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**Elements in rice on the Swedish market: 2. chromium, copper, iron, manganese, platinum, rubidium, selenium and zinc**

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11 **Elements in rice on the Swedish market: Part 2. Chromium,**  
12 **copper, iron, manganese, platinum, rubidium, selenium and zinc**  
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**Abstract**

A survey of the levels of some essential and non-essential trace elements 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; Cr: 0.008 mg kg<sup>-1</sup>, Cu: 1.9 mg kg<sup>-1</sup>, Fe: 4.7 mg kg<sup>-1</sup>, Mn: 16 mg kg<sup>-1</sup>, Pt: < 0.0003 mg kg<sup>-1</sup>, Rb: 3.3 mg kg<sup>-1</sup>, Se: 0.1 mg kg<sup>-1</sup> and Zn: 15 mg kg<sup>-1</sup>. ICP-MS was used for the determination of Pt, Rb and Se, after acid digestion. All other elements were determined using atomic absorption spectrometry (AAS) after dry ashing. Intake calculations were performed and it was concluded that rice may contribute considerably to the daily requirements of the essential elements Cu, Fe, Mn, Se and Zn if the rice consumption is high. The levels of some elements, e.g. Fe and Mn, were significantly higher in brown compared to white rice.

## 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. 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 trace elements and heavy metals in rice is therefore of global interest, from a nutritional point of view.

As the consumption of rice has increased markedly in Sweden it was decided to carry out a survey of the content of a number of different rice brands available on the Swedish market in 2001. The main purpose of the survey was to determine cadmium and lead, together with the results for arsenic (total and inorganic), for which the results are presented in a separate paper [Jorhem et al. 2007]. In addition there was an interest in determining the content of the essential elements copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), zinc (Zn) and selenium (Se) in the different brands of rice. Furthermore the concentration of platinum (Pt) is of interest from environmental concerns, and rubidium (Rb) as it is intriguing that the concentration is so high of an element that has no known role in human nutrition.

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5 Sweden is dependent on import of rice since the climate not allows domestic production. Rice  
6 is imported to the Swedish market from different parts of the world, *e.g.* Far East, USA and  
7 Europe. The occurrence data can be used to calculate the Swedish dietary intake of essential  
8 elements from rice, but also by using the WHO/GEMS Regional Food Diets [WHO, 2003]  
9 estimate the intake of essential elements from rice in other regions of the world.  
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16 The rice variety as well as the treatment of the rice may affect its elemental content. Brown  
17 rice, with the bran layer intact, is considered more nutritious than white rice, in which the  
18 bran layer is removed in a milling process. Much of the white rice on the market is parboiled  
19 (*i.e.* soaked in water, steamed under pressure and dried) prior to the milling. One claimed  
20 effect of the parboiling is that it modifies the starch and permits the retention of much of the  
21 natural vitamins and minerals in the kernels. In this way the nutritional value of the polished  
22 white rice is maintained when compared to the brown rice.  
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### 30 **Sampling and analysis**

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32 Forty-nine samples of imported rice were collected from retail stores in Uppsala, Sweden in  
33 2001. These samples represent the major brands on the Swedish market. The details of the  
34 samples are shown in Table 1. The area of production was often only vaguely described, *e.g.*  
35 just stated as being of USA, Thai, Italian, Himalayan or Australian origin. In some cases no  
36 indication was given regarding the area of production. The types of rice sampled comprised  
37 long grain (*Indica*) and short grain (*Japonica*).  
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44 The different samples of rice are primarily grouped according to the EU customs tariff system  
45 (Taric), *i.e.* after grain type and treatment, as shown in Table 1. The labelling on the packages  
46 was often incomplete regarding the treatment of the rice, but it was nevertheless possible to  
47 deduce some information from the packages. It should be noted that wild rice mix only  
48 contains about 15 % wild rice.  
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### 54 **Sample preparation**

#### 55 *Preparation of samples for the analysis of Cr, Cu, Fe, Mn and Zn*

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57 An aliquot of sample (10 g) was dry ashed at 450°C and quantitatively diluted to 30 ml. For  
58 details see: Preparation of samples for the analysis of Cd and Pb, in Jorhem et al. (2007).  
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### *Preparation of samples for the analysis of Pt, Rb and Se*

An aliquot of sample (0.5 g) was quantitatively digested in concentrated HNO<sub>3</sub> (5 ml) using a microwave-assisted digestion system. For details see: Preparation of samples for the analysis of total As, in Jorhem et al. (2007).

