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Elements in rice on the Swedish market: 1. Cadmium, lead and arsenic (total and inorganic)

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Abstract

A survey of the levels of cadmium, lead and arsenic in different types of rice available on the Swedish retail market was carried out in 2001 – 2003. The types of rice included long and short grain, brown, white and parboiled white rice. The mean levels found were; total As: 0.20 mg kg⁻¹, inorganic As: 0.11 mg kg⁻¹, Cd: 0.024 mg kg⁻¹ and Pb: 0.004 mg kg⁻¹, ICP-MS was used for the determination of As (total and inorganic), after acid digestion. Lead and cadmium were determined using GFAAS, after dry ashing. In countries where rice is a staple food it may represent a significant contribution in relation to the Provisional Tolerable Weekly Intake for Cd and inorganic As.

Introduction

Rice (*Oryza sativa*) is one of the most important food commodities on the international market, with a world wide production of nearly 600 million tonnes in 2003, of which approximately 90 % was produced in Asia, with China producing 166 million tonnes and India 134 million tonnes. Although the USA is not among the major producers, it is nevertheless one of the biggest exporters, ranking third, with an export of 2.6 million tonnes, after Thailand (7.6 million tonnes) and Viet Nam (3.7 million tonnes) [FAO 2004].

For some regions in the world rice is a dominating staple food. According to the GEMS/Food Regional Diets [WHO, 2003] the average per capita daily consumption of raw polished rice varies between 9 grams per day in Europe to 278 grams per day in the Far East [WHO, 2003]. Thus in some regions of the world rice is indeed an important staple food item.

To emphasise the importance of rice the UN General Assembly declared the year 2004 the International Year of Rice, under the slogan “Rice is life” [FAO 2004]. The content of environmental contaminants, e.g. metals, in rice is therefore of global interest. Of toxicological importance are mainly cadmium (Cd), lead (Pb) and arsenic (As). The FAO/WHO Joint Expert Committee (JECFA) established a provisional tolerable weekly intake (PTWI) for Cd of 0.007 mg kg⁻¹ bodyweight, based on the effects Cd may exert on

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3 kidney function [WHO, 2004]. For Pb, JECFA established a PTWI of 0.025 mg kg^{-1}
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5 bodyweight, corresponding to 0.20-0.25 mg/day for adults [WHO, 2000]. This is based on
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7 the neurodevelopmental effects of Pb, and covers all sources of exposure, *i.e.* not only dietary
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9 exposure. Inorganic arsenic (In-As) is carcinogenic in humans and a PTWI of 0.015 mg kg^{-1}
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11 bodyweight was established by JECFA in 1988 [WHO, 1988].
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14 As the consumption of rice has increased markedly in Sweden it was decided to carry out a
15
16 survey of the content of cadmium (Cd), lead (Pb) and arsenic (As) on a number of different
17
18 rice brands available on the Swedish market.
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21 In addition to the total concentration of an element in foods, the chemical form in which it is
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23 present is important when assessing the potential threat to human health. This is particularly
24
25 important for As where, in its inorganic forms ($\text{As}^{(\text{III})}$ and $\text{As}^{(\text{V})}$), it is genotoxic and
26
27 carcinogenic, whereas in its organo-forms, *e.g.*, arsenobetaine, it is considered to be of no
28
29 health concern [IARC, 2004].
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32 Rice is imported to the Swedish market from different parts of the world, *e.g.* Thailand and
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34 USA. Occurrence data could be used to calculate the Swedish dietary intake, and furthermore,
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36 by using the WHO/GEMS Regional Food Diets [WHO, 2003] to estimate the intake of Cd, Pb
37
38 and As from rice in other regions of the world.
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41 The rice variety as well as the treatment of the rice may affect its elemental content. Brown
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43 rice, with the bran layer intact, is considered more nutritious than white rice, in which the
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45 bran layer is removed in a milling process. Much of the white rice on the market is parboiled
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47 (*i.e.* soaked in water, steamed under pressure and dried) prior to the milling. One claimed
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49 effect of the parboiling is that it modifies the starch and permits the retention of much of the
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51 natural vitamins and minerals in the kernels. In this way the nutritional value of the polished
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53 white rice is maintained when compared to the brown rice.
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Sampling and analysis

Forty-nine samples of imported rice were collected from retail stores in Uppsala, Sweden in 2001. The details of the samples are shown in Table 1. The area of production was often only vaguely described, *e.g.* just stated as being of US, Thai, Italian, Himalayan or Australian origin. In some cases no indication was given regarding the area of production. The types of rice sampled comprised long grain (*Indica*) and short grain (*Japonica*). To reduce cost As was analysed in 40 of the 49 samples.

The different samples of rice are primarily grouped according to the EU customs tariff system (Taric), *i.e.* after grain type and treatment, as shown in Table 1. The labelling on the packages was often incomplete regarding the treatment of the rice, but it was nevertheless possible to deduce some information from the packages. It should be noted that wild rice mix only contains about 15 % wild rice.

Total and inorganic As, were measured at the Central Science Laboratory (CSL), York, UK. Lead and cadmium were measured at the National Food Administration (NFA), Uppsala, Sweden.

