Arsenic absorption by rice

Paul. N. Williams[1], M.R. Islam, S.A. Hussain, and A. Meharg

[1]School of Biological Sciences, University of Aberdeen, Cruickshank Building, St Machar Drive, Aberdeen, AB24 3UU, Scotland

Introduction

There is considerable concern globally about arsenic (As) in potable/drinking waters extracted from contaminated aquifers. The regions affected from contaminated ground water include the USA, Argentina, China, Myamar, Taiwan, Nepal, India and Bangladesh. The situation is at its worst in the Bengal Delta, with over 80 million people living in zones with arsenic above 50 µg/L arsenic in their groundwaters **(Smedley & Kinniburgh 2002)**

It is becoming apparent that ingestion of drinking water is not the only elevated source of arsenic to the diet in the Bengal Delta, irrigation of paddy rice fields with arsenic contaminated groundwaters has led to arsenic build-up in paddy soil, with subsequent elevation in rice grain arsenic **(Meharg and Rahman 2003)**. Meharg and Rahman **(2003)** calculated that even at "background" levels of arsenic in rice5 that rice contributed considerably to arsenic ingestion in affected areas of Bangladesh.

The forms of arsenic present in rice for direct food use need to be better characterised, as inorganic species are believed to be more toxic than methylated species **(Cullen & Reimer, 1989)**. The studies to date are relatively limited **(Heitkemper et al, 2001; Scoof et al, 1999; Kohlmeyer et al 2003; D'Amato et al, 2004)**. It appears that arsenite (As^{III}), arsenate (As^{V}) and dimethylarsinic acid (DMA^{V}) are the predominant species present.

We set out to provide a wide survey of As speciation in different rice varieties from different parts of the globe to understand the contribution of rice to arsenic exposure. Pot experiments were utilised to ascertain whether growing rice on As contaminated soil affected speciation and whether there was genetic variation in uptake and speciation.

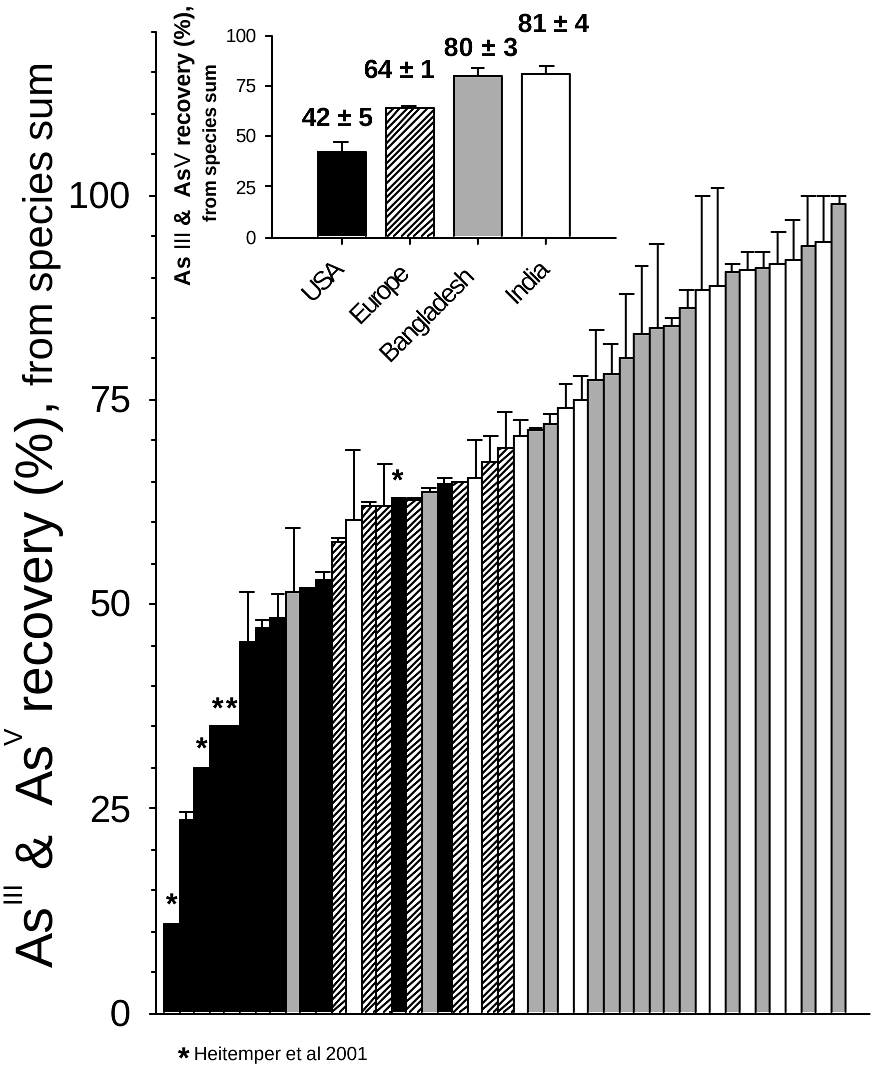
Method

For total concentrations of arsenic, milled sub-samples (0.1 – 0.2 g) were digested with nitric acid. Trifluoro-acetic acid (TFA) extractions were used to speciated arsenic in rice.

