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Accumulation of arsenic in tissues of rice plant (*Oryza sativa* L.) and its distribution in fractions of rice grain

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Abstract

A study was conducted to investigate the accumulation and distribution of arsenic in different fractions of rice grain (*Oryza sativa* L.) collected from arsenic affected area of Bangladesh. The agricultural soil of study area has become highly contaminated with arsenic due to the excessive use of arsenic-rich underground water (0.070 ± 0.006 mg l^{-1}, $n = 6$) for irrigation. Arsenic content in tissues of rice plant and in fractions of rice grain of two widely cultivated rice varieties, namely BRRI dhan28 and BRRI hybrid dhan1, were determined. Regardless of rice varieties, arsenic content was about 28- and 75-folds higher in root than that of shoot and raw rice grain, respectively. In fractions of parboiled and non-parboiled rice grain of both varieties, the order of arsenic concentrations was; rice hull > bran-polish > brown rice > raw rice > polish rice. Arsenic content was higher in non-parboiled rice grain than that of parboiled rice. Arsenic concentrations in parboiled and non-parboiled brown rice of BRRI dhan28 were 0.8 ± 0.1 and 0.5 ± 0.0 mg kg^{-1} dry weight, respectively while those of BRRI hybrid dhan1 were 0.8 ± 0.2 and 0.6 ± 0.2 mg kg^{-1} dry weight, respectively. However, parboiled and non-parboiled polish rice grain of BRRI dhan28 contained 0.4 ± 0.0 and 0.3 ± 0.1 mg kg^{-1} dry weight of arsenic, respectively while those of BRRI hybrid dhan1 contained 0.43 ± 0.01 and 0.5 ± 0.0 mg kg^{-1} dry weight, respectively. Both polish and brown rice are readily cooked for human consumption. The concentration of arsenic found in the present study is much lower than the permissible limit in rice (1.0 mg kg^{-1}) according to WHO recommendation. Thus, rice grown in soils of Bangladesh contaminated with arsenic of 14.5 ± 0.1 mg kg^{-1} could be considered safe for human consumption.

Keywords: Arsenic; Accumulation; Rice (*Oryza sativa* L.); Brown rice grain; Polish rice grain

1. Introduction

The rice cultivation is solely depended on underground water in Bangladesh, West Bengal, India, particularly in dry season, since the sources of surface water like river, dam, pond, etc. of these regions becomes dry throughout the season. Natural release of arsenic from aquifer rocks has been reported to contaminate this underground water in Bangladesh and West Bengal, India (Chakraborti and Das, 1997; Nickson et al., 1998, 2000; Chowdhury et al., 1999; Smith et al., 2000; Fazal et al., 2001; Chakraborti et al., 2002; Harvey et al., 2002; Hopenhayn, 2006). Long term use of arsenic contaminated underground water in irrigation may results in the increase of its concentration in agricultural soil and eventually in crop plants (Ullah, 1998; Imamul Huq et al., 2003; Rahman et al., 2007a,b). Survey on paddy soil throughout Bangladesh showed that arsenic concentrations were higher in agricultural soils of those areas where shallow tube wells (STWs) have been

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in operation for longer period of time and arsenic contaminated underground water from those STWs have been irrigated to the crop fields (Meharg and Rahman, 2003). Onken and Hossner (1995) reported that plants grown in soil treated with arsenic had higher rate of arsenic uptake compared to those grown in untreated soil. Some other researchers (Abedin et al., 2002a,b; Rahman et al., 2004, 2007a) also reported elevated content of arsenic in tissues of rice when the plant was grown in soils contaminated with higher concentrations of arsenic.

Because of groundwater contamination with high level of arsenic, scientists and researchers become interested to investigate the effects of arsenic contaminated soil and irrigation water on its accumulation and metabolism in rice (*Oryza sativa* L.). Recently, some reports focused on the effects of arsenic contaminated soils and irrigation water on its uptake in root, shoot, husk and grain of rice and its metabolism in rice at greenhouse condition (Abedin et al., 2002a,b; Rahman et al., 2004, 2007a). However, field level investigation on this aspect is inadequate. Limited literatures are found on arsenic accumulation in different fractions of rice gain as well as its retention in cooked rice following the traditional cooking methods used by the populations of arsenic epidemic areas.