The rice samples were analysed as received, *i.e.* air dry (fresh weight).

Sample preparation

Preparation of samples for the analysis of Cd and Pb

An aliquot of sample (10 g) was weighed into Pt-crucibles and ashed overnight at a maximum temperature of 450°C, following a temperature increase of approximately 50°C/hour. [Jorhem 1993, Jorhem 2000]. After wetting the sample ash with water and drying, the ashing cycle was repeated until the ash was free from visible carbon particles. The ash was then dissolved in 30 ml of 0.1 M HNO₃. Every 10th sample was analysed in duplicate, and the rest as single determinations. One Certified Reference Material (CRM) and two procedural blanks accompanied each set of samples and were taken through the complete ashing procedure.

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3 *Preparation of samples for the analysis of total As*
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5 An aliquot of sample (0.5 g) was quantitatively digested in concentrated HNO₃ (5 ml) using a
6 microwave-assisted digestion system (Multiwave, Perkin-Elmer Ltd, Beaconsfield, Bucks,
7 UK). Approximately every 10th sample was analysed in duplicate, and the rest as single
8 determinations. The power settings and timings were as *per* the manufacturer's preset
9 program. The digest solution was quantitatively transferred to a graduated test tube and made
10 up to volume with water (10 ml). An aliquot (1 ml) of the resulting solution was
11 quantitatively transferred to a test-tube, and an aqueous solution containing Rhenium, as
12 internal standard, was added (4 ml).
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21 *Preparation of samples for inorganic As analysis*
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23 An aliquot of sample (0.25 g) was quantitatively transferred to a PTFE centrifuge tube. Since
24 the samples were dry solids, one ml of water was added and the tube shaken so as to ensure
25 that the sample was thoroughly wetted. An aliquot (10 ml) of concentrated HCl (nominally 37
26 vol%) was added, and allowed to stand overnight. Hydrobromic acid (1 ml, 47 vol%) and
27 aqueous hydrazine sulphate (0.5 ml, 15 wt %) were added to the resulting solution and shaken
28 for 30 seconds). An aliquot of chloroform (4.8 ml) was added to the centrifuge tube and
29 shaken for 3 minutes. The mixture was centrifuged (15 minutes, 14,000 rpm) and the
30 chloroform removed (lower layer). This extraction procedure was repeated a further 2 times,
31 with the chloroform layers being collected and combined in a second centrifuge tube.
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41 An aliquot of 1.0 M hydrochloric acid (4.8 ml) was added to the combined chloroform
42 solution, and shaken (3 minutes). The mixture was centrifuged (15 minutes, 14,000 rpm) and
43 the acid solution removed (upper layer). This extraction procedure was repeated one more
44 time, with the acid layers being combined and collected into a volumetric flask (10 ml) and
45 made up to volume with 1.0 M HCl. An aliquot (5 ml) of this solution was quantitatively
46 transferred to a plastic test-tube and an aliquot of diluent containing gallium, as an internal
47 standard, added.
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Measurement procedures

Measurement of Cd and Pb was performed by graphite furnace atomic absorption spectrometry (GFAAS) using a Perkin Elmer 5100/HGA 600 instrument with Zeeman background correction (Perkin Elmer, Norwalk, Connecticut, USA). The method of standard addition was employed for both metals. The method parameters were previously optimised by establishing ash- and atomisation curves for each metal. Matrix modifiers were not used. The background correction systems was regularly checked for function. The operating conditions are given in Table 2.

Measurement of total As was performed on an inductively coupled plasma-mass spectrometer (ICP-MS) instrument (Elan-6000, Perkin-Elmer Ltd, Beaconsfield, Bucks, UK). The operating conditions are given in Table 3.

The concentration of ‘inorganic’ arsenic in the hydrochloric acid back-extractant solutions was measured using a high resolution ICP-MS instrument (Axiom, Thermo Elemental, Winsford, Cheshire, UK), operating at a resolution setting of 11 000 in order to resolve the arsenic signal from the ArCl^+ interferent produced in the plasma of the ICP. The operating conditions are given in Table 3.

Quality control procedures

Procedural blanks

The mean blank value was deducted from the readings before the result was calculated. The batch blank was used to decide if the results of the batch were acceptable or not, *i.e.* if the blank was unacceptably high the batch was re-analysed [EN 13804].

Limit of detection

The limit of detection (LOD) is defined as three times the standard deviation (σ) of the signal from a large number of procedural blanks (n is usually ≥ 20), corrected for sample weight and

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3 dilution. For Cd and Pb the LOD was 0.0003 and 0.001 mg kg⁻¹, respectively. For total and
4 inorganic As the LOD was 0.03 and 0.005 mg kg⁻¹, respectively.
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8 9 *Certified Reference Materials (CRMs)*

10 The results of the CRMs and Standard RMs (SRMs) analysed throughout this survey are
11 shown in Table 4. There were no CRM's available for inorganic As at the time of analysis,
12 but BCR 627 'Arsenic in Tuna Fish' reference material provides data for total arsenic,
13 arsenobetaine and DMA, allowing a calculation of the 'inorganic' portion, to be made. The
14 CRM DORM-2 had an indicative value of 0.122 mg kg⁻¹, based on a collaborative trial
15 involving CSL and several other laboratories (unpublished results).
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22 23 *Proficiency Testing Scheme participation*

