Inorganic arsenic contents in infant rice powders and infant rice snacks marketed in Korea determined by a highly sensitive gas chromatography-tandem mass spectrometry following derivatization with British Anti-Lewisite

Mun Yhung Jung^{1,2}

Received: 6 September 2017 / Revised: 23 October 2017 / Accepted: 9 November 2017 / Published online: 12 December 2017
© The Korean Society of Food Science and Technology and Springer Science+Business Media B.V., part of Springer Nature 2017

Abstract Toxic inorganic arsenic (iAs) has been reported to be present in high quantity in rice and rice-based products. The inorganic arsenic contents in infant foods ($n = 59$) of ready-to-cook infant rice powders and infant rice snacks marketed in Korea were determined by a highly sensitive gas chromatography-tandem mass spectrometry (GC–MS/MS). The mean iAs contents in the infant rice powder and infant rice snacks were 65.6 and 54.0 $\mu\text{g/kg}$, respectively. The percentages of rice powders and rice snack containing iAs over the maximum level (100 $\mu\text{g/kg}$) set by EU for the infant foods were found to be 21, and 6%, respectively. This result clearly suggested that regulation regarding the maximum limit of iAs levels for the baby rice products is urgently needed to be set in Korea. This represents the first report on the iAs levels in ready-to-cook infant rice powder products and infant snacks marketed in Korea.

Keywords Safety · Infant foods · Method validation · Gas chromatography–mass spectrometry

Introduction

Arsenic is a metalloid ubiquitously present in the environment including soil and waters. Arsenic in the environments is absorbed into plant crops, easily incorporating into the food chain. Rice contains significantly higher levels of arsenic species compared to the other important crops [1–3]. Inorganic arsenic (iAs) as well as organic arsenic (dimethylarsinic acid and monomethylarsonic) are the main arsenic species present in rice [4, 5]. iAs has been reported to be highly toxic and associated with the increased risk of certain type of cancer such as skin, lung, and bladder cancers. International Agency for Research on Cancer has classified iAs as a group 1 carcinogen [6]. However, common organoarsenic species are far less toxic. Thus, only the iAs contents in rice and rice-based foods is of great concern [7, 8]. South Korea and China have set the legislations in place for the maximum levels (MLs) (200 and 150 $\mu\text{g/kg}$, respectively) of iAs in polished rice. European Union (EU) has also established a legislation (as effective on January 2016) on the maximum levels for iAs in rice and rice products [9].

Infants and children are particularly susceptible to the toxic effects of iAs [10]. Early-life exposure to fairly low levels of iAs is associated with increased infant morbidity, mortality, and impaired child development during pregnancy [11–13]. In Korea, rice-based infant product is particularly a dominant carbohydrate source to weaning infants due to its high nutritional value, low allergen potential, absence of gluten, convenience for cooking, and strong gastronomic cultural background. This is an increasingly recognized concern due to the higher food consumption per body weight and narrower diversity of their diet sources compared to adults. In 2016, US FDA proposed an iAs threshold action level (100 $\mu\text{g/kg}$) in rice

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s10068-017-0260-6>) contains supplementary material, which is available to authorized users.

✉ Mun Yhung Jung
munjung@woosuk.ac.kr

¹ Department of Food and Biotechnology, Graduate School, Woosuk University, Samnye-Eup, Wanju-Gun, Jeonbuk Province 565-701, Republic of Korea

² Agricultural and Food Product Safety Analysis Center, Woosuk University, Wanju-Gun, Republic of Korea

for the infant foods [14]. A regulation on maximum level of iAs in infant and children's foods (100 µg/kg) has been recently established in EU [9]. The iAs levels in rice and rice-based infant products in several different countries have been reported [1, 15–19]. There are several published papers on the iAs content in Korean white rice and rice products for adult consumption [20–23]. There is an internal project report conducted by Korean Food & Drug Administration regarding the iAs levels in cereal based infant formula (mixture of various grains and sorghums) available in Korea [24]. However, the iAs levels in ready-to-cook infant rice powders and infant rice snacks marketed in Korea have never been previously reported. Thus, monitoring the iAs levels in popular infant foods marketed in Korea such as ready-to-cook rice powder products and infant rice snacks is urgently needed to secure the safety of the infants, especially those with heavy dependency on these products.