Speciation analysis was performed on a HP1100 HPLC system (Agilent Technologies, Stockport, Cheshire, UK). Optimal separation of arsenic species was achieved with a PRP-X100 anion-exchange column and a mobile phase of 6.66 mM ammonium hydrophosphate ($NH_4H_2PO_4$) and 6.66 mM ammonium nitrate (NH_4NO_3), pH 6.2. Post-column, element specific detection of arsenic was performed using an ICP-MS 7500 (Agilent Technologies). Nitrogen and carbon content was determined using a NCS analyser. Phosphorus was determined using flow injection colourimetric analysis.

Results

Percentage of inorganic arsenic in rice. The legend shows the mean, plus or minus s.e, of the percentage inorganic arsenic levels in rice for the USA, Europe, Bangladesh and India



This study found highly significant differences ($p = < 0.001$) in total arsenic concentration between Bangladeshi, USA, Indian and European rice. No differences were observed between white and brown rice. USA long grain rice had the highest mean arsenic level in the grain at 0.26 µg As g^{-1} ($n = 7$), and the highest grain arsenic value of the survey at 0.40 µg As g^{-1}. This fits well with other USA rice surveys, which range from mean values of 0.24 to 0.30 µg/g^{-1} (n = 11 samples).

Bangladeshi wet season rice's mean arsenic level was 0.13 µg As g^{-1} (n = 15), ranging from 0.03 to 0.30 µg As g^{-1}. This is similar to a previous Aman rice survey **(Duxbury et al, 2003)**, with a mean arsenic grain level of 0.12 µg As g^{-1} (0.07 to 0.17 µg As g^{-1}). However, there is large variability in the mean arsenic values of other Bangladeshi rice surveys, 0.10 – 0.95 µg As g^{-1} (n= 151 samples). This is mirrored by the large variability in soil arsenic level of individual paddy fields in Bangladesh (3.1- 42.5) µg As g^{-1} **(Meharg & Rahman, 2003)**.

The main species detected were $As^{(III)}$, $DMA^{(V)}$ and $As^{(V)}$; quantifiable amounts of MMA were observed in one Indian sample and also in the CRM. In European, Bangladeshi and Indian rice 64 ± 1 % (n=7), 80 ± 3 % (n = 11) and 81 ± 4 % (n = 15) of the recovered arsenic was found to be inorganic, with $As^{(III)}$ predominating. Scoof *et al* **(1998)** report similar values of 61%, 58% and 67% for Taiwanese rice. In contrast $DMA^{(V)}$ was the predominant species in rice from the USA, with only 42 ± 5 % (n = 12) of the arsenic being inorganic. This data concurs with Scoof *et al* **(1999)** who report that DMA contributes 54% (n = 4) to the arsenic in the grain of US rice. This study found highly significant differences ($p = < 0.001$) in the percentage of recovered inorganic arsenic between Bangladeshi, USA, Indian and European market rice. No differences were observed between white and brown rice.

References

Cullen, WR; Reimer, KJ; Arsenic speciation in the environment, CHEM REV, **1989**, 89, 713-764

D'Amato, M; Forte, G; Caroli, S; Identification and quantification of major species of arsenic in rice, J AOAC INT, **2004**, 87, 238-243

Duxbury, JM; Mayer, AB; Lauren, JG; Hassan, N; Food chain aspects of arsenic contamination in Bangladesh: Effects on quality and productivity of rice, J ENVIRON SCI HEAL A, **2003**, 38, 61-69

Heitkemper, DT; Vela, NP; Stewart, KR; Westphal, CS; Determination of total and speciated arsenic in rice by ion chromatography and inductively coupled plasma mass spectrometry, J ANAL ATOM SPECTROM, **2001**, 16, 299-306

Kohlmeyer, **U**; Jantzen, E; Kuballa, J; Jakubik, S; Benefits of high resolution IC-ICP-MS for the routine analysis of inorganic and organic arsenic species in food products of marine and terrestrial origin, ANAL BIOANAL CHEM, **2003**, 377, 6-13

Meharg AA, Rahman M; Arsenic contamination of Bangladesh paddy field soils: Implications for rice contribution to arsenic consumption, ENVIRON SCI TECHNOL **2003**, 37, 229-234

Schoof, RA; Yost, LJ; Eickhoff, J; Crecelius, EA; Cragin, DW; Meacher, DM; Menzel, DB; A market basket survey of inorganic arsenic in food, FOOD CHEM TOXICOL, **1999**, 37, 839-846

Smedley, PL; Kinniburgh, DG; A review of the source, behaviour and distribution of arsenic in natural waters, APPL GEOCHEM, **2002**, 17, 517-568