24 The NFA and the CSL participated in several proficiency tests during the period of this study,
25 for which the results are shown in Table 5. The z-score is an independent assessment of a
26 laboratory's competence, and z-scores within ± 2 are considered acceptable, whereas z-scores
27 between ± 2 and 3 are generally considered to be questionable, but not immediately
28 unacceptable.
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34 35 *Measurement uncertainty*

36 Results from samples analysed in official control should be accompanied by their
37 measurement uncertainty (U), according to ISO standard [ISO/IEC 17025, 2005]. The U
38 include all known sources of uncertainty and a coverage factor of two ($= u \times 2$). Lead and Cd
39 are the only elements in this study for which Maximum Limits are established within the EU,
40 and thus targets for official control. The U for Pb and Cd in this study were 0.005 – 0.009
41 mg/kg for the concentration range 0.002 – 0.016 mg/kg, and 0.001 – 0.019 mg/kg for the
42 concentration range 0.001 – 0.088 mg/kg, respectively. The results from the duplicate analysis
43 of every 10th rice sample showed that the repeatability SD was consistently lower than U/2 (=
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56 57 58 59 60 *Intake calculations*

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3 The calculated intakes of Cd, Pb and As were based on the average consumption of dry rice
4 (11 g day⁻¹) by Swedish adults aged 19-54 years, according to the Swedish consumption
5 survey “Riksmaten” that was performed in 1998 [Becker & Pearson, 2002]. However, it is
6 known from the *per capita* statistics [SJV 2006] that the rice consumption in Sweden has
7 increased since then, and therefore the consumption data was adjusted accordingly. The latest
8 data are derived from the year 2004 and the adjustment resulted in a 38 % increase compared
9 to the rice consumption in 1998, and a total average daily consumption of 15 g rice.

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11 In addition, the WHO/FAO GEMS Food Regional Diets [WHO. 2003] were used to estimate
12 the contribution of rice to the intake of Cd, Pb and As. The intake was related to PTWI's
13 established by JECFA [WHO. 1988, WHO. 200, WHO. 2004].
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25 **Results and discussion**

26 All sample results are expressed on an air dry basis (i.e., fresh weight) (CRMs were analysed
27 on dry weight basis). The water content of rice was on average 7.6 % (range 5.7 –11.6; n = 8),
28 which means that calculated on dry matter the results would have been correspondingly
29 higher.
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34 *Analytical quality control*

35 The results presented in tables 4 and 5 of results from the analysis of CRMs as well as
36 participation in PT-programmes indicate that the analytical quality control is satisfactory and
37 that the results, allowing for U, must be considered reliable.
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42 *Cadmium*

43 The grand mean Cd-level of 0.024 ± 0.020 (SD) mg kg⁻¹ (range <0.001 - 0.088 mg kg⁻¹) was
44 much lower than the current European ML of 0.2 mg kg⁻¹ [EC Directive 466/2001]. See Table
45 6. No sample exceeded the ML.
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51 The mean Cd concentration was similar in brown, white and parboiled white rice (0.021,
52 0.020, 0.025 mg kg⁻¹, respectively) but the variation in Cd within each group of rice was
53 considerable, possibly indicating influence of other parameters like *e.g.* variation in Cd
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3 concentrations in soil [Jung and Thornton, 1997] or differences in Cd uptake between
4 genotypes [Cui et al., 2004]. In a previous survey on rice on the Swedish market including
5 both brown and white rice, a mean of 0.029 mg kg⁻¹ was reported [Jorhem et al. 1984].
6 Several studies carried out in recent years have found mean levels of the same magnitude,
7 ranging between <0.006 – 0.050 mg kg⁻¹ (range of individual samples <0.006-0.070)
8 [Phuong et al. 1999, Shimbo et al. 2001, Alam et al 2002, Gorbunov et al. 2003, Lin et al.
9 2004]. These results indicate that the Cd levels in rice, grown on presumably uncontaminated
10 soil, rarely exceed 0.1 mg kg⁻¹. Shindoh and Yasui (2003) concluded that washing and
11 soaking of polished rice reduced the cadmium content by about 7 % indicating that Cd intake
12 is overestimated when using data on Cd concentration in rice as traded.
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23 In Table 8, the contribution of Cd in rice in relation to the PTWI is given using the average,
24 minimum and maximum Cd level found in this survey, and the lowest and highest average
25 consumption of rice according to GEMS/Food Regional Diets [WHO, 2003]. In Sweden rice
26 contributes to 0.6 % (0-2.2 %) of PTWI for Cd. In an average European diet rice contributes
27 to a mean of 0.4 % (range 0.0 – 1.3 %), while in regions with higher consumption of rice like
28 Far East, the corresponding values are on average 11 % (range 0.5 % – 41 %) of the PTWI,
29 depending on the Cd concentration in the rice consumed. Thus it can be concluded that long-
30 time large consumption of rice, and concomitantly high Cd levels in rice will result in a large
31 part of the PTWI being covered by rice alone. On the other hand, in regions where the
32 consumption of rice is low, like in Sweden, it is not likely that rice will contribute to more
33 than a few percentages of the PTWI for Cd.
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43 *Lead*