### ***Measurement procedures***

Measurement of Cr 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 all metals. The method parameters were optimised previously by establishing ash- and atomisation curves for each metal. Matrix modifiers were not used. The background correction system was regularly checked for function. The operating conditions are given in Table 2.

Measurement of Cu, Fe, Mn and Zn was performed by flame AAS on a Varian SpectrAA-300 instrument (Varian, Melbourne, Australia), using an oxidising air-acetylene flame at the wavelength of 213.9, 324.8, 248.3 and 279.5 nm, respectively. Background correction was not used.

Measurement of Pt, Rb and Se 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.

### **Analytical 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 gave a significant contribution to the result the batch was re-analysed (EN 13804).

#### *Limit of detection*

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

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3 dilution. The LOD's were as follows: Cr 0.001, Cu 0.015, Fe 0.03, Mn 0.003, Pt 0.0003, Rb  
4 0.005, Se 0.1, and Zn 0.009 mg kg<sup>-1</sup>.  
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#### 8 *Certified Reference Materials (CRMs)*

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10 The results of the CRMs and Standard RMs (SRMs) analysed throughout this survey are  
11 shown in Table 4.  
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#### 14 *Proficiency Testing Scheme participation*

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16 The NFA and the CSL participated in several proficiency tests during the period of this study,  
17 for which the results are shown in Table 5. The z-score is an independent assessment of a  
18 laboratory's competence, and z-scores within  $\pm 2$  are considered acceptable, whereas z-scores  
19 between  $\pm 2$  and 3 are generally considered to be questionable, but not immediately  
20 unacceptable. For Pt and Rb in food there are no PT-programmes available, therefore the  
21 recovery of spikes was estimated. They were found to be 95.5, 105, and 108%, respectively  
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#### 30 **Intake calculations**

31 The calculated intakes of Cu, Fe, Mn, Se, Zn, Cr, Pt and Rb were based on the average  
32 consumption of rice (11 g day<sup>-1</sup> of air dry rice) by Swedish adults aged 19-54 years, according  
33 to the Swedish consumption survey "Riksmaten" that was performed in 1998 [Becker &  
34 Pearson, 2002]. However, it is known from the updated *per capita* statistics [SJV, 2006] that  
35 the rice consumption in Sweden has increased since then, and therefore the consumption data  
36 was adjusted accordingly. The latest data are derived from the year 2004 and the adjustment  
37 resulted in a 38 % increase compared to the rice consumption in 1998, *i.e.* a total average  
38 daily consumption of 15 g rice.  
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46 In addition, the WHO/FAO GEMS Food Regional Diets [WHO, 2004] for Europe and Far  
47 East, representing the lower and upper consumption volumes, respectively on a global scale,  
48 were used to estimate the contribution of rice to the intake of the studied elements. The intake  
49 of the essential elements Cu, Fe, Mn, Se and Zn were related to provisional tolerable intakes  
50 established by Nordic Nutrition Recommendations [NNR, 2004] or evaluations by other  
51 bodies.  
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## Results and discussion

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

### *Analytical quality control*

There is a lack of CRMs and PT-programmes for the analysis of Pt and Rb, which is somewhat compensated by acceptable spike recoveries. These recoveries, and the results presented in tables 4 and 5 of results from the analysis of CRMs as well as participation in PT-programmes indicate that the analytical quality control is satisfactory and that the results, allowing for U, must be considered reliable.

## Essential elements

### *Copper*

The Cu levels showed little variation, ranging from 0.77-3.9 mg kg<sup>-1</sup>, with a mean of 1.9 mg kg<sup>-1</sup> (Table 7), and no significant difference between brown and white rice. From several recent studies similar levels have been reported, ranging between 2-5 mg kg<sup>-1</sup> [Phuong et al.1999, Alam et al. 2002, Gorbunov et al. 2003, Lin et al. 2004]. A daily copper intake of 0.7 mg for women and 0.9 mg for men is recommended by the Nordic Nutrition Recommendations [NNR, 2004]. In the Swedish diet, rice contributes to 4.1 % (range 1.7 - 8.4 %). Rice in the European and Far East WHO Regional Diets contributes to 2.5 % (range 1.0 – 5.1 %) and 77 % (range 31 – 156 %) of the RDI for women, respectively (Table 9). It can be concluded that rice on average almost covers the copper requirements in the Far East WHO Regional Diets, if assuming that the requirements are similar worldwide.