High performance liquid chromatography-inductively coupled plasma mass spectrometry (HPLC–ICP–MS), selective hydride generation-inductively coupled plasma mass spectrometry (HG–ICP–MS), HG-atomic absorption spectrometry (HG–AAS), HPLC-hyphenated with atomic absorption spectrometry (AAS) or atomic fluorescence spectrometry (HPLC–AFS) has been successfully introduced to analyze the arsenic species with a main focus on the analysis of iAs [1, 5, 25–28]. Recently, in our laboratory, a highly selective and sensitive gas chromatography-tandem mass spectrometry in combination with one step derivatization with British Anti-Lewisite (BAL) was successfully developed and validated for the determination of iAs content in rice and rice products [20].

The objective of this research was to determine the contents of toxic iAs in rice based infant foods ($n = 59$) of ready-to-cook infant rice powder and infant rice snack marketed in Korea by a highly sensitive GC–MS/MS method following one step derivatization with British Anti-Lewisite (BAL), which was successfully developed and validated previously in this laboratory. In this study, the analytical method was once again validated for the analysis of iAs in the infant rice powder and rice-based infant snack samples.

Materials and methods

Materials and reagents

Sodium arsenite solution (NaAsO_2) and disodium hydrogen arsenate heptahydrate ($\text{Na}_2\text{HAsO}_4 \cdot 7\text{H}_2\text{O}$) were obtained from Merck KGAA (Darmstadt, Germany) and Waco (Tokyo, Japan), respectively. Dimercapto-1-propanol (BAL, $\text{C}_3\text{H}_8\text{OS}_2$) and dichloromethane (HPLC grade)

were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Ultra-pure nitric acid (70%, w/v) was obtained from Dongwoo Whain Co (Iksan, Korea). Deionized water obtained with Millipore Water Treatment System (Bedford, MA, USA) was used for the extraction and the preparation of sample and reagents. Derivatization reagent (BAL solution, 0.2%, w/v) was prepared by dissolving the dimercapto-1-propanol in deionized water. Stock standard solutions (1.0 mg/mL) of As(III) and As(V) were prepared in 0.28 M HNO_3 solution (m/v). Working standard solutions with the concentration range of 0.2–200 ng/mL were prepared by a serial dilution of the stock standard solutions with 0.28 M HNO_3 solution. Ready-to-cook infant rice powder ($n = 28$) and infant rice snacks ($n = 31$, puffed-type rice snacks) were randomly purchased from the local or online markets. Standard Reference Material (SRM) ERM-BC211 rice powder was purchased from the Institute for Reference Materials and Measurements (IRMM, Geel, Belgium).

Extraction of iAs from samples

Infant rice snack samples were ground with a food grinder (FM909T, Hanil Electric Co., Seoul, Republic of Korea) and passed through a standard sieve (250 µm) to obtain fine homogeneous powder. Since the ready-to-cook rice products were very fine powder, the products were directly used as samples for the iAs extraction. The sample (2.0 g) and 1.764% HNO_3 solution (w/v) (20 mL) were transferred, in triplicate, into a 50 mL-capacity polypropylene tube. Then, the extraction of iAs in the samples was performed in a water-bath at 95 °C for 90 min according to the previous report [29].

Derivatization

The sample solution (1 mL) and derivatization reagent (1.2 mL, 0.2% BAL solution) were transferred into a 10 mL-capacity glass tube. Then, derivatization was conducted in the water bath at 50 °C for 30 min according to our previous reports [20, 21]. The iAs–BAL complex was extracted with dichloromethane (1 mL). The collected dichloromethane layer was used for the analysis of iAs.

GC–MS/MS operation

A GC–MS/MS operation conditions were adopted from the previous report [21] with slight modification. A GC–MS system comprising of a GC (2010Plus, Shimadzu, Tokyo, Japan) and triple quadrupole mass spectrometer (TQ8030, Shimadzu) was used. The temperatures of injector, mass selective detector (MSD) transfer line, and ion-source were 300, 280, and 280 °C, respectively. The column used was a

short non-polar capillary column (SLB-5MS, 6 m $\times$ 0.18 mm I.D., 0.18 μ m film thickness, Supelco, Bellefonte, PA, USA). Sample injection volume was 1 mL. A programmed oven temperature (initial temperature of 50 $^{\circ}$ C for 0.5 min at the gradient rate of 240 $^{\circ}$ C/min to 310 $^{\circ}$ C with 0.6 min holding time at the final oven temperature) was used for the GC operation. The linear velocity of carrier gas (helium) was 114.7 cm/sec. The quantitative transition and qualitative transitions (m/z 212 > 165 at collision induced dissociation energy (CIDE) 15 V and m/z 212 > 107 at CIDE 35 V, respectively) were also adopted from the previous reports [20, 21]. For confirming the identity of iAs peak in gas chromatograms, the ratio of quantitative transition to the quantitative transition was also monitored.

