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Reduction of Arsenic Level in Rice by Different Preparation and Cooking Methods

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Abstract

Rice, a crop that grows underwater, can absorb more arsenic and cause dietary exposure to arsenic. Arsenic levels can be reduced by using different methods. This study aimed to determine the arsenic level in rice by different preparation and cooking methods. Rice was prepared by 4 different preparations and 7 different cooking methods, and arsenic levels were analysed by ICP-MS method. Arsenic level was 0.05 ± 0.009 mg/kg in raw rice, while arsenic levels varied between 0.03 - 0.04 mg/kg in different preparation methods and 0.01 - 0.02 mg/kg in different cooking methods. Arsenic levels decreased with cooking, and the highest arsenic removal percentage was achieved in cooking by filtration and steaming methods (for both 80%). In conclusion, the arsenic level in raw rice was below the reference limits, with the appropriate preparation and cooking methods this amount can be reduced.

Keywords: Arsenic, cooking methods, preparation methods, rice.

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INTRODUCTION

Agricultural practices such as the widespread use of fertilizers and pesticides, the increase in industrialization, and industrial urban wastes accelerate the heavy metal pollution in the soil and the environment (Sönmez and Kılıç, 2021). With the use of arsenic-contaminated groundwater in agricultural practices, plants become contaminated with arsenic and arsenic reaches the table through the food chain. One of the foods affected by this condition is rice (Öztürk et al., 2017).

Rice, which has an important place in human nutrition, also has a very important place in world grain production. It is the main food source for more than half of the world's population. Per capita consumption in the Far East and South Asian countries is up to 200 kilograms (Semerci and Everest, 2021). The Republic of China ranks first in world rice production. This country is followed by India, Indonesia and Bangladesh. These are the Asian countries with the largest paddy cultivation area in the world and meet about 68% of the world's rice production. According to the 2021 report of the Ministry of Agriculture and Forestry, it was reported that 600 thousand tons of rice were obtained from 126 thousand hectares of land in Turkey (TEGPE, 2021). Although paddy is produced in 31 provinces in our country, Edirne ranks first in paddy production (Hayati et al., 2015).

It is stated that the arsenic concentration is high in rice grown in wetlands (Öztürk et al., 2017). Rice has a relatively higher tendency to absorb inorganic arsenic because it is grown in submerged soil conditions. Among populations not exposed to inorganic arsenic in drinking water, rice contributes significantly to inorganic arsenic uptake (Davis et al., 2017). People who are exposed to high amounts of arsenic experience disorders such as blood circulation disorders, dermatological problems, nervous system disorders, gastrointestinal system problems, weakness, loss of appetite, fatigue, and loss of consciousness. As a result of long-term exposure, serious health problems such as lung, skin, kidney, and liver cancer are observed (Akbal et al., 2013; Sinczuk et al., 2010).

Due to the effects of arsenic on human health, research has shown that preparation and cooking methods are also effective in reducing arsenic level in rice (Rahman et al., 2006; Sengupta et al., 2006; Raab et al., 2008; Mihucz et al., 2007). In these studies, arsenic levels in rice were examined after soaking in cold and hot water Mihucz et al., 2007), washed or unwashed cooking (Sengupta et al., 2006), low and high-volume cooking (Rahman et al. 2006; Sengupta et al., 2006; Raab et al., 2008), and boiling was used as the cooking method.

. A comprehensive study investigating the arsenic levels in rice that was soaked in water at different pHs during the preparation stage and cooked by different methods such as steaming, boiling, and roasting could not be found. Therefore, preparation in different kinds of water and cooking with different methods should also be evaluated. In this study, it was aimed to analyse and compare arsenic levels in rice made with different preparation and cooking methods.

MATERIAL and METHOD

Sample Selection and Collection

In January 2023, a total of 3 kg of rice (3 packets of 1 kg with the same serial number) were purchased from a local market in the Maltepe district of Istanbul. The production place of those rice was Edirne – Turkey. It has been reported that Edirne alone has more than 40% of the paddy agricultural areas of Turkey (TEPGE, 2021). The type of rice was "Osmancık-97" which has long, wide and glassy grains with matte appearance. It is an ideal type of rice for cooking pilaf due to its easy consistency (TFC, 2010).

