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DETERMINATION OF BIOACCESSIBILITY FOR ARSENIC FORMS ACCORDING TO ARTIFICIAL DIGESTION MODEL IN FOOD

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Introduction

Arsenic and inorganic arsenic are naturally occurring substances, but they are raising social concerns because they can be detected in commonly consumed foods. In the case of South Korea, the staple food is rice, and large amounts of seaweed are consumed. These foods are high in arsenic(KNHANES, SCOOP, 2004).

When conducting a risk assessment on heavy metals in foods, it is assumed that all the heavy metal contents in food are absorbed in the body as they are, but there is a difference between the heavy metal contents in food and the actual amount entering the body through the intake of food.

Total arsenic and inorganic arsenic concentrations in rice (white rice and brown rice) and seaweed (hizikia fusiforme), which are commonly consumed and are high in arsenic, were measured according to food processing type (cleaning, maceration, steaming, digestion, etc.) in this study. Then, bio-accessibility through digestion was calculated, and risk reduction levels were evaluated.

Materials and methods

1. Selection of food products & Determination of heavy metal levels

White rice and brown rice, among grains, and hizikia fusiforme, among seaweed, were selected as commonly consumed foods that are high in arsenic. The processing types for white rice and brown rice were unprocessed, maceration, and steaming. Along with each processing type, the application of digestive juices and the water that was used during cleaning were analyzed together. The processing types for hizikia fusiforme were unprocessed and blanching after cleaning. The application of digestive juices and the water that was used during blanching were analyzed with each processing type. As for digestive juices, artificial digestive juices(Oomen, 2003; versantvoort, 2005) were produced, and the conditions of an artificial digestion model were applied to the samples(RIVM, 2004).

The concentrations of arsenic in the food products were determined using inductively coupled plasma mass spectrometry (ICP-MS, NEXION 300D, PerkinElmer, USA). And the concentrations of inorganic-arsenic in the food products were determined using high performance liquid chromatography inductively coupled plasma-mass spectrometer (HPLC-ICP-MS, , Series 200, PerkinElmer, USA).

2. Estimation of bioaccessibility

Bio-accessibility refers to a ratio of body absorption after gastrointestinal procedures. Since the substances ingested are mostly absorbed into the body through the small intestine, bio-accessibility was calculated by applying the amount of liquid-state chyme after digestive procedures(RIVM, 2004).

the equation for the bioaccessibility (%) was calculated as follows:

Bioaccessibility(%)= ((Arsenic concentration of Chyme)/(Arsenic concentration offood sample))×100

3. Estimation of average daily intakes & Risk assessment

To identify dietary patterns, target items listed in the Korean nutrient database were categorized into seven age groups(≤2 age, 3-6 age, 7-12 age, 13-19 age, 20-64 age, ≥65 age, All age). A PTWI for arsenic of 350 ug/kg-week was established by the JECFA (2000).

Results and discussion

1. Heavy metal levels of food products

The mass balance for the arsenic content per 100 g of food materials (raw samples with moisture in the case of sea mustard) was estimated.
As a result of the total arsenic analysis of white rice, the total arsenic material volumes were 3.3 – 4.6 ug/100 g-cereal in the unprocessed, cleaned, macerated, and cooked white rice, 0.5 - 0.8 ug /100 g-cereal in the cleaning water and maceration water, 2.5 - 3.4 ug /100 g-cereal in the digestive juices, and 1.3 - 1.8 ug /100 g-cereal in the residue after digestion. As for brown rice, the total arsenic material volumes were 3.7 - 4.1 ug /100 g-cereal in the unprocessed, cleaned, macerated, and cooked brown rice, 0.3 - 0.5 ug /100 g-cereal in the cleaning water and maceration water, 1.3 - 2.8 ug /100 g-cereal in the digestive juices, and 1.0 - 2.3 ug /100 g-cereal in the residue after digestion. As for hizikia fusiforme, the total arsenic volumes were 1.11 mg/100 g-brown algae in the unprocessed hizikia fusiforme, 0.16 mg /100 g-brown algae in the cleaning water, 1.07 mg /100 g-brown algae in the maceration water, 0.44 mg /100 g-brown algae in the macerated hizikia fusiforme, 0.22 - 0.34 mg /100 g-brown algae in the digestive juices, and 0.17 ~ 0.28 mg /100g-brown algae in the digestion residue.
As a result of the inorganic arsenic analysis, the inorganic arsenic material volumes were 3.9, 2.9, and 2.0 ug /100 g-cereal in the unprocessed white rice, digestive juices-unprocessed white rice, and digestive juices-cooked white rice, respectively. The inorganic arsenic material volumes of brown rice were 5.2, 2.4, and 1.2 ug /100 g-cereal in the unprocessed brown rice, digestive juices-unprocessed brown rice, and digestive juices-cooked brown rice, respectively. The inorganic arsenic material volumes of hizikia fusiforme were 0.53, 0.14, and 0.17 mg /100 g-brown algae in the unprocessed hizikia fusiforme, blanched hizikia fusiforme, and digestive juices-blanched hizikia fusiforme, respectively.