44 The Pb levels ranged from <0.002 to 0.016 mg kg⁻¹, with a mean level of 0.004 mg kg⁻¹
45 (Table 6). This was markedly lower than the current European ML of 0.2 mg kg⁻¹ [EC
46 Directive 466/2001]. An earlier survey [Jorhem et al. 1984] found a similar range in imported
47 brown and white rice (0.003-0.066 mg kg⁻¹). Comparable results were recently reported by
48 Shimbo et al. (2001) and Lin et al. (2004) with means of 0.002 and 0.01 mg kg⁻¹, respectively.
49 Others have, however, reported much higher levels: Al-Saleh et al. (2001) reported a mean
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3 level of 0.135 mg kg^{-1} . Gorbunov et al. (2003) reported a mean of 1.58 mg kg^{-1} , Bennet et al.
4 (2000) reported a mean for wild rice of 0.96 mg kg^{-1} and Alam et al. (2002) found a mean as
5 high as 7.71 mg kg^{-1} dry wt (range 2.60-15.89). Such high Pb levels are remarkable,
6 considering that the rice samples were not reported as coming from contaminated areas.
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12 However, we conclude that in the present study, rice from several regions of the world
13 contain very low Pb levels. Even calculated as a worst-case scenario, *i.e.* using the maximum
14 Pb concentration in rice and the highest daily consumption according to GEMS Regional
15 Food Diets [WHO, 2003] Pb intake from rice is only 2 % of PTWI (Table 8).
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19 20 21 *Arsenic, total and inorganic*

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23 The mean level of total arsenic (T-As) in long grain brown rice (0.24 mg kg^{-1} ; range 0.09-
24 0.35 mg kg^{-1}) was similar to that of parboiled white rice (0.21 mg kg^{-1} ; range 0.09-0.40 mg
25 kg^{-1}), whereas the white rice contained considerably less (0.10 mg kg^{-1} ; range 0.04-0.16 mg
26 kg^{-1}) as can be seen in Table 7. Whether the lower level in white rice is due to the polishing
27 process, area of production or rice variety is not possible to elucidate. It is noteworthy,
28 however, that most of the parboiled rice (both brown and white) in this study originates from
29 the USA and that the white rice is imported from Southeast Asia. The T-As levels found were
30 similar to those reported previously of 0.286 mg kg^{-1} , 0.074 mg kg^{-1} and $0.05\text{-}0.26 \text{ mg kg}^{-1}$
31 [Park et al. 1994; Dabeka et al. 1993; Schoof et al. 1999].
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40 Rice is, besides fish and seafood, one of the major contributors to dietary As intake [Tao and
41 Bolger 1999]. From a toxicological point of view the amount of inorganic As (In-As) is
42 considered the most important. However, the analytical methods for speciation of As have
43 only recently been developed and therefore there are only limited information on the content
44 of In-As in rice and other foods [Bohari et al. 2002; Lamont et al. 2003; D`Amato et al. 2004;
45 Vela and Heitkemper. 2004; Williams et al. 2005].
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52 The content of In-As averaged 0.11 mg kg^{-1} (range $0.04\text{-}0.19 \text{ mg kg}^{-1}$) and can be seen in
53 Table 7. These results are in good agreement with others [Lamont 2003, D`Amato et al. 2004]
54 who reported mean levels of In-As of 0.112 and 0.132 mg kg^{-1} , respectively.
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5 In Figure 1, in which the rice samples were compiled into groups different from those in table
6 7, the ratio of In-As/T-As is shown for different types of rice. An average of 64 % (range 17-
7 100 %) of the T-As in rice in the present study consisted of In-As. The lowest proportion of
8 organic As was seen in rice from the south East Asia (i.e. basmati and jasmine). Similarly,
9 Williams et al. (2005) found on average 64 % In-As in European rice, 80 % in rice from
10 Bangladesh and 81 % in Indian rice. However, the numbers of rice varieties are in some cases
11 low in our study, and furthermore the results for the T-As in Basmati rice is in some cases
12 below the limit of quantification (10σ for the blank). Therefore no firm conclusions can be
13 made.
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23 The current PTWI for In-As is 0.015 mg kg^{-1} body weight [WHO, 1988]. In Table 8, the
24 dietary intake of In-As from rice is shown for different consumption scenarios. In Sweden,
25 rice contributed to 1.3 % of the PTWI for In-As. In a WHO European diet, rice contributes on
26 average 0.8 % (range 0.3 – 1.3 %) to the current PTWI for In-As, while in the WHO Far East
27 diet, the corresponding values are considerably higher with a mean of 24 % (range 8.9 - 41
28 %). The latter is in line with previous reports [Williams et al., 2005; Meharg and Rahman,
29 2003].
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37 **Conclusions**

38 Cd levels were low in rice on the Swedish market (average 0.024 , range <0.001 - 0.088 mg
39 kg^{-1}), as were indeed the Pb levels (average 0.004 mg kg^{-1}). The level of In-As in rice was on
40 average 0.11 , range 0.04 - 0.19 mg kg^{-1} . Rice can be a large contributor in relation to the PTWI
41 for Cd and In-As, if the consumption of rice is high. On the opposite, Pb intake from rice
42 remains low even if the rice consumption is comparatively high.
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4 Project (SWE 12004).
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References

Alam MGM, Allison G, Stagnitti F, Tanaka A, Westbrook M. 2002. Metal concentrations in rice and pulses of Samta village, Bangladesh, *Bulletin of Environmental Contamination and Toxicology* 69:323-329.