Sample Preparation

Four different preparation methods and seven different cooking methods were used (Figure 1).

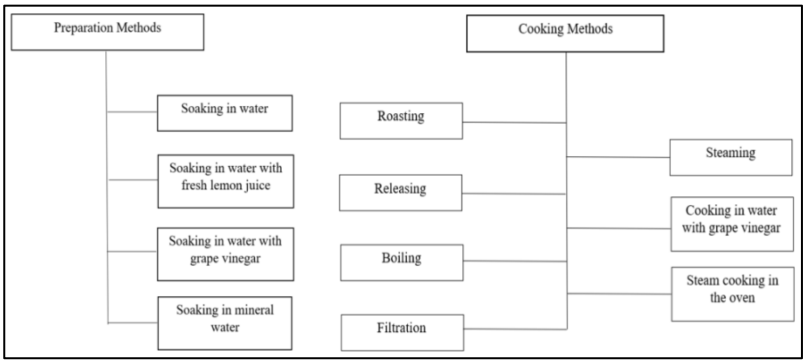

Figure 1. Preparation and cooking methods

Preparation Methods

To investigate the effect of changing the pH value of the water, the rice was kept in waters of different pH values as follows:

1. Soaking in water: 200 g of rice was soaked in 400 ml of water for 45 minutes at room temperature (25 to 32 °C) and the pH was measured as 7.8.

2. Soaking in water with fresh lemon juice: 200 g of rice was soaked in 400 ml of water containing fresh lemon juice (5%) for 45 minutes at room temperature (25 to 32 °C) and the pH of the water was measured as 1.95.

3. Soaking in water with grape vinegar: 200 g of rice was soaked in 400 ml of water containing vinegar (5%) for 45 minutes at room temperature (25 to 32 °C) and the pH of the water was measured as 3.90.

4. Soaking in mineral water: 200 g of rice was soaked in 400 ml of mineral water for 45 minutes at room temperature (25 to 32 °C). The pH value of the mineral water was measured as 5.55.

Cooking Methods

1. Roasting: 200 g of rice was added to 20 g of butter melted in the pan and roasted at 180 °C. When the rice grains started to become transparent, 400 ml of water and 2 g of salt were added. It was cooked on low heat with the lid of the pot closed. When the rice dried up, the stove was turned off and the rice was left to infuse for 30 minutes.

2. Releasing: 400 ml of water, 30 g of sunflower oil and 2 g of salt were boiled in the pot, then 200 g of rice was added to the pot and cooked at 100 °C until the water evaporated. It was infused for about 30 minutes after the stove was turned off.

3. Boiling: 200 g of rice was added to 400 ml of boiling water (with 2 g of salt) and cooked at 100 °C until the water evaporated. 20 g of butter were added, and the stove was turned off. Then it was infused for about 30 minutes.

4. Filtration: After washing 200 g of rice, the water was filtered. Two of salt, 30 g of sunflower oil and rice were added to 1000 ml of boiling water. After boiling for 5 minutes at 100 °C, the water was filtered in a strainer. 20 g of butter was added to drained rice and the lid of the pot was closed and cooked on low heat for 10 minutes. It was then left to infuse for 30 minutes.

5. Steaming: Two gram of salt and 200 g of rice were added to 1000 ml of boiling water and boiled at 96 °C for 10 minutes and then the water was filtered. Some boiling water was placed in the pot and a strainer with rice was placed on it. The lid was closed and steamed for 10 minutes.

6. Cooking in water with grape vinegar: Four hundred ml of water and 20 g of grape vinegar were boiled in a pan at 100 °C. Then 200 g of rice was added and boiled for 10 minutes. Before the rice was fully softened, the bottom of the stove was turned off and the rice was filtered. The rice was roasted in a pan with 1 g of salt and 30 g of sunflower oil for 5 minutes and rested for 30 minutes.

7. Steam cooking in the oven: Four-hundred ml of water, 1 g of salt, 30 g of sunflower oil and 200 g of rice were added to a Pyrex and the lid was closed. It was steam-cooked in the oven at 200 °C for 35 minutes. It was taken out of the oven when the water was completely absorbed.

