recommended by the producers and applied by the consumers, on the total arsenic concentration in rice. It therefore provides a more realistic view on the actual exposure of the consumer to arsenic because of the growing popularity of rice species from Turkey in our country, we also measured arsenic concentrations in a number of Turkish brands.

2. Materials and methods

2.1 Preparation of rice products

Total arsenic concentrations were measured using instrumental neutron activation analysis (INAA) in a number of rice species from Thailand and Turkey, all easily available in Dutch supermarkets and stores. In the cooking and frying experiments a white and brown rice from Thailand, Pandan and Zilvervlies, were used.

Cooking: According to the recommendations of the producer portions of 20 g of rice were heated in 150 ml water. The white rice was put in boiling water during ten minutes, while the boiling time of the brown rice was 25 minutes. During heating and boiling the rice was stirred every minute. After boiling the rice was sieved until no water was leaking. The rice was collected in plastic tubes and stored in the freezer at a temperature of -18° C.

Frying: Firstly 250 g of white rice was boiled during ten minutes. After that the rice was put in a wok; olive oil, herbs, pieces of omelet and vegetables, mainly leek, were added. No ham was used because of the high concentration of sodium, which could interfere with the measurement of arsenic. This mix was heated during ten minutes and stirred every minute. Samples of 20 grams were put in plastic tubes and stored in the freezer at -18°C. After 24 hours all samples of the cooked and fried rice were freeze-dried (FTS System Inc., Stone Ridge, New York, USA) during 72 hours (vacuum 7Pa; temp -54°C) and then they were stored in a dissicator with silica gel. To study the effect of just heating without water, a sample of 20 g of white rice was heated during one hour until the rice was colored black.

2.2. INAA measurement and statistics

Out of each stored sample 200 mg was taken and put in special polyethylene capsules. These were put in the nuclear reactor and irradiated for 90 minutes at a thermal flux of $4^{*}10^{12}cm^{-2}s^{-1}$ (Reactor Institute Delft). By this irradiation the natural isotope ^{75}As is converted to the radioactive isotope ^{76}As, which decays to ^{76}Se. After three days all the irradiated samples were measured in a well-type Ge detector (Ortec, USA) and analyzed using the APOLLO software [6]. All experiments were performed in triplo and each sample was measured in duplo. The mean of each type of preparation was taken and results compared using the SPSS statistics program (IBM Statistics 20).

Results

Total arsenic concentrations were measured in a number of rice species from Thailand and Turkey, all available in supermarkets and stores. As presented in figure 1, all species contain arsenic. The highest concentrations were measured in the brown rice species (zilvervlies and migros kepekli), still containing hulls. The migros kepeki had a value slightly above the European maximum limit of 0.3 mg/kg. All other species stayed beneath the limit.

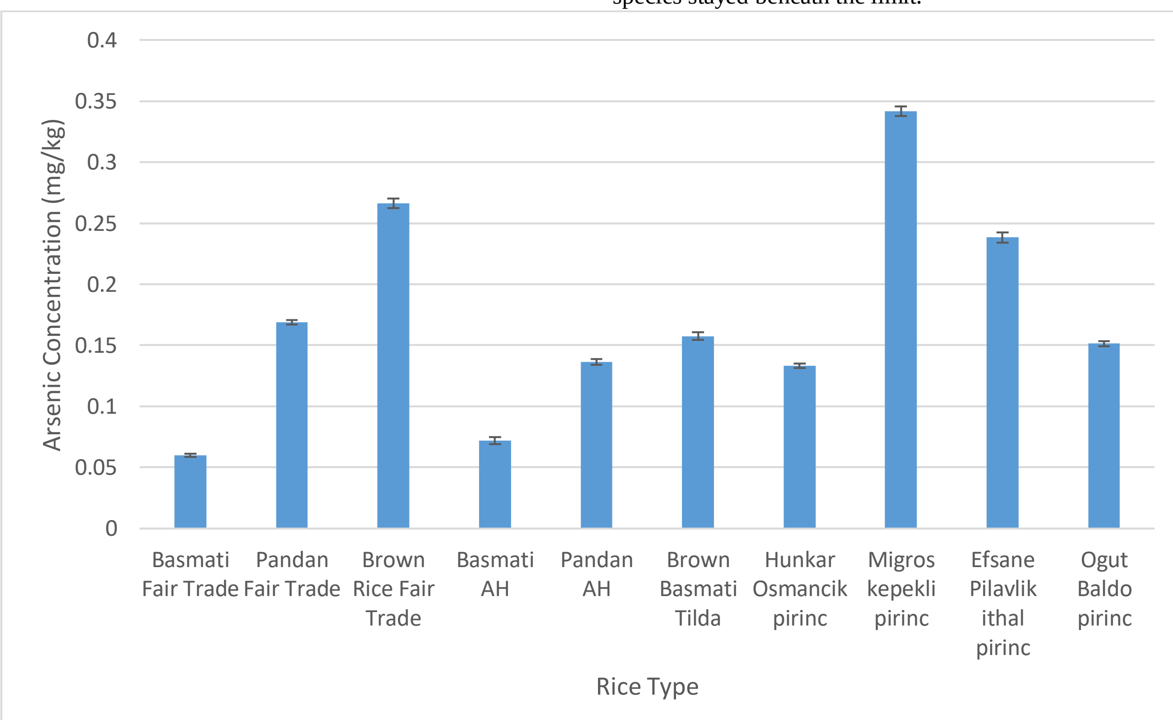

Figure 1: arsenic concentrations in various rice species from Thailand and Turkey