Al-Saleh I, Shinwari N. 2001. Report on the levels of cadmium, lead and mercury in imported rice grain samples, *Biological Trace Element Research* 83: 91-96.

Becker W, Pearson M. 2002. Riksmaten 1997-1998, Kostvanor och näringsintag I Sverige – metod och resultatanalys. Livsmedelsverket, Uppsala, Sweden

Bennet JP, Chiriboga E, Coleman J, Waller DM. 2000. Heavy metals in wild rice from northern Wisconsin. *The Science of the Total Environment* 246: 261-269.

Bohari Y, Lobos G, Pinochet H, Pannier F, Astruc A, Potin-Gautier M. 2002. Speciation of arsenic in plants by HPLC-HG-AFS: extraction optimisation on CRM materials and application to cultivated samples. *Journal of Environmental Monitoring* 4:596-602.

Cui YJ, Zhu YG, Smith FA, Smith SE. 2004. Cadmium uptake by different rice genotypes that produce white or dark grains. *Journal of Environmental Science (China)* 16:962-967.

D'Amato M, Forte G, Caroli S. 2004. Identification and quantification of major species of arsenic in rice. absorption spectrometry after dry ashing: NMKL collaborative study. *Journal of AOAC International* 87:238-243.

Dabeka RW, McKenzie AD, Lacroix GM, Cleroux C, Bowe S, Graham RA, Conacher HB, Verdier P. 1993. Survey of arsenic in total diet food composites and estimation of the dietary intake of arsenic by Canadian adults and children. *Journal of AOAC International* 76:14-25.

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2
3
4
5 EUROPEAN COMMISSION, 2001, COMMISSION REGULATION (EC) NO 466/2001. Setting
6 maximum levels for certain contaminants in foodstuffs. Official Journal of the European
7 Community, L77 (16 March 2001), 1-13.
8
9

10
11
12 EN 13804, EUROPEAN STANDARD,. 2002. Foodstuffs – Determination of trace elements –
13 Performance criteria, general considerations and sample preparation. European Committee for
14 Standardisation, Management Centre: Rue de Strassart, 36 B-1050 Brussels.
15
16
17

18
19 FAO. 2004. International year of rice 2004. Food and Agricultural Organisation, Rome.
20
21

22 Gorbunov AV, Frontasyeva MV, Kistanov AA, Lyapunov SM, Okina OI, Ramadan AB.
23 2003. Heavy and toxic metals in staple foodstuffs and agriproducts from contaminated soils.
24 Journal of Environmental Science and Health B38:181-192.
25
26
27

28
29 IARC, 2004. IARC Monographs on the evaluation of carcinogenic risks to humans. Some
30 drinking-water disinfectants and contaminants, including arsenic. Volume 84. International
31 Agency for Research on Cancer. Lyon, France. pp 39-271.
32
33
34

35
36 ISO/IEC 17025, 1999, General requirements for the competence of testing and calibration
37 laboratories. International Organisation for Standardisation. Geneva, Switzerland.
38
39
40

41 Jorhem L, Mattson P, Slorach, S. 1984. Lead, cadmium and certain other metals in food on
42 the Swedish Market. Vår Föda, Supplement 3.
43
44
45

46
47 Jorhem L. 1993. Determination of metals in foodstuffs by atomic absorption
48 spectrophotometry after dry ashing: NMKL interlaboratory study of lead, cadmium, zinc,
49 copper, iron, chromium and nickel. Journal of AOAC International 76:798-813.
50
51
52

53
54 Jorhem L. 2000. Determination of metals in foods by atomic absorption spectrometry after
55 dry ashing: NMKL collaborative study. Journal of AOAC International 83:1204-1211.
56
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1
2
3
4
5 Jung MC and Thornton I. 1997. Environmental contamination and seasonal variation of
6 metals in soils, plants and waters in the paddy fields around a Pb-Zn mine in Korea. *Science*
7 *of the Total Environment* 198:105-121.
8
9

10
11
12 Lamont WH. 2003. Concentration of inorganic arsenic in samples of white rice from the
13 United States. *Journal of Food Composition and Analysis* 16:687-95.
14
15

16
17
18 Lin HT, Wong SS, Li GC. 2004. Heavy metal content of rice and shellfish in Taiwan. *Journal*
19 *of Food and Drug Analysis* 12:167-174.
20
21

22
23 Meharg AA, Rahman M. 2003. Arsenic contamination of Bangladesh paddy field soils:
24 implications for rice contribution to arsenic consumption. *Environmental Science and*
25 *Technology* 37:229-234.
26
27