### *Iron*

The average Fe content in all rice samples was 4.7 mg kg<sup>-1</sup> (range 1.0 - 18 mg kg<sup>-1</sup>). However, the mean Fe level of 10 mg kg<sup>-1</sup> (range 7.4 – 18 mg kg<sup>-1</sup>) in brown rice (Table 7), was markedly higher than the mean level of 2.5 mg kg<sup>-1</sup> (range 1.0 – 5.7 mg kg<sup>-1</sup>) in white rice (produced in Asia), and also higher than the mean level of 4.3 mg kg<sup>-1</sup> (range 2.2 – 8.6 mg kg<sup>-1</sup>) in parboiled white rice (Table 7). This is similar to that by Phuong et al. [1999] who reported mean levels of 6.5 and 12.06 mg kg<sup>-1</sup> in Vietnamese white and brown rice, respectively, and Koivistoinen [1980] reported mean levels of 12 mg kg<sup>-1</sup> and 36 mg kg<sup>-1</sup> in

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3 white and brown rice, respectively. It is however not known if there are any other differences  
4 between the brown and white rice *e.g.* cultivars, place of origin etc., that could explain the  
5 higher Fe levels reported in brown vs white/parboiled rice. In a previous survey, mean levels  
6 of 12 mg kg<sup>-1</sup> for both brown and white rice were reported in rice on the Swedish market  
7 [Jorhem et al. 1984]. Gorbunov et al. (2003) reported a mean level of 137 mg kg<sup>-1</sup> in rice  
8 from the Astrakhan region of Russia.  
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15 A daily iron intake of 9 - 15 mg for women, where the highest is for women in their  
16 reproductive age, and 9 mg for men is recommended by the Nordic Nutrition  
17 Recommendations [NNR, 2004]. Rice consumption in Sweden contributes to an average of  
18 0.6 % (range 0.1-2.3 %) of the Nordic RDI for women. In the European and Far East WHO  
19 Regional diets rice contributes to 0.3 % (0.1 – 1.4 %) and 11 % (2.3 – 42 %) of the RDI for  
20 women, respectively (Table 9). For comparison, using the average Fe concentration found in  
21 brown rice for calculation of the Fe intake, rice could contribute to on average 1.3, 0.8 and 23  
22 % of the RDI for the Swedish diet, and the European and Far East Regional WHO Diets,  
23 respectively. Iron deficiency is considered the most common worldwide micronutrient  
24 deficiency [NNR, 2004], and it can be concluded that in regions relying heavily on rice as  
25 staple food, rice can be an important source of Fe.  
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### 36 37 *Manganese*

38 The overall average content of Mn in rice was 16 mg kg<sup>-1</sup> (range 6.4 - 52 mg kg<sup>-1</sup>). The  
39 mean Mn level of 42 mg kg<sup>-1</sup> (range 22 – 52 mg kg<sup>-1</sup>) (Table 7) in brown rice was on  
40 average four times as high as in white and parboiled white rice, with means of 10 and 11 mg  
41 kg<sup>-1</sup> (range 6.4 - 18). Results from Viet Nam with means of 24 – 41 mg kg<sup>-1</sup> for brown rice  
42 and 9.9 - 13.6 mg kg<sup>-1</sup> for white rice [Phuong et al.1999], together with results from Finland  
43 reporting means of 24 and 9 mg kg<sup>-1</sup> for brown and white rice [Koivistoinen, 1980], appear to  
44 confirm these differences in concentration. The evaluations of the nutritional requirements of  
45 Mn are diverging in their conclusions. The European Scientific Committee for Food  
46 concluded that 1 - 10 mg day<sup>-1</sup> is safe and adequate [SCF, 2003], and the Nordic Nutrition  
47 Recommendations [NNR, 2004] concluded that available data did not allow daily  
48 requirements for manganese to be established. On the other hand, the US National Academy  
49 of Science calculated an adequate intake for adult men and women to 2.3 and 1.8 mg day<sup>-1</sup>,  
50 respectively [USNAS, 2001]. In the Swedish diet rice contributes to on average 2.4 % (range  
51 1.0 - 7.8 %) of the upper safe intake proposed by SCF. Rice contributes to on average 1.4 %  
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(range 0.6 – 4.7 %) of the upper SCF ‘safe and adequate intake’ level in the European WHO Regional Diet (Table 9). Correspondingly, in the Far East WHO Regional Diet rice contributes to as much as 44 % (range 18 - 145 %) (Table 9).