2. Estimation of bioaccessibility

Concentration of the digestion step the inorganic arsenic concentration than the raw material(white rice, brown rice and hizikia fusiforme was decreased to 50%, 76% and 68%, respectively(Figure 1).
The arsenic bio-accessibilities by each food processing step and the bio-accessibilities from unprocessed food materials to the final intake forms were calculated for purposes of comparison. In the case of total arsenic, bio-accessibility was 71% for the direct consumption of unprocessed food materials, 48% for grains cooked without cleaning, and 55% for cooked grains after cleaning. Finally, the bio-accessibility of total arsenic due to digestive procedures during the intake of cooked grains was 48%. As for seaweed, the total arsenic bio-accessibility was 32% for unprocessed food materials, and 33% for maceration or blanching. Finally, the bio-accessibility of the total arsenic due to digestive procedures during the intake of cooked seaweed was 16%.
As for inorganic arsenic, bio-accessibility was 46 – 74% for the direct consumption of unprocessed rice, and 24 – 52% for cooked rice after cleaning. Finally, the estimated bio-accessibility of total arsenic due to digestive procedures during the intake of cooked grains (white rice and brown rice) was 37%, and that of inorganic arsenic contained in the unprocessed seaweed due to digestive procedures was 22 – 99%. The bio-accessibility of total arsenic due to digestive procedures during the intake of the cooked seaweed (hizikia fusiforme) was 20%.

3. Estimation of average daily intakes & Risk assessment

Risk assessment was conducted for the average and 95% intake groups of the dietary intake of each food that was calculated from the KNHANES (2008 – 2010) data, and then it was compared with the risk assessment that applied bio-accessibility(Figure 2). Among the food subjects, white rice showed the highest intake and risks, hizikia fusiforme showed the second highest intake and risks, and brown rice showed the lowest risks. When bio-accessibility was reflected, the results of the risk assessment were lower than those of the previous risk assessment.

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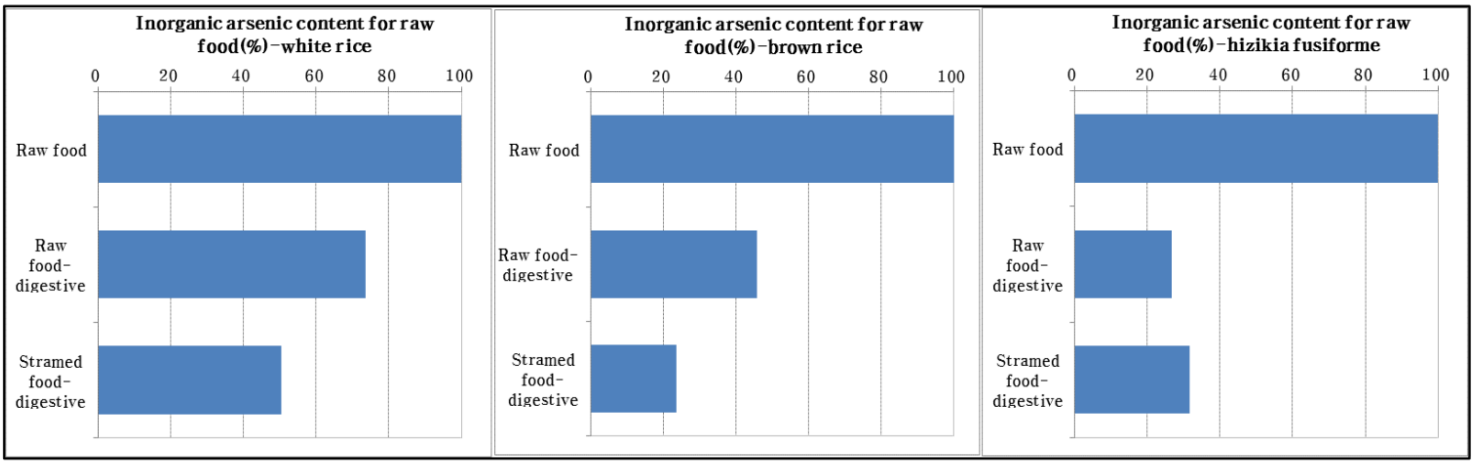