Arsenic Analysis

Samples of 200 g were taken from raw rice, rice prepared with different preparation methods, and rice cooked with different cooking methods, and placed in zip-lock storage bags. Analysis of the samples was carried out in A&T Food Control Laboratory which has been accredited by TÜRKAK according to AB-0509-T and TS EN ISO/IEC 17025 standards. 0.5 g were taken from the samples and dissolved in the microwave with 6 mL of nitric acid (HNO3, 65%) and 2 mL of hydrogen peroxide (H2O2, 30%). The samples were homogenized using shredder at 10.000 rpm for 2 minutes. Then, water was added and the solution was completed to 50 ml and the inorganic arsenic level was measured in the ICP-MS device.

Samples were first analyzed using ICP-MS (Thermo-Fisher Scientific iCAP-Q and iCAP-TQ; Thermo Fischer Scientific). For this analysis, a certain amount of rice flour from each sample was digested in HNO3 in perfluoroalkoxy (PFA) containers. Milli-Q was diluted with water before elemental analysis by inductively coupled plasma mass spectrometry (ICP-MS). The device was operated using a collision cell (Q cell) using He (He-cell) with kinetic energy discrimination to eliminate polyatomic interferences. Samples were included from an autosampler (Cetac ASX-520) incorporating an ASXpress quick retrieval module. Internal standards are introduced to the sample stream on a separate line via the ASXpress unit. Sample processing was performed using Qtegra software (Thermo-Fisher Scientific) using external cross-calibration between pulse counting and analogue detector modes as needed. The expanded measurement uncertainty, using a coverage factor k=2 which gives a level of confidence of approximately 95%. All the analyzes were carried out in triplicate.

Calculation and Comparison

The inorganic arsenic values found were compared with the reference limits of Codex Alimentarius, Joint FAO/WHO Expert Committee on Food Additives (JECFA) and EU Commission Regulation (Wu, 2014; JECFA, 2010; EU, 2015).

The percentage of inorganic arsenic removal for each different preparation and cooking technique was calculated by using the formulation below (Mihucz et al., 2007):

As Removal % = [(As value before processing – As value after processing) / As value before processing]

RESULTS and DISCUSSION

Inorganic arsenic levels in rice samples were given in Table 1, and inorganic arsenic removal percentages were shown in Figure 2. None of the rice samples exceeded the reference limits.

The inorganic arsenic level in raw rice was 0.05 ± 0.009 mg/kg. It was determined that inorganic arsenic levels in raw rice soaked in water with different pH values decreased slightly.While the inorganic arsenic level was the same (0.03 ± 0.005 mg/kg) both in water with grape vinegar, mineral water and water solely, it was higher in the water with fresh lemon juice (0.04 ± 0.007 mg/kg).

Inorganic arsenic levels decreased in rice samples with cooking. Among the cooking methods, the highest level of inorganic arsenic removal was achieved in cooking by filtration (80%) and steam cooking (80%).

Inorganic arsenic levels were found to be the same (0.02 ± 0.004 mg/kg) in the releasing, roasting, boiling, steam cooking in the oven and cooking in water with grape vinegar and 60% of the inorganic arsenic level was removed by these methods.

Table 1. Inorganic arsenic levels in rice samples

	Analysis result (mg/kg) Mean ± SD
Raw rice	0.05 ± 0.009
Preparation methods	
Soaking in water	0.03 ± 0.005
Soaking in water with grape vinegar	0.03 ± 0.005
Soaking in mineral water	0.03 ± 0.005
Soaking in water with fresh lemon juice	0.04 ± 0.007
Cooking methods	
Releasing	0.02 ± 0.004
Roasting	0.02 ± 0.004
Boiling	0.02 ± 0.004
Steam cooking in the oven	0.02 ± 0.004
Cooking in water with grape vinegar	0.02 ± 0.004
Filtration	0.01 ± 0.002
Steaming	0.01 ± 0.002