Being rice one of the major food crops in many countries, the populations of different countries cook rice differently. Majority of the people of Bangladesh and West Bengal, India, parboil raw rice before cooking though, the people of some other countries like Thailand, Japan and China cook rice without parboiling. Moreover, rice is milled to remove the husk (hull) before cooking. Some times, the bran-polish (the outer thin layer of milled rice) becomes detached from the rice grain during milling. Thus, the total arsenic in raw rice grain does not correspond to the definite amount of arsenic retained in cooked rice.

The objective of the present study was to determine arsenic distribution in different fractions of both parboiled and non-parboiled rice. The studies would help to determine the amount of arsenic retained in cooked rice and to assess the possible amount of arsenic taken by the populations of arsenic epidemic areas from rice. As far we know this is the first report on the distribution of arsenic in different fractions of parboiled and non-parboiled cooked rice grain.

2. Materials and methods

2.1. Sample collection

Samples of two rice varieties named BRRI dhan28 and BRRI hybrid dhan1 were collected from three sampling points (2 m^2 of area) of selected plot in each of the two locations. Soil samples were also collected from three points of 2 m^2 areas and 10–15 cm depth of the selected plots using soil auger. Locations of the sampling area are shown in Fig. 1. Samples were collected during harvest and sun dried immediately after collection, tagged properly, kept air tied in poly bag and brought to the laboratory for further analysis.

Water samples were collected from STWs nearby the rice field. Water has been irrigated from those STWs for rice cultivation. The populations of near by villages are

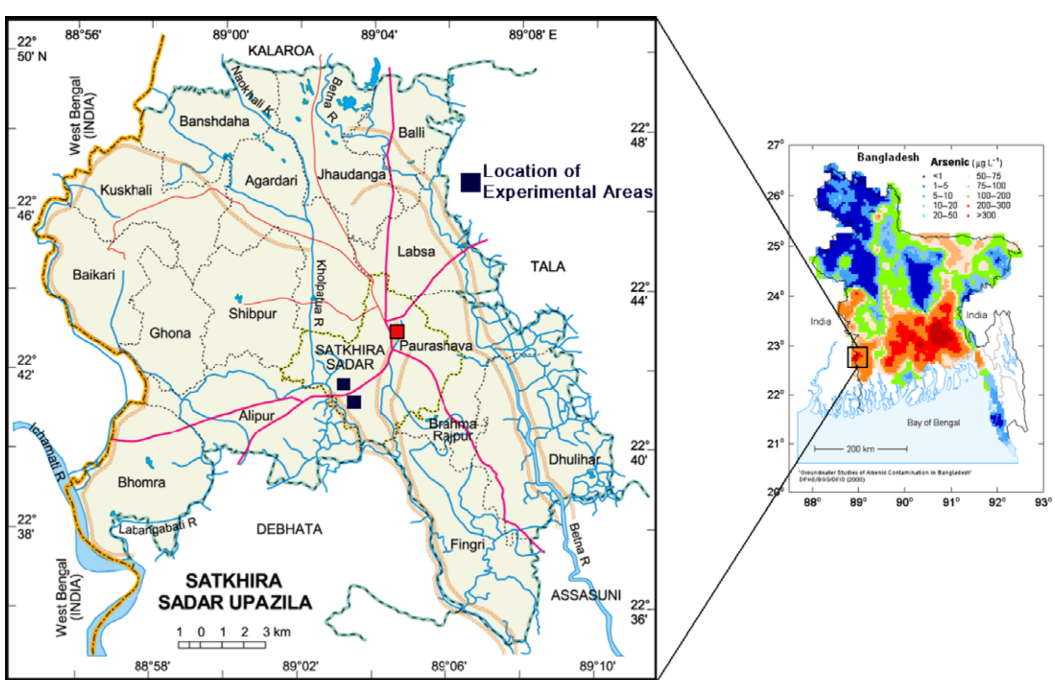

Fig. 1. Site map of sampling locations; Itagasa and Guddirdangi village of Satkhira sador thana in Satkhira district is on of the severely arsenic affected areas in Bangladesh. The sampling area was located at 22°40′–22°42′ altitudes and 89°02′–89°04′ longitude.