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Supplementary Material

Arsenic concentrations and speciation in Australian and imported rice and commercial rice products

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Supplementary Table S1. References used for data comparison of As concentrations in paddock grown rice from different regions

Australia

1 Fransisca et al., 2015

2 Islam et al., 2017

3 Rahman et al., 2014

Asia

1 Fu et al., 2011

2 Juhasz et al., 2006

3 Liang et al., 2010

4 Narukawa et al., 2014

5 Nookabkaew et al., 2013

6 Praveena and Omar, 2017

6 Sun et al., 2008

7 Williams et al., 2006

Europe

1 Pétursdóttir et al., 2014

2 Sofuoglu et al., 2014

3 Torres-Escribano et al., 2008

4 Williams et al., 2005

5 Meharg et al., 2009

USA

1 Ackerman et al., 2005

2 Bhadha and VanWeelden

3 Lamont, 2003

4 Heitkemper et al., 2001

South America

1 Batista et al., 2011

2 da Silva et al., 2018

Supplementary Table S2. References used for data comparison of As concentrations in rice products from different regions

1 Burló et al., 2012

2 Carbonell-Barrachina et al., 2012

3 Jackson et al., 2012a

4 Jackson et al., 2012b

5 Juskelis et al., 2013

6 Llorente-Mirandes et al., 2014

7 Llorente-Mirandes et al., 2012

8 Ljung et al., 2011

9 dos Santos et al., 2017

10 Meharg et al., 2008b

11 Meharg et al., 2008a

12 Rothenberg et al., 2017

13 Signes-Pastor et al., 2016

14 Signes-Pastor et al., 2009

15 Sun et al., 2008

ACKERMAN, A. H., CREED, P. A., PARKS, A. N., FRICKE, M. W., SCHWEGEL, C. A., CREED, J. T., HEITKEMPER, D. T. & VELA, N. P. 2005. Comparison of a chemical and enzymatic extraction of arsenic from rice and an assessment of the arsenic absorption from contaminated water by cooked rice. *Environmental science & technology*, 39, 5241-5246.

BATISTA, B. L., SOUZA, J. M., DE SOUZA, S. S. & BARBOSA JR, F. 2011. Speciation of arsenic in rice and estimation of daily intake of different arsenic species by Brazilians through rice consumption. *Journal of hazardous materials*, 191, 342-348.

BHADHA, J. H. & VANWEELDEN, M. T. Arsenic Accumulation in Rice (*Oryza sativa*): An Overview.

BURLÓ, F., RAMÍREZ-GANDOLFO, A., SIGNES-PASTOR, A. J., HARIS, P. I. & CARBONELL-BARRACHINA, Á. A. 2012. Arsenic contents in Spanish infant rice, pureed infant foods, and rice. *Journal of food science*, 77.

