Journal of Food Composition and Analysis 69 (2018) 25–32

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Monitoring of arsenic contents in domestic rice and human risk assessment for daily intake of inorganic arsenic in Korea

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ARTICLE INFO

Chemical compound studied in this article:
Monomethylarsonate
Dimethylarsinate
Nitric acid
Hydrogen peroxide
Malonic acid
Sodium arsenite
Sodium arsenate dibasic heptahydrate
Cacodylic acid
Disodium methyl arsonate hexahydrate
Ammonia solution

Keywords:
Food analysis
HPLC-ICP-MS
Husked rice
Polished rice
Inorganic arsenic
Arsenic speciation
Dietary intake
Risk assessment

ABSTRACT

Rice can be the major contributor to exposure of inorganic arsenic (iAs). A total of 485 domestic rice (polished rice, n = 368; husked rice, n = 117) samples produced in 2014 were determined for total arsenic (tAs) and As species. The determination of As species was conducted by HPLC-ICP-MS. AsIII was the major detected species. AsV, DMA, and MMA were occurred in lower level in both types of rice. In polished rice, iAs represented 43–91% of tAs: tAs = 0.088 ± 0.021 mg/kg; iAs = 0.060 ± 0.013 mg/kg. In husked rice, iAs ranged from 55% to 91% of tAs; tAs = 0.160 ± 0.042 mg/kg, iAs = 0.114 ± 0.029 mg/kg. The iAs level of polished rice samples was below the current maximum limit of the Chinese and German standard (0.2 mg/kg for inorganic arsenic in milled rice). Also, husked rice samples did not exceed the standard for iAs. Average dietary exposure to iAs from polished rice consumption was calculated as 0.17 ± 0.21 μg/kg·bw/day which was 8.09% level of Provisional Tolerable Weekly Intake. The result obtained in the present study provide a reference data of iAs in Korean rice for the establishment of safety standards.

1. Introduction

Rice is a major staple for over fifty percent of the world's population (Meharg et al., 2009). It consists of carbohydrates, proteins, fats, fiber and significant nutritional components including minerals and vitamins (D'Ilio et al., 2002). However, rice also contains various toxic micro-elements originated from the environment, such as arsenic (As), lead, cadmium and mercury (D'Ilio et al., 2002; Shimbo et al., 2001; Zhang et al., 2010). Rice is regarded a main dietary source of inorganic As (iAs), because it contains about 10–90% of the total As (tAs) as iAs (Zavala et al., 2008b). Also, organic species of As such as monomethylarsonate (MMA) and dimethylarsinate (DMA) have been determined in rice. The extent of contamination level of iAs in the rice is greatly influenced by soil biochemistry, cooking, cultivation method and genetic variation (Meharg and Zhao, 2012). Besides, whereas seafood and seaweed contain high levels of tAs, iAs content was quite low, and most As exists as nontoxic arsenobetaine species (Maher, 1983).

Asian region accounts for large production and consumption of rice. The average consumption of rice per capita in Korea was 65.1 kg (= 0.178 kg in a day) in 2014, which is high compared with that in the world (Ministry of Agriculture, Food and Rural Affairs, MAFRA 2015). The 55% of total domestic cereal consumption was occupied with rice intake (Ministry of Agriculture, Food and Rural Affairs, MAFRA 2015). In addition, rice production in South Korea is estimated to be 6.136 million tons in 2010, which is 0.8% of the total production in the world of 701 million tons (F.S. Yearbook, 2013).

Arsenic exists in a wide array of oxidation states (−3, +3 and +5), and is largely divided into organic and inorganic compounds. Its

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https://doi.org/10.1016/j.jfca.2018.02.004
Received 21 May 2017; Received in revised form 9 January 2018; Accepted 8 February 2018
Available online 10 February 2018
0889-1575/