28
29
30 Park KS, Kim NB, Kim YS, Lee KY, Chun SK, Yoon YY. 1994. A survey of trace elements
31 in fresh-water fish and rice along the Han River by neutron activation analysis.
32 *Biological Trace Element Research* 43-45:229-237.
33
34

35
36
37 Phuong TD, Chuong PV, Khiem DT, Kokot S. 1999. Elemental content of Vietnamese rice
38 Part 1. Sampling, analysis and comparison with previous studies. *Analyst* 124:553-560.
39
40

41
42
43 Schoof RA, Yost L J, Eickhoff J, Crecelius EA, Cragin DW, Meacher DM, Menzel DB.
44 1999. A market basket survey of inorganic arsenic in food. *Food and Chemical Toxicology*
45 37:839-846.
46
47

48
49
50 Shimbo S, Zhang ZW, Watanabe T, Nakatasuka H, Matsuda-Inoguchi N, Higashikawa K,
51 Ikeda M. 2001. Cadmium and lead contents in rice and other cereal products in Japan in 1998-
52 2000. *The Science of the Total Environment* 281:165-175.
53
54
55
56
57
58
59
60

1
2
3 Shindoh K, Yasui A. 2003. Changes in cadmium concentration in rice during cooking, Food
4 Science and Technological Research 9:193-196.
5
6

7
8 SJV. 2006. Statistik från Jordbruksverket, Statistikrapport 2006:2. Jordbruksverket,
9 Jönköping, Sweden.
10
11

12
13 Tao SS, Bolger PM. 1999. Dietary arsenic intakes in the United States: FDA Total Diet
14 Study, September 1991-December 1996. Food Additives and Contaminants. 16:465-472.
15
16

17
18 Vela NP, Heitkemper DT. 2004. Total arsenic determination and speciation in infant food
19 products by ion chromatography-inductively coupled plasma-mass spectrometry.
20 Journal of AOAC International 87:244-252.
21
22

23
24
25 WHO. 1988. Arsenic. Joint Expert WHO/FAO Expert Committee on Food Additives and
26 Contaminants. Food Additives Series 24. World Health Organization, Geneva.
27
28

29
30 WHO. 2000. Lead. In: Safety evaluation of certain food additives and contaminants. Fifty-
31 third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO
32 Food Additives Series: 44. World Health Organization, Geneva.
33
34

35
36
37 WHO. 2003. Global Environment Monitoring System - Food Contamination Monitoring and
38 Assessment Programme (GEMS/Food) Regional Diets. World Health Organization, Geneva.
39 Available at: http://www.who.int/foodsafety/chem/gems_regional_diet.pdf.
40
41
42

43
44 WHO. 2004. Cadmium. In: Safety evaluation of certain food additives and contaminants.
45 Sixty-first meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA).
46 WHO Food Additives Series: 52. World Health Organization, Geneva.
47
48
49

50
51
52 Williams PN, Price AH, Raab A, Hossain SA, Feldmann J, Meharg AA. 2005. Variation in
53 arsenic speciation and concentration in paddy rice related to dietary exposure. Environmental
54 Science & Technology 39:5531-5540.
55
56
57
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Table 1. Types of rice found on the Swedish market and included in this survey.

Grain	Type	Other information	Imported from	
Long grain (<i>Indica</i>)	Brown		Not known	
	Parboiled brown		Not known	
			USA	
	White (polished)	Asian		Thailand
		Basmati		India/Pakistan
		Jasmin		Thailand
		Ecological Jasmin		Thailand
	Parboiled white (Polished after parboiling)	Instant		Not known
				Not known
				USA
Ecological			Italy	
			USA/Italy	
Short grain (<i>Japonica</i>)	Brown	Ecological brown	Australia/Italy	
	White (polished)	Instant flakes		Not known
				Not known
				USA
		Ecological		Italy
Parboiled white	Parboiled Avorio		Not known	

Table 2. Graphite Furnace AAS operating conditions.

Element	Wavelength	Slit	Ash temp. °C/time s.	Atomize temp. °C/ time s.	Sample volume	Diluent volume
Cd	228.8 nm	0.7 Low	300	1500	5 µl	5 µl
Pb	283.3 nm	0.7 Low	500	1700	10 µl	10 µl

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Table 3. ICP-MS operating conditions.

Parameter	ELAN6000 (quadrupole)	Axiom (high resolution)
ICP Power (W)	1100 ¹	1250
Nebuliser gas flow rate (L/min)	0.70 ¹	0.75
Lens setting	AutoLens	---
Nebuliser type	Glass concentric	Glass concentric
Interface cones	Nickel	Nickel
<i>MS Acquisition setting</i>		
Resolution setting	---	10,000
Dwell time (msec)	70	20
Number of sweeps/reading	1	20
Number of readings/replicate	55	---
Number of replicates	1	---
Scan mode	Peak hopping	Normal
Detector	Dual	Multiplier
Isotopes monitored	⁷⁵ As, ¹⁰³ Rh	⁷² Ga, ⁷⁵ As

¹Optimised to meet criteria relating to the levels of oxide (< 3%) and double charged species (< 2%) present in the plasma.

