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Arsenic burden of cooked rice: Traditional and modern methods

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Abstract

Arsenic contamination of rice by irrigation with contaminated groundwater and secondarily increased soil arsenic compounds the arsenic burden of populations dependent on subsistence rice-diets. The arsenic concentration of cooked rice is known to increase with the arsenic concentration of the cooking water but the effects of cooking methods have not been defined. We tested the three major rice cooking procedures followed globally. Using low-arsenic water (As < 3 μg/L), the traditional method of the Indian subcontinent (wash until clear; cook with rice: water :: 1:6; discard excess water) removed up to 57% of the arsenic from rice containing arsenic 203–540 μg/kg. Approximately half of the arsenic was lost in the wash water, half in the discard water. A simple inexpensive rice cooker based on this method has been designed and used for this purpose. Despite the use of low-arsenic water, the contemporary method of cooking unwashed rice at rice:water :: 1:1.5–2.0 until no discard water remains did not modify the arsenic content. Preliminary washing until clear did remove 28% of the rice arsenic. The results were not influenced by water source (tubewell, dug well, pond or rain); cooking vessel (aluminium, steel, glass or earthenware); or the absolute weight of rice or volume of water. The use of low-As water in the traditional preparation of arsenic contaminated rice can reduce the ingested burden of arsenic.

Keywords: Arsenic; Cooked rice; Traditional method; Low dietary exposure

1. Introduction

Groundwater arsenic contamination in the Bengal delta has been termed the largest chemical poisoning in history (Smith et al., 2000). A large part of the Ganga–Meghna–Brahmaputra plain (GMB) with area and population 569,749 km^2 and over 500 million is at risk (Chakraborti et al., 2004). New instances have recently been found elsewhere in Asia including Lao People Democratic Republic, Cambodia, Myanmar and new sites in China (The International Conference on Water Quality Arsenic Mitigation, 2004), Nepal (Shrestha et al., 2003), Vietnam (Berg et al., 2001), Pakistan (Nickson et al., 2005) and Lower Mekong (Stanger et al., 2005).

There is increasing concern over the high concentrations of arsenic in rice irrigated with contaminated groundwater with secondary increase in soil arsenic (Abedin et al., 2002; Meharg and Rahman, 2003; Duxbury et al., 2003; Williams et al., 2005). The contaminated rice is viewed as a newly recognized disaster for south-east Asia (Meharg, 2004), where rice is the staple food, and as the primary source of As in the non-seafood diet of Europe (Robberecht et al., 2002) and United States (Tao and Bolger, 1999). Populations in the arsenic affected regions often use arsenic contaminated water for cooking and the few available reports show an increase in the arsenic content after cooking rice in contaminated water (Bae et al., 2002; Misbahuddin, 2003).

This communication investigates the effect of using high-arsenic (100–500 μg/L) and low-arsenic (<3 μg/L; minimum detection limit of our instrument with 95% confidence level) water on the arsenic content of rice cooked by each of the three major cooking methods followed globally, and of

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low-As water source, cooking container type, and quantitative variations in amount of rice and water. We also investigated how to facilitate cooking by one of the methods (method A), by designing a cooking device (rice cooker).

2. Methods

Worldwide, there are three common methods of cooking rice: (A) The traditional method still used by more than 90% of the villagers in Bengal delta: raw rice is washed till the washings become clear (5–6 times), washings are discarded and then the rice is boiled in excess water (5–6 times the weight of raw rice) till cooked, finally discarding the remaining water (discard water) by tilting the pan against the lid before serving the rice; (B) the rice is washed as in A and boiled with water of a volume 1.5–2 times the weight of rice until no water is left to discard; (C) unwashed rice is boiled with water 1.5–2 times the weight of rice; The wash and discard steps are both omitted. This is the contemporary method.

Twelve samples of arsenic contaminated raw rice were procured from arsenic affected villages in West Bengal, India and three from a City market, Kolkata, West Bengal, India. Four different rice varieties were self selected for carrying out further experiments on cooked rice. The details about rice samples are provided in Table 1.

The first experiment was conducted to investigate effect of container type, arsenic in raw rice and cooking water on the arsenic content in the cooked rice. In this experiment consisting of 48 trials, two rice varieties containing 203.5 and 380.3 μg/kg As were cooked following method A, in four kinds of containers: aluminium, steel, earthenware and glass, using distilled water with the addition of one of six different As concentrations (<3, 10, 100, 200, 300, 500 μg/L).

The second experiment was carried out to investigate effect of arsenic in raw rice, type of low-As water source and cooking method on the arsenic content in the cooked rice. In this experiment having 36 trials, three rice varieties (203.5, 440, 540 μg/kg As) were cooked in an aluminium container (as it is widely used for cooking rice in the Bengal Delta) using four different low-As water sources collected from dugwell, pond water, rainwater and tubewell, following methods A, B and C.

The third experiment was to investigate effect of arsenic in raw rice and amount of raw rice on the arsenic content in the cooked rice. In this experiment consisting of 12 trials three different amounts (25, 100 and 250 g) of four rice variants (As concentration 203.5, 380.3, 440.0 and 540.0 μg/kg) were cooked in aluminium container, using low-As water (keeping rice:water ratio fixed at 1:6) employing cooking method A.

The fourth experiment was done to investigate effect of arsenic in raw rice, amount of cooking water on the arsenic content in the cooked rice. In this experiment having 14 trials, two rice variants (203.5, 380.3 μg/kg As) were cooked in aluminium container following method A, adding seven different amounts of low-As water (150, 200, 250, 300, 350, 400 and 500 mL), keeping the amount of rice fixed at 25 g in all the cases.

All the individual treatments were run in triplicate and the mean was considered. The co-efficient of variation was within 5%. All individual

Table 1
Details of raw rice samples procured

S. no.	Sample ID	Type of rice	Location	Mean As concentration (μg/kg)	Standard error (SE)
1	S4	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	380.3	0.67
2	KBR1	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	430.2	4.19
3	KBR4	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	326	1.18
4	KBR4A	Aman	Arsenic affected areas of North-24-Parganas district, West Bengal	163.3	4.08
5	KBR8	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	540	1.69
6	KBR10	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	440	1.31
7	KCR1	Aman	Arsenic affected areas of North-24-Parganas district, West Bengal	144.4	3.55
8	KCR1A	Aman	Arsenic affected areas of North-24-Parganas district, West Bengal	119.1	3.29
9	KCR2	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	514.9	4.72
10	KCR3	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	396.1	4.28
11	B1	Boro	Arsenic affected areas of North-24-Parganas district, West Bengal	352.8	5.42
12	B2	Aman	Arsenic affected areas of North-24-Parganas district, West Bengal	125.0	2.38
13	JU1	[a]	Jadavpur Market, Kolkata 32	203.5	4.78
14	JU2	[a]	Jadavpur Market, Kolkata 32	111.0	2.42
15	JU4	[a]	Jadavpur Market, Kolkata 32	122.6	2.82

Note: Boro: irrigation done by groundwater. Aman: irrigation done by rainwater.
[a] Type of rice is not known.

Fig. 1a. Different parts of rice cooker designed by SOES.