Figure 2 shows the effect of cooking on the arsenic concentration of white and brown rice. Not only does brown rice contain higher concentrations of arsenic, but the effect of cooking in decreasing the arsenic concentration is significantly lower (27% in brown rice versus 46% in white rice) despite a longer boiling time.

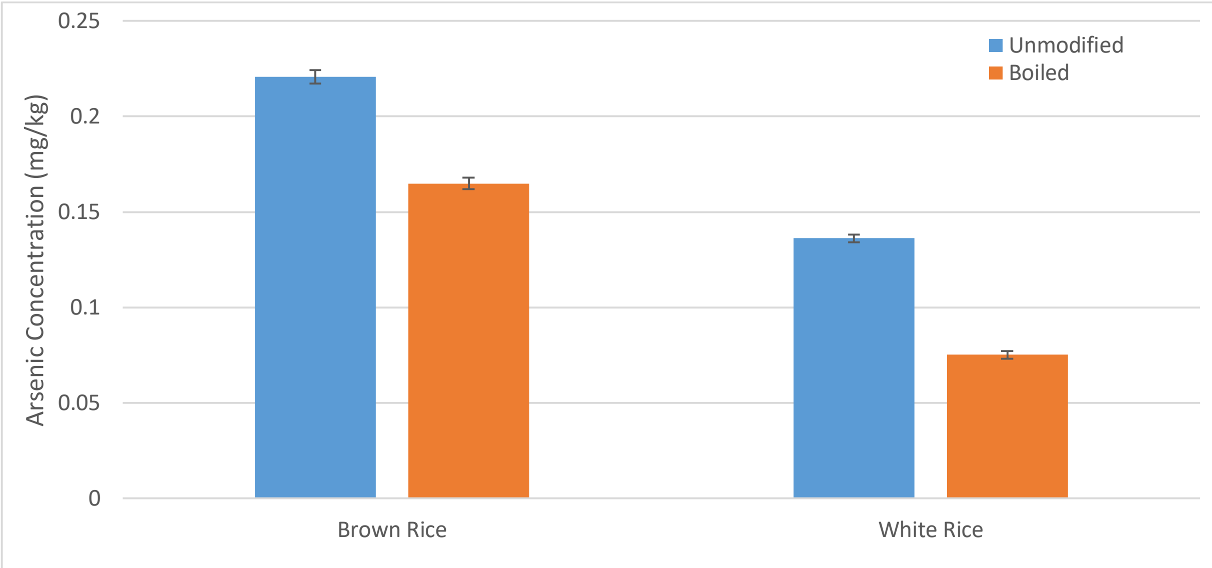

Figure 2: arsenic concentrations in brown and white rice before and after cooking

Finally we also measured arsenic concentrations in fried rice, in which procedure the already cooked rice is fried for another ten minutes. This fried rice is used in popular dishes like nasi goreng and paella that also contain a number of other ingredients like herbs, meat, pieces of omelet and a mix of vegetables. Because the addition of other ingredients may result in an inhomogeneous distribution of arsenic, concentrations were measured after blending. As shown in figure 3 the cooked rice contains 53% of the original arsenic concentration while the fried rice contains 32% suggesting an additive effect of 20%. However, measurements were done in samples of the same weight, so this further reduction should be attributed for the most part to dilution by the addition of other ingredients in this dish. In a separate experiment we heated a sample of rice for one hour without water until it was burned, which resulted in a decrease of the arsenic concentration of only 10%. Since the heating time in the frying experiment was only ten minutes, the contribution of this extra heating would be less than 10%.