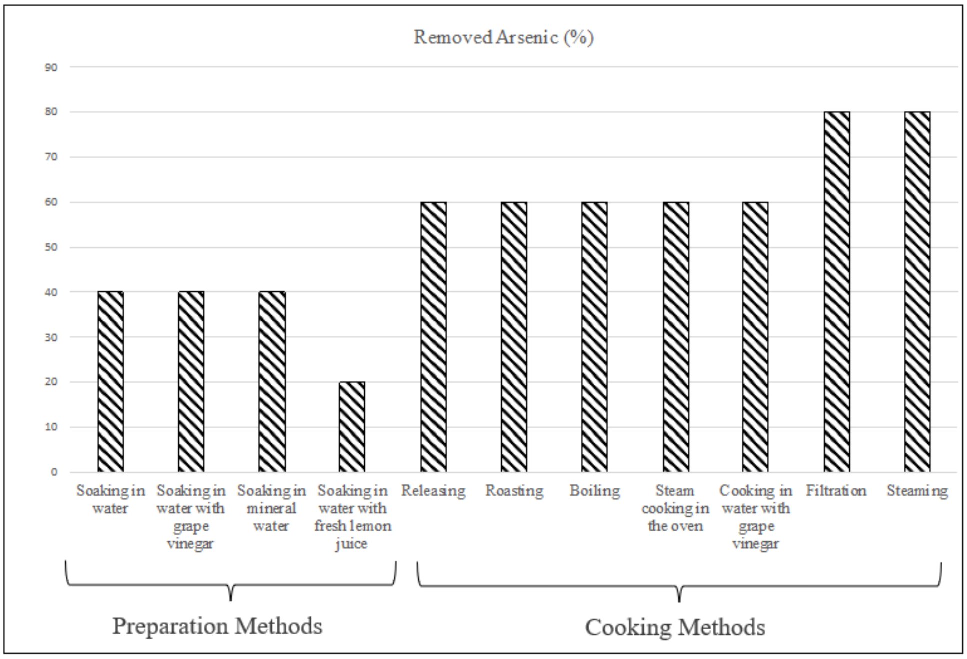

Figure 2. Inorganic arsenic removal by different methods

Rice is one of the most consumed foods in our country and in the world and is prepared and cooked in different methods. Studies in the literature show that different preparation and cooking methods can be effective in removing arsenic from rice (Diaz et al., 2004; Cubadda et al., 2003; Misbahuddin, 2003; Rahman et al., 2006; Sengupta et al., 2006; Signes-Pastor et al., 2008; Raab et al., 2008; Mihucz et al., 2007).

In this study, the effects of different preparation and cooking methods on inorganic arsenic levels in rice were investigated.

Comparing with the reference limits

In the Turkish Food Codex, there is no upper limit for arsenic in terms of heavy metal contamination in rice in the "Regulation on Maximum Limits of Contaminants in Foodstuffs" dated May 17, 2008 and numbered 26879 (TFC 2008). When the international legislation on heavy metal pollution in rice is examined; in the Codex Alimentarius, only the upper limit value was given for inorganic arsenic among the arsenic species found in rice. The maximum inorganic arsenic level for husked rice was 0.35 mg/kg, and the maximum inorganic arsenic level for polished rice was 0.2 mg/kg (Wu, 2014). The arsenic limit set by the European Union for rice in 2015 is 0.2 mg/kg (EU, 2015). It was determined that all the rice samples used in the study met the Codex Alimentarius and European Union standards. The type of rice used in the study was Osmancık-97, and the arsenic level of raw rice was found to be 0.05 ± 0.009 mg/kg.

Effect of pH

A study on arsenic removal in drinking water at different pH values was investigated by using Fe and Al electrodes. Depending on the pH value of the aqueous medium, arsenic levels were found to change through coprecipitation and adsorption reactions. It was determined that arsenic removal increased when the pH value of the water was changed from 4.5 to 8.5. It was stated that the optimum pH value for arsenic removal was between 6.5 and 7.0 (Kobya et al., 2011). In this study, rice was soaked in water with different pH values (mineral water: 5.55, water with grape vinegar: 3.90, water with fresh lemon juice: 1.95, water = 7.8) and it was found that the inorganic arsenic level in rice decreased in all methods. Moreover, inorganic arsenic removal was found to be the lowest in the water with fresh lemon juice.