Figure 1. Content ratio of the digestive process by arsenic of food

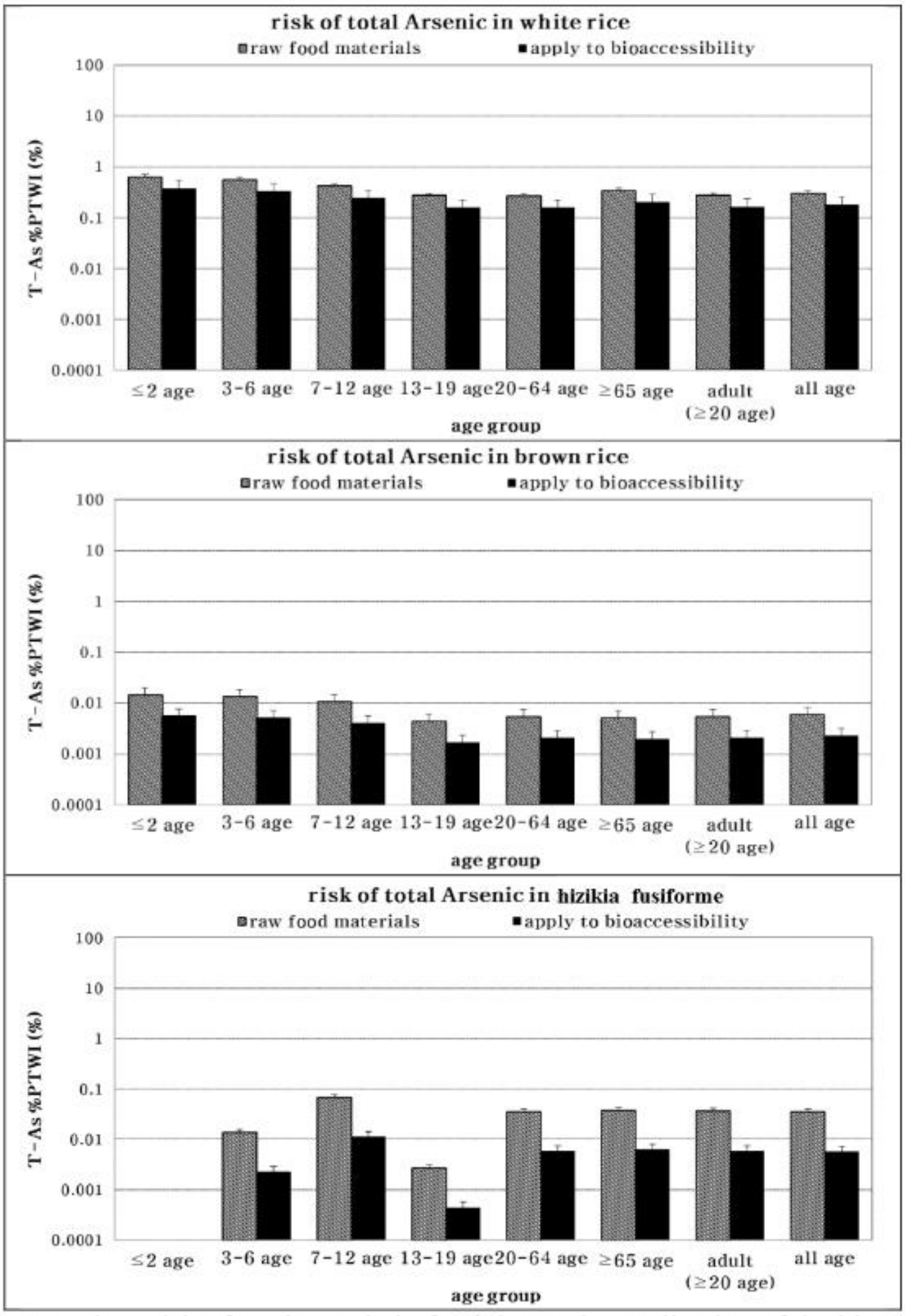

Figure 2. Comparison risk of total arsenic in food due to the application of the bioaccessibility