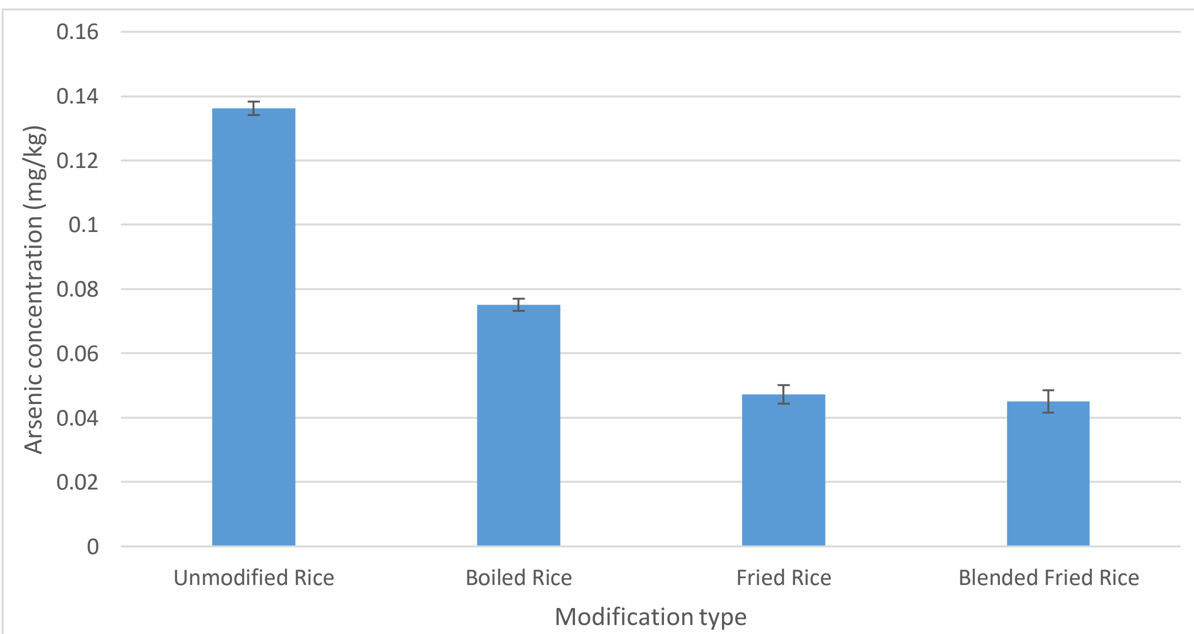

Figure 3: arsenic concentrations in cooked and then fried rice

Discussion

Since arsenic is present in the soil of large regions of eastern Asia, rice from countries like Bangladesh, India, China and Thailand contains arsenic. However, it has also been reported that the presence of arsenic in rice is not restricted to these areas, but that rice originating from European countries as well as from the USA also contains arsenic [7]. Our study shows that concentration of arsenic in Turkish rice is comparable to that in rice from Thailand. Apart from origin, species and cultivation, industrial processing may also influence the final concentration. To reduce exposition as much as possible, a maximum limit (ML) of 0.3 mg/kg inorganic arsenic has been introduced for food products in Europe since January 2016 [8]. Although the As concentration in the brown rice migros kepekli pirinc was somewhat above the legal upper limit, it should be realized that we measured total arsenic in our experiments, so the amount of inorganic arsenic present in this rice may well be under this limit. Brown species have higher concentrations of arsenic than the white polished ones, because the bran layer of rice concentrates more arsenic than the endosperm [9]. In the production of white rice this bran layer is removed mechanically.

In this study we decided to use instrumental neutron activation analysis (INAA) to measure arsenic concentrations in the rice products. Although the method is somewhat less sensitive than advanced forms of mass spectrometry, it has the advantage that materials hardly need any preparation and there is no need to convert or dilute a sample into a suitable solution prior to analysis with inherent risks of contamination or element loss

Our study shows that preparations of rice as used in the consumer's kitchen can result in a significant reduction of the arsenic concentration, which is in agreement with data from experiments performed in a more laboratorial setting, with reductions of 40-50% for white rice and 30% for brown rice [10-11]. In case the ratio of water to rice is too small (< 2.5:1), as e.g. in steaming of rice, significantly less arsenic is removed [12]. It has to be noted that by using a lot of water in the cooking process, not only arsenic, but also a number of beneficial nutrients like vitamins will be removed as well [13]. By percolating cooking water, a further reduction of the arsenic concentration can be achieved, which can be useful in the process of the production of bran products [14]. On the other hand it can not be totally ruled out that some contamination in extensive boiling may occur from the pots and pans used, since these may contain various metals [15].

Because of the popularity of fried rice dishes in our country, like nasi goreng and paella, we also decided to measure the arsenic concentration in such a fried product. In this product cooked rice is heated for another ten minutes together with herbs, pieces of omelet and a mix of vegetables like leek, onions, carrots and cabbage. This results in a further reduction of the arsenic concentration, which should be mainly attributed to the diluting effect of the addition of other ingredients and only for a small part to the heating during the frying process. Although a significant reduction of the total arsenic concentration in rice can be established by cooking and frying, it can however not been ruled out that these procedures also influence the chemistry of the arsenic, which may be relevant to health as well.

Conclusions

Rice products contain arsenic, which may be harmful for health. The actual arsenic concentration depends on species, origin (land, region), and industrial processing. When this concentration is close to the legal maximum limit of 0.3 mg/kg, it can be decreased significantly by cooking according to recommendations of the producer. The current study shows that the cooking and frying of rice as used in the Dutch kitchen is associated with a significant reduction of the total arsenic concentration. Together with the international standards and rules for producers and the relative small intake of the mean Dutch consumer, the risk of overexposure and health problems is small.

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