Effect of preparation and cooking

Cooking affects arsenic absorption in rice (Sengupta et al., 2006; Signes-Pastor et al., 2008). Raab et al. (2008) were investigated the effects of rinse washing on the arsenic level of rice. While approximately 10% of total and inorganic arsenic was removed from basmati rice by rinse washing, this process was less effective in other types of rice. In another study, three samples of West Bengal rice were rinse-washed 5-6 times until the water was clear and then cooked in a high volume of water. Rinse washing removed 28% of the arsenic in raw rice (Sengupta et al., 2006).

Furthermore, in Mihucz et al.'s (2007), most of the arsenic was removed by cooking in water (26-49%), while the amount of removed arsenic was found to be less by washing (8-17%). In the present study, rinse washing was done with safe drinking water in boiling, roasting and filtration methods. While 60% of the inorganic arsenic was removed by boiling and roasting methods, 80% of arsenic was removed in the filtration method in which rice is cooked with a higher water volume. Rinse washing was not done in low-volume water-cooking methods such as releasing, steam cooking in the oven, and cooking in water with grape vinegar; rinse washing was done in boiling and roasting methods. All these methods removed 60% of the inorganic arsenic in rice. No effect of rinse washing was found on the inorganic arsenic level of rice cooked in low-volume water.

The water used in the cooking process is an important factor in the arsenic level in rice. Rice cooked with uncontaminated water has a lower arsenic level (Diaz et al., 2004; Cubadda et al., 2003). In areas with high arsenic pollution in Bangladesh, the amount of arsenic in cooked rice was approximately 10-35% higher than in raw rice. It has been stated that the reason for this is cooking water with arsenic contamination (Misbahuddin, 2003).

Since the arsenic concentration of groundwater used as cooking water in South Asian countries is well above the maximum allowable limit (10 µg/L) set by the World Health Organization (WHO). The effect of arsenic concentration in cooking water on arsenic retention in cooked rice is significant in these countries (Sengupta et al., 2006; Signes-Pastor et al., 2008). Rahman et al. (2006) observed that when there is arsenic contamination in cooking water, the arsenic concentration in cooked rice increases as the rice absorbs the arsenic in the water. In this study, inorganic arsenic levels decreased as a result of cooking. This is thought to be due to the use of safe drinking water as cooking water.

Effect of water volume

The effects of rinse cooking in low volume (2.5:1 water: rice) and high volume (6:1 water: rice) water on different rice varieties were investigated and it was found that cooking with low volume water did not remove arsenic. In the method of cooking in high-volume water, the inorganic arsenic level of long grain and basmati rice decreased by 45% compared to raw rice (Raab et al., 2008). In another study, three different types of rice were used. When cooking with high-volume water (6:1, water:rice), a 42-63% decrease was found in the total amount of arsenic in cooked rice (Mihucz et al., 2007).

Sengupta et al. (2006) investigated the arsenic load in rice cooked with traditional and modern methods (2006), using low As-containing water (As <3 mcg/L). By using the traditional method of the Indian subcontinent (wash until clear; cook with rice: water 1:6; discard excess water) the arsenic was removed by 57% from the rice. Using low-As water in the traditional preparation of arsenic-contaminated rice reduced the arsenic load. Cooking unwashed rice until there is no water left, with a rice:water ratio of 1:1.5-2.0, which is the frequently used method nowadays, did not change the arsenic content despite using low-As water (Signes-Pastor et al., 2008).

Similar to the previous studies, high-volume water was used in filtration and steaming methods in this study. In addition, rinse washing was done with safe drinking water in the filtration method. In the current study, among the cooking methods, filtering and steaming methods were minimized the inorganic arsenic level and 80% of arsenic was removed from rice cooked by these methods. The limitation of this study is that the arsenic level of the water used in the preparation and cooking of rice was not measured. Another limitation is the use of only one type of rice. In addition, the use of many preparation and cooking methods is the strength of the study.

CONCLUSION

The most effective methods of removing inorganic arsenic are filtration and steaming methods. Unlike other methods, the use of high volumes of safe drinking water in filtration and steaming has a significant effect on reducing the inorganic arsenic level.

In addition, rinse washing with drinking water in the filtration method was effective in reducing the inorganic arsenic level. Although the inorganic arsenic level in raw rice is below the reference limits in the study, this amount can be further reduced with the right preparation and cooking methods. With the use of appropriate preparation and cooking methods, caution can be taken to protect food safety and public health.

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