Standard addition method for quantification

Standard addition method with two point spiked levels was applied for the quantification of iAs [20, 21, 30]. The two additional spiked As(III) levels were 10.0, and 30.0 ng/mL. The iAs concentration originally present in the rice extract was calculated by extrapolation from the standard addition calibration curve obtained with spiked samples [30]. All samples were prepared and analyzed in triplicate.

Method validation

For the method validation, linearity of calibration curves, limit of detection (LOD), limit of quantification (LOQ), precision and accuracy of the analytical method was studied. The LOD and LOQ were calculated as the amounts of iAs injected that gave 3 and 10 of signal to baseline noise ratio (S/N), respectively. Repeated analysis (10 times) of the iAs standard solutions at three different concentrations (1, 5, and 25 ng/mL) were conducted to monitor the intraday repeatability. Inter-day repeatability of the GC-MS/MS method was studied by repeatedly conducting the analysis of the samples (ready-to-eat rice and infant snacks) for the 4 different dates (triplicate analysis per sample per day). The accuracy of the method was tested by studying the recovery of the spiked iAs levels in ready-to-eat rice products ($n = 2$) and rice samples ($n = 4$) at three different levels. The accuracy of the method was further confirmed with standard reference material ERM BC-211 rice flour.

Statistical analysis

Analysis of variance (ANOVA) and Tukey's multiple range test (a Post-hoc test) were conducted to monitor the statistical significance of the iAs contents between the sample groups (rice powder and rice snack) at $\alpha = 0.05$ by

using a SPSS statistical analysis program (SPSS 14.0 K, SPSS, Chicago, IL, USA).

Results and discussion

Method validation

Representative gas chromatograms for ready-to-cook infant rice powder and infant rice snack are shown in Fig. 1. The total gas chromatographic operation time was 2.5 min with the retention time of iAs peak at 1.72 min (Fig. 1). As shown in Fig. 1, no considerable interference was observed for the analysis of iAs in all the sample matrices studied. The high selectivity may be due to the double mass filter system of tandem mass spectrometry. The analytical calibration curves for As(III) and As(V) with excellent linearity ($r^2 > 0.999$) were obtained (Table S1). The LOD (0.015 pg) and LOQ (0.05 pg) obtained in the present study was the same as those of our previous data [21], further confirming its high sensitivity (Table S1). The LOD and LOQ levels in samples equates to 0.15 and 0.5 μ g/kg, respectively. Relative standard deviation (RSD) of the intra-day ($\leq 6.5\%$) and inter-day repeatability ($\leq 8.3\%$) also doubly confirmed the high precision of the applied method (Tables S2 and S3). The recoveries of the iAs in the spiked infant rice powders ($n = 2$) and infant rice snack samples ($n = 2$) were close to the 100% with the range of 94–119% (Table S4). The analyzed iAs levels in ERM-BC211 rice flour was 120 ± 3.1 μ g/kg, which was 94% accuracy of its certified value of 124 ± 11 μ g/kg (data not shown).

Inorganic arsenic levels in ready-to-cook infant rice powder and infant rice snacks

The iAs contents in ready-to-cook infant rice powder products and infant rice snacks are shown in Fig. 2. The mean iAs content in the ready-to-cook infant rice products marketed in Korea was 65.7 μ g/kg with the range of 11.0–187.3 μ g/kg and median value of 59.97 μ g/kg (Fig. 2). The results clearly showed that the iAs content greatly varied with products, showing 17 fold variation in iAs level with different brand. This study also showed that high percentage (21%) of ready-to-cook rice products was not appropriate for the infant and young children foods according to the iAs maximum level (100 μ g/kg) set by EU. It was noteworthy that the iAs level of one of the products was 187.3 μ g/kg, which was even over the maximum legislative level (150 μ g/kg) set for adult consumption in China. The mean iAs content in the infant snacks marketed in Korea was 54.0 μ g/kg with the range of 15.9–120.9 μ g/kg and median value of 45.3 μ g/kg (Fig. 2). Among the 31 infant snack samples, two contained the iAs