Table 4. Results from certified reference materials, analysed in parallel to the samples. All results in mg kg⁻¹ dry wt. Values in bracket are indicative only.

	Element	n	Found mean	Certified value
NIST SRM	Cd	2	0.019	0.022
Rice flour 1568a	Pb	2	<0.014	(<0.010)
	As	1	0.39	0.29
NRCC DORM-2	As	1	20.8	18
Dogfish muscle	As inorg.	1	0.13	(0.122)
BCR 627 Tuna fish muscle	As inorg.	1	0.081	(0.081)

Table 5. Results from proficiency tests for certain metals. All results in mg kg⁻¹ dry wt

PT-provider	Round, date	Test sample	Metal	Found result	Assigned value	z-score
FAPAS ¹	7-31, 2001-06	Sunflower seed	Cd	0.612	0.711	-0.8
FAPAS	7-31, 2001-06	Sunflower seed	Pb	0.105	0.124	-0.7
NFA ²	T-6, 2001-11	Potato powder	Cd	0.126	0.140	-0.5
NFA	T-6, 2001-11	Potato powder	Pb	0.003	0.025	-1.1
Euromet 565 ³	2002-02	Rice	Cd	1.68	1.618	2,2
FAPAS	07-43, 2003-06	Milk powder	Cd	0.045	0.0442	0.1
FAPAS	07-43, 2003-06	Milk powder	Pb	0.198	0.188	0.3
FAPAS	7-46, 2003-10	Canned Fish	As	0.88	0.74	1.1
FAPAS	7-48, 2004-04	Canned crab meat	As	9.9	9.83	0.1

¹FAPAS Secretariat, Central Science Laboratory, York, UK

² National Food Administration, Uppsala, Sweden

³ Institute for Reference Materials and Measurement, JRC, Geel, Belgium. Result converted from nmol/g.

Table 6. Concentration of Cd and Pb in different types of rice on the Swedish market (mg kg⁻¹ fresh weight).

Type	Other information	Imported from	n	Cd			Pb			
				Mean	Min	Max	Mean	Min	Max	
Long grain (<i>Indica</i>)										
Brown		Not known	2	0.028	0.027	0.030	0.004	0.003	0.004	
Parboiled brown		Not known	2	0.021	0.006	0.035	0.004	0.004	0.004	
		USA	3	0.017	< 0.001	0.027	0.006	0.005	0.007	
Brown mean				7	0.021	< 0.001	0.035	0.005	0.003	0.007
White	Asian	Thailand	1	0.025			< 0.002			
	Basmati	India/Pakistan	5	0.023	0.003	0.036	0.003	<0.002	0.005	
	Jasmin	Thailand	7	0.018	0.007	0.037	0.004	<0.002	0.010	
	Ecological Jasmin	Thailand	1	0.010			< 0.002			
White mean				14	0.020	0.003	0.037	0.003	<0.002	0.010
Parboiled white	Instant	Not known	2	0.002	0.002	0.002	0.004	0.003	0.004	
		Not known	2	0.024	0.020	0.027	0.003	0.002	0.003	
		USA	10	0.020	0.004	0.032	0.006	0.003	0.016	
	Ecological	Italy	2	0.061	0.058	0.064	0.006	0.005	0.006	
USA/Italy		1	0.047			0.003				
Parboiled white mean				17	0.025	0.002	0.064	0.005	0.002	0.016
Parboiled white	Wild rice mix	Not known	2	0.005	0.005	0.006	0.005	0.005	0.006	
		USA	1	0.032			0.006			
Wild rice mix mean				3	0.014	0.005	0.032	0.006	0.005	0.006
Short grain (<i>Japonica</i>)										
Brown	Ecological	Australia/Italy	1	<0.001			0.003			
White	Instant flakes	Not known	2	0.057	0.027	0.088	0.004	0.003	0.006	
		Not known	2	0.051	0.047	0.054	< 0.002	0.001	0.001	
		USA	1	0.001			< 0.002			
	Ecological	Italy	1	0.047	0.047	0.047	< 0.002			
White mean				6	0.044	0.001	0.088	0.002	<0.002	0.006
Parboiled white	Avorio	Not known	1	0.029			0.003			
Grand mean				49	0.024	< 0.001	0.088	0.004	<0.002	0.016

Table 7. Concentration of total and inorganic As, in different types of rice on the Swedish market in mg kg⁻¹ fresh weight.