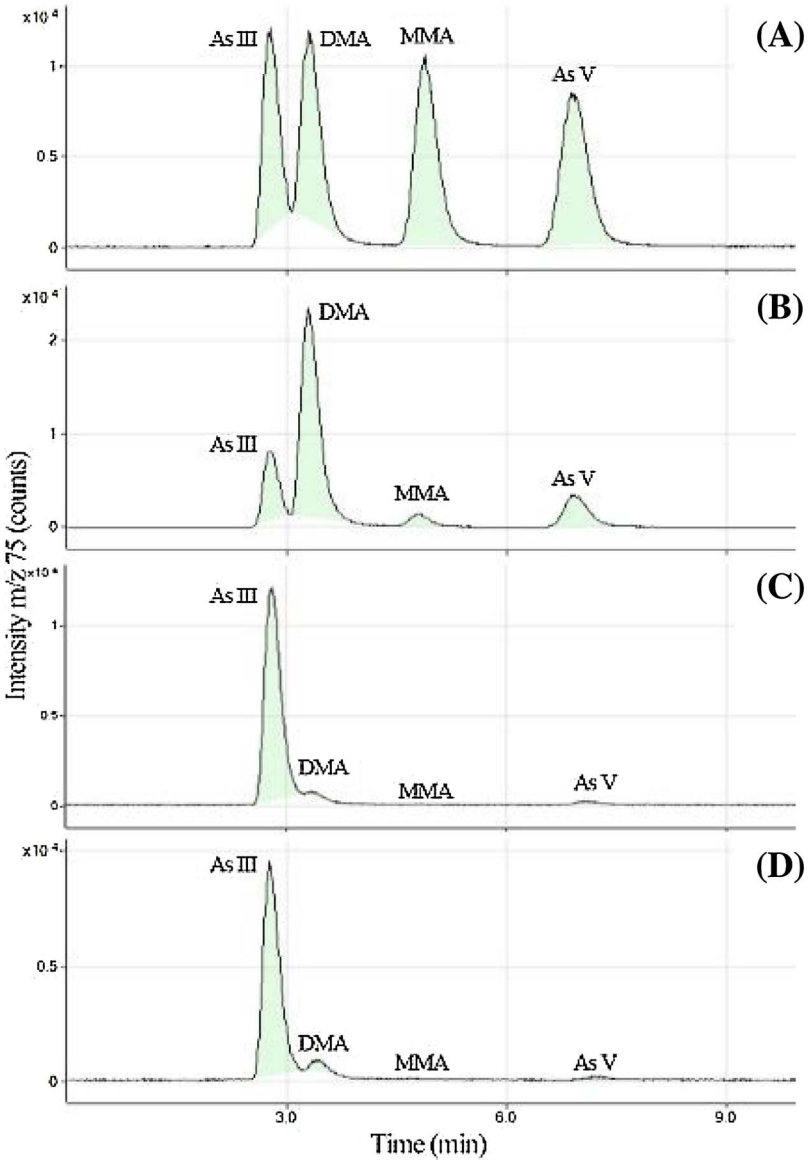

Fig. 1. HPLC separation of As species in 10 ng/L standard mix of the four As species and extract of CRM, polished rice and husked rice. Conditions: Hamilton PRP-X100 (250 × 4.1 mm, 10 µm at 25 °C and a mobile phase of 5 mM malonic acid pH 5.6 at 1 mL/min, 50 µL injection volume. (A) 10 ng/mL standard solution (B) CRM 1568b (C) Polished rice (D) husked rice.

toxicity varies depending on the chemical forms. Most organic arsenic compounds are less toxic than inorganic ones (Edmonds and Francesconi, 1993). Inorganic arsenic, a generic term referring to the sum of trivalent arsenite (AsIII) and pentavalent arsenate (AsV) content, is widely known as a class 1 carcinogen (Rousseau et al., 2005). And exposure to inorganic arsenic is connected with health risk for a tumor of skin, liver, lung and kidney (Abernathy et al., 1999).

Due to the different toxicity between chemical forms, the importance of speciation analysis has been emphasized. In addition, rice has higher iAs level than most other foods, and therefore, food mainly composed with rice may contribute to exposure to the most iAs (Schoof et al., 1999).

Not many reports of iAs concentration in rice are found in Korea. Accurate measurement of iAs in rice will helpful for risk assessment. We monitored the content of total As and 4 different As species i.e. AsIII, AsV, DMA and MMA in polished and husked rice produced in Korea by High-performance liquid chromatography- inductively coupled plasma mass spectrometry (HPLC-ICP-MS). Risk index (%) for exposure level of As through dietary intake is assessed with comparing the exposure with provisional tolerable weekly intake (PTWI) established by Joint FAO/WHO expert committee on food additives JECFA. Because PTWI of iAs is not currently established, we applied the previous PTWI (15 µg inorganic As/week/kg body weight), which was withdrawn in 2010 (Joint et al., 2010) in this health risk assessment. The object of this study was to collect data about As species in rice in Korea, that could provide important input to the establishment of limits for iAs of rice in Korea.

2. Materials and methods

2.1. Sample collection and sample preparation

Total of 485 samples of polished rice (n = 368) and husked rice (n = 117) were randomly purchased from online shopping or supermarket. All the samples had source information of place of origin including province, and were produced in Korea, 2014; Regardless of rice type, samples were collected from a total of eight provinces of Korea as follows: Gyeonggi, South Chungcheong, North Chungcheong, South Gyeongsang, North Gyeongsang, South Jeolla, North Jeolla, and Gangwon province. Rice samples were finely pulverized by using a