Fig. 1 Representative gas chromatograms for standard iAs solutions (0.1 and 100 ng/mL), ready-to-cook infant rice powder, and rice-based infant snack analyzed by a gas chromatography-tandem mass spectrometry

Fig. 2 Box and whisker plot with central lines (median), box (first and third quartiles), whiskers (lower and higher boundaries), and dots (outliers) for iAs levels in ready-to-cook infant rice powder and rice-based infant snack

over 100 µg/kg, the maximum level set for infant by EU. Early life exposure to iAs is of particular concern due to the high susceptibility of its toxic effects, which may induce, even at low to moderate levels of exposure, considerable impact throughout the lifespan [10, 31–33]. In Korea, rice-based infants product is a predominant carbohydrate source to weaning infants due to its high nutritional value, low allergen potential, absence of gluten, convenience for cooking, and strong Korean gastronomic culture. This is an increasingly recognized concern due to the higher food consumption per body weight and narrower diversity of their diet sources compared to adults. Thus, the information on the iAs level in the ready-to-cook infant rice products marketed in Korea is urgently required to secure the safety for the Korean infants. There are several published reports on the iAs contents in various types of Korean rice and microwavable ready-to-eat rice products [20–23]. There was an internal project report conducted by Korean Food & Drug Administration regarding the iAs levels in cereal-based infant formula (mixture of various grains and sorghums along with various food additives) available in Korea [24]. Unfortunately, however, the iAs content in the ready-to-cook infant rice powders has never been previously published. The iAs levels in infant rice products in this present study were lower than those in infant cereals marketed in Spain. The iAs contents in 9 infant cereal products marketed in Spain has been reported to be in range from 8.1 to 73.7 µg/kg with a mean value of 23.0 µg/kg [34]. However, the iAs contents in infant rice products in present study were lower than those in the rice-based infant cereals reported in other studies [15, 16, 18, 34–37]. The higher percentage of rice in the infant cereal showed the higher iAs contents in the products [34]. It has been

reported that the total As content in pure rice-based infant cereal was an order of magnitude higher than the non-rice-based infant cereals [34]. The iAs concentration in 29 baby rice from UK market has been reported to range from 56 to 268 µg/kg [1]. In September 2013, the US Food and Drug Administration (US FDA) released analytical results of iAs levels a large number (approximately 1100 samples) of rice and rice products from the US market, including 85 samples of baby rice under the product subcategory of infant cereals and toddler cereals [38]. The median iAs value in baby rice from the USA market is 114 µg/kg with a range of 39–254 µg/kg. The present results showed that the iAs contents in infant rice powder and infant snacks was lower than those from USA market. These present results are also lower than the 17 samples of baby rice obtained in the city of Aberdeen, UK, and reported a median iAs content of 110 µg/kg [15].

In a brief summary, it was found that considerably high percentage (21%) of ready-to-cook infant rice products contained the iAs higher than the maximum allowed level (100 µg/kg) for the infant and young children foods set by EU. Furthermore, 2 out of 31 infant rice snacks were also contained iAs higher than the maximum legal level set for infant and young children's food by EU. The relatively high iAs contents in infant rice powders and snacks may pose a health risk for infants and young children in Korea. There are currently no regulations applicable to iAs levels in infant foods in Korea. Since infants at the very early stage of life are especially vulnerable to the toxicity of iAs, this study warrants the urgent needs for regulatory limit set and continuous monitoring on iAs levels in rice-based infant foods in Korea.

Acknowledgements The author greatly appreciates Ms. Ju Hee Kang and Ms. Hyun Jeong Jung for their technical assistances.

Compliance with ethical standards

Conflict of interest The author declares no conflict of interest.

References

- Signes-Pastor AJ, Carey M, Meharg AA. Inorganic arsenic in rice-based products for infants and young children. *Food Chem.* 191: 128–134 (2016).
- William PN, Villada A, Deacon C, Raab A, Figuerola J, Green AJ, Feldmann J, Meharg AA. Greatly enhanced arsenic shoot assimilation in rice lead to elevate grain levels compared to wheat and barley. *Environ. Sci. Technol.* 41: 6854–6859 (2007).
- Xu XY, McGrath SP, Meharg AA, Zhao FJ. Growing rice aerobically markedly decreases arsenic accumulation. *Environ. Sci. Technol.* 42: 5574–5579 (2008).
- Sun G, Williams PN, Carey A, Zhu Y, Deacon C, Raab A, Feldmann J, Islam RM, Meharg AA. Inorganic arsenic in rice bran and its products are an order of magnitude higher than in bulk grain. *Environ. Sci. Technol.* 42: 7542–7546 (2008).