Type	Other information	Source	n	Total As			Inorganic As			
				Mean	Min	Max	Mean	Min	Max	
Long grain (<i>Indica</i>)										
Brown		Not known	2	0.23	0.19	0.27	0.13	0.11	0.16	
Parboiled brown		Not known	2	0.33	0.31	0.35	0.18	0.17	0.19	
		USA	3	0.20	0.09	0.28	0.11	0.08	0.13	
Brown mean				7	0.24	0.09	0.35	0.14	0.08	0.19
White	Basmati	India/Pakistan	4	0.06	0.04	0.06	0.04	0.04	0.04	
	Jasmin	Thailand	5	0.13	0.09	0.15	0.09	0.07	0.11	
	Ecological Jasmin	Thailand	1	0.16			0.11			
White mean				10	0.10	0.04	0.16	0.07	0.04	0.11
Parboiled white	Instant	Not known	2	0.13	0.13	0.13	0.10	0.10	0.10	
		Not known	1	0.26			0.15			
		USA	6	0.28	0.09	0.40	0.14	0.07	0.17	
	Ecological	Italy	2	0.11	0.10	0.11	0.10	0.10	0.11	
		USA/Italy	1	0.15			0.10			
Parboiled white mean				12	0.21	0.09	0.40	0.13	0.07	0.17
Parboiled white	Wild rice mix	Not known	2	0.26	0.24	0.27	0.14	0.14	0.14	
		USA	1	0.35			0.18			
Wild rice mix mean				3	0.29	0.24	0.35	0.15	0.14	0.18
Short grain (<i>Japonica</i>)										
Brown	Ecological brown	Australia/Italy	1	0.63			0.17			
White	Instant flakes	Not known	2	0.16	0.15	0.16	0.11	0.11	0.11	
		Not known	2	0.16	0.12	0.20	0.09	0.08	0.09	
		USA	1	0.20			0.07			
	Ecological	Italy	1	0.18			0.14			
White mean				6	0.17	0.12	0.20	0.10	0.07	0.14
Parboiled white	Avorio	Not known	1	0.15			0.12	0.12	0.12	
Rice, grand mean				40	0.20	0.04	0.63	0.11	0.04	0.19

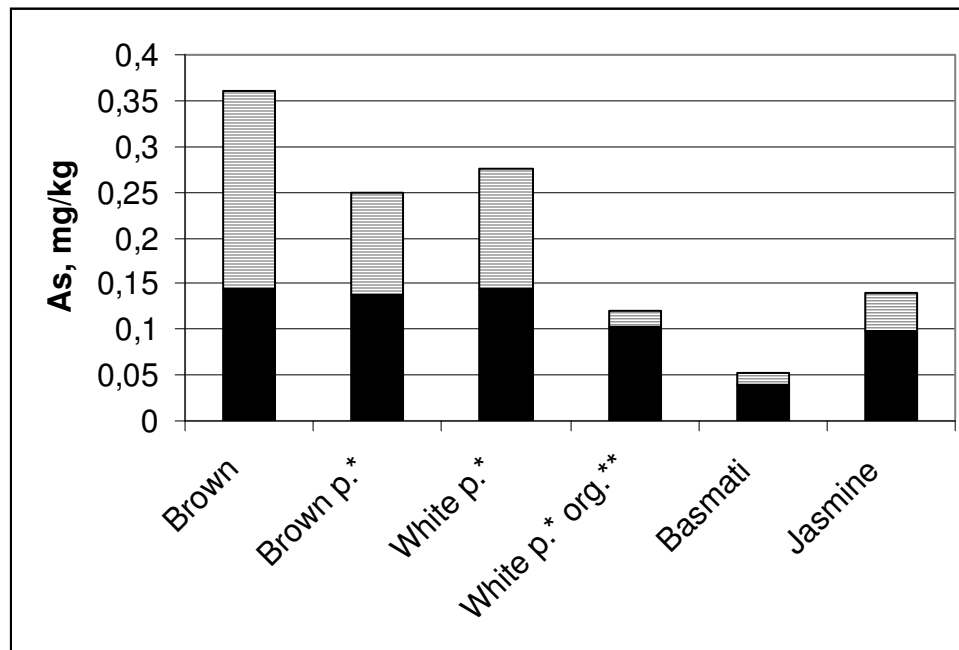
Table 8. The contribution of consumption of rice in relation to WHO/FAO Provisional Tolerable Weekly Intake (PTWI) (WHO, 1988; 2000; 2004) Cd, Pb and Inorganic As. The calculations are made using the average and min-max values reported in Tables 6 and 7.

	% PTWI mean (range)		
	Consumption of rice, grams/day ¹		
	15 ¹ (Sweden)	9 ² (Europe)	278 ² (Far East)
Cadmium	0.6 (0.0-2.2)	0.4 (0.0 – 1.3)	11 (0.5 - 41)
Lead	0.0 (0.0 – 0.1)	0.0 (0.0 – 0.1)	0.5 (0.3 - 2.1)
Inorganic arsenic	1.3 (0.5-2.2)	0.8 (0.3 – 1.3)	24 (8.9 – 41)

¹ estimated average daily consumption in Sweden based on consumption survey [Becker & Pearson, 2002] and updated per capita statistics

² average consumption of raw rice according to GEMS/Food Regional Diets [WHO, 2003].

Figure 1.



*parboiled rice

** Ecological production

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3 Figure 1. Total and inorganic arsenic (mg kg^{-1}) in rice purchased on the Swedish market in 1999-2001. The height of the bars
4 applies to the concentration of total As, the black bars show the concentration of inorganic As in brown (n = 3), brown
5 parboiled (n = 5), white parboiled (n = 7), white parboiled organic (n = 3), basmati (n = 4) and jasmine rice (n = 7). Brown
6 and white parboiled rice were imported mainly from the USA, basmati from India/Pakistan and jasmine rice from
7 Thailand.
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