- CARBONELL-BARRACHINA, Á. A., WU, X., RAMÍREZ-GANDOLFO, A., NORTON, G. J., BURLÓ, F., DEACON, C. & MEHARG, A. A. 2012. Inorganic arsenic contents in rice-based infant foods from Spain, UK, China and USA. *Environmental Pollution*, 163, 77-83.
- DA SILVA, I. J. S., PAIM, A. P. S. & DA SILVA, M. J. 2018. Composition and estimate of daily mineral intake from samples of Brazilian rice. *Microchemical Journal*, 137, 131-138.
- DOS SANTOS, G. M., POZEBON, D., CERVEIRA, C. & DE MORAES, D. P. 2017. Inorganic arsenic speciation in rice products using selective hydride generation and atomic absorption spectrometry (AAS). *Microchemical Journal*, 133, 265-271.
- FRANSISCA, Y., SMALL, D. M., MORRISON, P. D., SPENCER, M. J., BALL, A. S. & JONES, O. A. 2015. Assessment of arsenic in Australian grown and imported rice varieties on sale in Australia and potential links with irrigation practises and soil geochemistry. *Chemosphere*, 138, 1008-1013.
- FU, Y., CHEN, M., BI, X., HE, Y., REN, L., XIANG, W., QIAO, S., YAN, S., LI, Z. & MA, Z. 2011. Occurrence of arsenic in brown rice and its relationship to soil properties from Hainan Island, China. *Environmental pollution*, 159, 1757-1762.
- HEITKEMPER, D. T., VELA, N. P., STEWART, K. R. & WESTPHAL, C. S. 2001. Determination of total and speciated arsenic in rice by ion chromatography and inductively coupled plasma mass spectrometry. *Journal of Analytical Atomic Spectrometry*, 16, 299-306.
- ISLAM, S., RAHMAN, M. M., RAHMAN, M. A. & NAIDU, R. 2017. Inorganic arsenic in rice and rice-based diets: Health risk assessment. *Food Control*, 82, 196-202.
- JACKSON, B. P., TAYLOR, V. F., KARAGAS, M. R., PUNSHON, T. & COTTINGHAM, K. L. 2012a. Arsenic, organic foods, and brown rice syrup. *Environmental health perspectives*, 120, 623.
- JACKSON, B. P., TAYLOR, V. F., PUNSHON, T. & COTTINGHAM, K. L. 2012b. Arsenic concentration and speciation in infant formulas and first foods. *Pure and Applied Chemistry*, 84, 215-223.
- JUHASZ, A. L., SMITH, E., WEBER, J., REES, M., ROFE, A., KUCHEL, T., SANSOM, L. & NAIDU, R. 2006. In vivo assessment of arsenic bioavailability in rice and its significance for human health risk assessment. *Environmental Health Perspectives*, 114, 1826.
- JUSKELIS, R., LI, W., NELSON, J. & CAPPOZZO, J. C. 2013. Arsenic speciation in rice cereals for infants. *Journal of agricultural and food chemistry*, 61, 10670-10676.
- LAMONT, W. H. 2003. Concentration of inorganic arsenic in samples of white rice from the United States. *Journal of food composition and analysis*, 16, 687-695.
- LIANG, F., LI, Y., ZHANG, G., TAN, M., LIN, J., LIU, W., LI, Y. & LU, W. 2010. Total and speciated arsenic levels in rice from China. *Food Additives and Contaminants*, 27, 810-816.
- LJUNG, K., PALM, B., GRANDÉR, M. & VAHTER, M. 2011. High concentrations of essential and toxic elements in infant formula and infant foods—A matter of concern. *Food chemistry*, 127, 943-951.
- LLORENTE-MIRANDES, T., CALDERÓN, J., CENTRICH, F., RUBIO, R. & LÓPEZ-SÁNCHEZ, J. F. 2014. A need for determination of arsenic species at low levels in cereal-based food and infant cereals. Validation of a method by IC-ICPMS. *Food chemistry*, 147, 377-385.
- LLORENTE-MIRANDES, T., CALDERÓN, J., LÓPEZ-SÁNCHEZ, J. F., CENTRICH, F. & RUBIO, R. 2012. A fully validated method for the determination of arsenic species in rice and infant cereal products. *Pure and Applied Chemistry*, 84, 225-238.
- MEHARG, A. A., DEACON, C., CAMPBELL, R. C., CAREY, A.-M., WILLIAMS, P. N., FELDMANN, J. & RAAB, A. 2008a. Inorganic arsenic levels in rice milk exceed EU and US drinking water standards. *Journal of Environmental Monitoring*, 10, 428-431.
- MEHARG, A. A., SUN, G., WILLIAMS, P. N., ADOMAKO, E., DEACON, C., ZHU, Y.-G., FELDMANN, J. & RAAB, A. 2008b. Inorganic arsenic levels in baby rice are of concern. *Environmental Pollution*, 152, 746-749.
- MEHARG, A. A., WILLIAMS, P. N., ADOMAKO, E., LAWGALI, Y. Y., DEACON, C., VILLADA, A., CAMPBELL, R. C., SUN, G., ZHU, Y.-G. & FELDMANN, J. 2009. Geographical variation in total and inorganic