5. Sánchez-Rodas D, Corns WT, Chen B, Stockwell PB, Atomic fluorescence spectrometry: a suitable detection technique in speciation studies for arsenic, selenium, antimony and mercury. *J. Anal. Atom. Spectrom.* 25: 933–946 (2010).
6. International Agency for Research on Cancer (IARC). In: IARC monographs on the evaluation of carcinogenic risks to humans, Volume 100, A review of human carcinogens, Part C: Arsenic, metals, fibers, and dusts. Lyon (France): IARC; 2012, p. 41–93.
7. Chen G, Chen T. SPE speciation of inorganic arsenic in rice followed by hydride-generation atomic fluorescence spectrometric quantification. *Talanta* 119: 202–206 (2014).
8. Ali J, Tuzen M, Kazi TG, Hazer B, Inorganic arsenic speciation in water samples by miniaturized solid phase microextraction using a new polystyrene polydimethyl siloxane polymer in micropipette tip of syringe system. *Talanta* 161: 450–4 (2016).
9. European Commission, Commission Regulation (EU) 2015/1006 of 25 June 2015, amending Regulation (EC) No 1881/2006 as regards maximum levels of inorganic arsenic in food stuffs.
10. Vahter M. Effects of arsenic on maternal and fetal health. *Annu. Rev. Nutr.* 29: 381–399 (2009).
11. Parvez F, Wasserman GA, Factor-Litvak P, Liu X, Slavkovich V, Siddique AB, Sultana R, Sultana R, Islam T, Levy D, Mey JL, van Geen A, Khan K, Kline J, Ahsan H, Graziano JH. Arsenic exposure and motor function among children in Bangladesh. *Environ. Health Perspect.* 119: 1665–1670 (2011).
12. Wasserman GA, Liu X, Parvez F, Ahsan H, Factor-Litvak P, Kline J, van Geen A, Slavkovich V, Loiacono NJ, Levy D, Cheng Z, Graziano JH. Water arsenic exposure and intellectual function in 6-year-old children in Araihaazar, Bangladesh. *Environ. Health Perspect.* 115:285–289 (2007).
13. Rahman A, Vahter M, Smith AH, Nermell B, Yunus M, El Arifeen S, Persson LA, Ekström EC. Arsenic exposure during pregnancy and size at birth: a prospective cohort study in Bangladesh. *Am. J. Epidemiol.* 169(3):304–12 (2009).
14. FDA, 2016. FDA proposes limit for inorganic arsenic in infant rice cereal.
15. Meharg AA, Sun G, Williams PN, Adamako E, Deacon C, Zhu YG, Feldmann J, Raab A. Inorganic arsenic levels in baby rice are of concern. *Environ. Pollut.* 152:746–9 (2008).
16. Llorente-Mirandes T, Calderon J, Lopez-Sanchez JF, Centrich F, Rubio R. A fully validated method for the determination of arsenic species in rice and infant cereal products. *Pure Appl. Chem.* 84: 225–238 (2012).
17. Ljung K, Palm B, Grandér M, Vahter M. High concentrations of essential and toxic elements in infant formula and infant foods—a matter of concern. *Food Chem.* 127:943–51 (2011).
18. Carbonell-Barrachina ÁA, Wu X, Ramírez-Gandolfo A, Norton GJ, Burló F, Deacon C, Meharg AA. Inorganic arsenic contents in rice-based infant foods from Spain, UK, China and USA, *Environ. Pollut.* 163: 77–83 (2012).
19. Burló F, Ramírez-Gandolfo A, Signes-Pastor AJ, Haris PI, Carbonell-Barrachina ÁA. Arsenic contents in Spanish infant rice, pureed infant foods, and rice. *J. Food Sci.* 77: T15–19 (2012).
20. Kang JH, Jung HJ, Jung MY. One step derivatization with British Anti-Lewisite in combination with gas chromatography coupled to triple-quadrupole tandem mass spectrometry for the fast and selective analysis of inorganic arsenic in rice. *Anal. Chim. Acta* 934: 231–238 (2016).
21. Jung MY, Kang JH, Jung HJ, Ma SY. Inorganic arsenic contents in ready-to-eat rice products and various Korean rice determined by a highly sensitive gas chromatography-tandem mass spectrometry. *Food Chem.* 240: 1179–1183 (2018).
