ABSTRACT

Arsenic (As) can exist in the environment in several different forms, each of which has unique chemical characteristics that influence its toxicity. Within the last decade or so, the increased focus on speciated As (both the inorganic and organic forms) and its potential toxicity has resulted in a large body of literature on speciated As in different food types. We evaluated the state of knowledge of As speciation in food and calculated the average levels of several species of As measured in food. Because inorganic arsenic (iAs) is considered the most toxicologically important form of As, we focused our analysis on papers presenting information on total iAs and speciated iAs (iAs³⁺ or iAs⁵⁺). Other As species (e.g., monomethylarsenic acid [MMA], dimethylarsinic acid [DMA]) were also evaluated when presented with iAs information. Publications were drawn from the peer-reviewed literature and reports by authoritative health agencies. We compiled a large database of measurements, including over 6,000 unique iAs data points. Our analysis demonstrated that iAs in foods can vary widely by type and even by sample, with mean iAs concentrations ranging from undetectable (in milk) to 8,100 µg/kg in seaweed (algaes). After seaweed, the highest mean iAs concentrations were found in rice and bran, followed by rice and rice cereals. We also found a high percentage of non-measurable As present in many food types and, in some cases, even between samples. InAs = Inorganic arsenic.

METHODS

Data Collection
- Performed comprehensive literature search (PubMed and Scopus search engines and the Toxline and Agriola catalogs).
- Identified available studies from 1995 through July 2013.
- Focused on compilation of information on iAs only, but recorded data on other As forms when present with iAs.
- Categorized each analysis by food group, with potential further division into food type subcategories.
- Excluded data from food grown on anthropogenically contaminated sites.

DATA ANALYSIS

Calculated a weighted mean for each food group (i.e., the mean of each study mean, giving consideration to sample size).

If a study reported both raw data and a mean, the reported mean was used.

When only raw data were presented, we calculated an arithmetic mean.

For the purposes of mean calculations:

- “Trace” data typically defined as a value above the limit of detection (LOD) but below the limit of quantitation (LOQ), with no measurable concentration) set as the reported LOD.
- Values reported as “undetected” or below the LOD set as half the LOD.

Performed several sensitivity analyses to determine the impact of various assumptions related to treatment of wet weight versus dry weight data, undetected values, and unreported LODs.

RESULTS

Mean concentration and the percent of iAs in foods can vary widely by type and even sample within a given food type.

High percentage of non-measurable As present in many food types, for some food groups, substituting a “0” value instead of half the LOD (for values <LOD) substantially lowered the mean total iAs concentration by 2-100%.

Most of the sensitivity analyses yielded mean iAs concentrations not substantially different from the main analysis.

DISCUSSION

The broad applicability of our analysis is limited by variability and limitations in the available data, including small sample sizes, unreported and varying LODs, and low As extraction efficiencies.

Because of the limitations in several studies, caution should be exercised when applying these data to analyses of dietary As consumption and risk in humans.

Several food types had very limited data. When data are limited, the means calculated for each food type or group may be driven by one or two values and may not accurately represent typical food samples.

A comprehensive evaluation of inorganic arsenic in food and considerations for dietary intake analyses.

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