- arsenic content of polished (white) rice. *Environmental Science & Technology*, 43, 1612-1617.
- NARUKAWA, T., MATSUMOTO, E., NISHIMURA, T. & HIOKI, A. 2014. Determination of sixteen elements and arsenic species in brown, polished and milled rice. *Analytical Sciences*, 30, 245-250.
- NOOKABKAEW, S., RANGKADILOK, N., MAHIDOL, C., PROMSUK, G. & SATAYAVIVAD, J. 2013. Determination of arsenic species in rice from Thailand and other Asian countries using simple extraction and HPLC-ICP-MS analysis. *Journal of agricultural and food chemistry*, 61, 6991-6998.
- PÉTURSDÓTTIR, Á. H., FRIEDRICH, N., MUSIL, S., RAAB, A., GUNNLAUGSDÓTTIR, H., KRUPP, E. M. & FELDMANN, J. 2014. Hydride generation ICP-MS as a simple method for determination of inorganic arsenic in rice for routine biomonitoring. *Analytical Methods*, 6, 5392-5396.
- PRAVEENA, S. & OMAR, N. 2017. Heavy metal exposure from cooked rice grain ingestion and its potential health risks to humans from total and bioavailable forms analysis. *Food chemistry*, 235, 203-211.
- RAHMAN, M. A., RAHMAN, M. M., REICHMAN, S. M., LIM, R. P. & NAIDU, R. 2014. Arsenic speciation in Australian-grown and imported rice on sale in Australia: implications for human health risk. *Journal of agricultural and food chemistry*, 62, 6016-6024.
- ROTHENBERG, S. E., JACKSON, B. P., MCCALLA, G. C., DONOHUE, A. & EMMONS, A. M. 2017. Co-exposure to methylmercury and inorganic arsenic in baby rice cereals and rice-containing teething biscuits. *Environmental research*, 159, 639-647.
- SIGNES-PASTOR, A. J., CAREY, M. & MEHARG, A. A. 2016. Inorganic arsenic in rice-based products for infants and young children. *Food chemistry*, 191, 128-134.
- SIGNES-PASTOR, A. J., DEACON, C., JENKINS, R. O., HARIS, P. I., CARBONELL-BARRACHINA, Á. A. & MEHARG, A. A. 2009. Arsenic speciation in Japanese rice drinks and condiments. *Journal of Environmental Monitoring*, 11, 1930-1934.
- SOFUOGLU, S. C., GÜZELKAYA, H., AKGÜL, Ö., KAVCAR, P., KURUCAOVALI, F. & SOFUOGLU, A. 2014. Speciated arsenic concentrations, exposure, and associated health risks for rice and bulgur. *Food and chemical toxicology*, 64, 184-191.
- SUN, G.-X., WILLIAMS, P. N., CAREY, A.-M., ZHU, Y.-G., DEACON, C., RAAB, A., FELDMANN, J., ISLAM, R. M. & MEHARG, A. A. 2008. Inorganic arsenic in rice bran and its products are an order of magnitude higher than in bulk grain. *Environmental science & technology*, 42, 7542-7546.
- TORRES-ESCRIBANO, S., LEAL, M., VÉLEZ, D. & MONTORO, R. 2008. Total and inorganic arsenic concentrations in rice sold in Spain, effect of cooking, and risk assessments. *Environmental Science & Technology*, 42, 3867-3872.
- WILLIAMS, P., PRICE, A., RAAB, A., HOSSAIN, S., FELDMANN, J. & MEHARG, A. A. 2005. Variation in arsenic speciation and concentration in paddy rice related to dietary exposure. *Environmental Science & Technology*, 39, 5531-5540.
- WILLIAMS, P. N., ISLAM, M., ADOMAKO, E., RAAB, A., HOSSAIN, S., ZHU, Y., FELDMANN, J. & MEHARG, A. A. 2006. Increase in rice grain arsenic for regions of Bangladesh irrigating paddies with elevated arsenic in groundwaters. *Environmental Science & Technology*, 40, 4903-4908.