22. Choi, J. Y., Khan, N., Nho, E. Y., Choi H., Park K. S., Cho M. J., Youn H. J. & Kim K. S., (2016). Speciation of arsenic in rice by high-performance liquid chromatography-inductively coupled plasma mass spectrometry. *Analytical Letters*, 49, 1926–1937.
23. Yim SR, Park GY, Lee KW, Chung M, Shim S. Determination of total arsenic content and arsenic speciation in different types of rice. *Food Sci. Biotech.* 26: 293–298 (2017).
24. Park SH et al., Risk assessment of heavy metals in infant & young children foods. A report of internal research project, Korea Food & Drug Administration (2012)
25. Oliveira A, Gonzalez MH, Queiroz HM, Cadore S. Fractionation of inorganic arsenic by adjusting hydrogen ion concentration. *Food Chem.* 213: 76–82 (2016).
26. Musil S, Pétursdóttir ÁH, Raab A, Gunnlaugsdóttir H, Krupp E, Feldmann J. Speciation without chromatography using selective hydride generation: inorganic arsenic in rice and samples of marine origin. *Anal. Chem.* 86: 993–999 (2014).
27. Anawar HM. Arsenic speciation in environmental samples by hydride generation and electrothermal atomic absorption spectrometry. *Talanta* 88 30–42 (2012)..
28. Narukawa T, Chiba K, Sinaviwat S, Feldmann J, A rapid monitoring method for inorganic arsenic in rice flour using reversed phase-high performance liquid chromatography-inductively coupled plasma mass spectrometry. *J. Chromatogr. A.* 1479: 129–136 (2017).
29. Huang J, Ilgen G, Fecher P, Quantitative chemical extraction for arsenic speciation in rice grains. *J. Anal. Atom. Spectrom.* 25: 800–802 (2010)..
30. Frenich AG, Vidal JLM, Moreno JLF, Romero-González R, Compensation for matrix effects in gas chromatography–tandem mass spectrometry using a single point standard addition. *J. Chromatogr. A.* 1216: 4798–4808 (2009).
31. Farzan SF, Li Z, Korrick SA, Spiegelman D, Enelow R, Nadeau K, Baker E, Karagas, MR, Infant infections and respiratory symptoms in relation to arsenic exposure in a U.S. Cohort. *Environ. Health Perspect.* 124: 840–847 (2016).
32. Gilbert-Diamond D, Emond JA, Baker ER, Korrick SA, Karagas MR. Relation between in Utero arsenic exposure and birth outcomes in a cohort of mothers and their newborns from New Hampshire. *Environ. Health Perspect.* 124: 1299–1307 (2016).
33. Rodríguez-Barranco M, Gil F, Hernández AF, Alguacil J, Lorca A, Mendoza R, Gómez I, Molina-Villalba I, González-Alzaga B, Aguilar-Garduño C, Rohlman DS, Lacasaña M, Postnatal arsenic exposure and attention impairment in school children. *Cortex* 74, 370–382 (2016).
34. Llorente-Mirandes T, Calderón J, Centrich F, Rubio R., López-Sánchez JF, 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 Chem.* 147: 377–385 (2014).
35. Hernández-Martínez R, Navarro-Blasco I. Survey of total mercury and arsenic content in infant cereals marketed in Spain and estimated dietary intake. *Food Control* 30: 423–432 (2013).
36. Jackson BP, Taylor VF, Punshon T, Cottingham KL. Arsenic concentration and speciation in infant formulas and first foods. *Pure and Applied Chemistry*, 84: 215–223 (2012).
37. Rintala E, Ekholm P, Koivisto P, Peltonen K, Venalainen E. The intake of inorganic arsenic from long grain rice and rice-based baby food in Finland—Low safety margin warrants follow up. *Food Chem.* 150: 199–205 (2014).
38. USFDA (U.S. Food and Drug Administration). (2013). Arsenic in rice: Full analytical results from rice/rice products. Available: <http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm319916.htm>. Online 23 July 2014.