### *Selenium*

The overall mean Se content was 0.1 mg kg<sup>-1</sup>. The mean Se level in brown rice was 0.2 mg kg<sup>-1</sup>, in white rice 0.1 mg kg<sup>-1</sup>, and in parboiled white < 0.1 mg kg<sup>-1</sup> (Table 9). The observed levels are similar to previously reported Se concentrations in rice. Kelly et al. (2002) found a range of 0.00 to 0.40 mg kg<sup>-1</sup> in rice from Asia, Europe and USA. It was not shown, however, whether the results referred to brown or white rice. Kumar and Krishnaswamy (1997) reported a mean of 0.099 mg kg<sup>-1</sup> in 1997 and Koivistoinen a mean of 0.020 mg kg<sup>-1</sup> [Koivistoinen, 1980]. In wild rice Bennet et al. (2000) reported a mean level of 0.21 mg kg<sup>-1</sup>.

A daily Se intake of 0.040 mg for women and 0.050 mg for men is recommended by the Nordic Nutrition Recommendations [NNR, 2004]. Rice in the Swedish diet contributes to a minor part of the Nordic RDI (3.8 - 15 %) and similarly in the European Regional WHO Diet (2.3 – 9 %). On the other hand, rice is a very important Se source in the Far East Regional WHO Diet, contributing to 70 - 280 % of the RDI (Table 9).

### *Zinc*

The overall mean Zn content in rice was 15 mg kg<sup>-1</sup>. In brown rice, the mean Zn level was 20 mg kg<sup>-1</sup> (range 13 - 23 mg kg<sup>-1</sup>) (Table 7), whereas the level in white (mean 17 mg kg<sup>-1</sup>; range 15 – 18 mg kg<sup>-1</sup>) and parboiled white rice (mean 10 mg kg<sup>-1</sup>; range 5 – 15 mg kg<sup>-1</sup>) was somewhat lower. In a previous survey [Jorhem et al. 1984] it was found a mean of 15 mg kg<sup>-1</sup> and 11 mg kg<sup>-1</sup> in brown and white rice, respectively. Several other studies have reported similar mean results ranging from 12.7 – 22.9 mg kg<sup>-1</sup> [Phuong et al. 1999, Alam et al. 2002, Herawati 2000, Gorbunov et al. 2003, Lin et al. 2004]. A daily zinc intake of 7 mg for women and 9 mg for men is recommended by the Nordic Nutrition Recommendations [NNR, 2004]. The Swedish diet contributes to on average 3.2 % (range 1.1 % - 4.9 %), while in the European and Far East WHO Regional Diets, rice contributes to 1.9 % (range 0.7 – 2.9 %) and 59 % (range 21 - 91 %) of the RDI recommended by NNR, respectively.

## Elements with no RDI or PTWI established

### *Chromium*

The Cr levels in rice sold on the Swedish market ranged between <0.003-0.033 mg kg<sup>-1</sup>, average 0.008 mg kg<sup>-1</sup>, with no significant difference between brown and white rice (Table 6). This is considerably lower than what has been reported in other recent studies. Lin et al. (2004) reported a mean Cr concentration of 0.07 mg kg<sup>-1</sup> ± 0.20 (SD) in rice available on the Taiwanese market. Gorbunov et al. (2003) reported a mean Cr level of 0.16 ± 0.03 mg kg<sup>-1</sup> in rice from the Astrakhan region of Russia. In a survey of wild rice Bennet et al. (2000) found a mean Cr concentration of 0.49 mg kg<sup>-1</sup> dry wt in seeds of wild rice. These seeds had, however, been ground in a stainless steel mill, and may therefore be overestimations. The low level presented here are consistent with the range of 0.010-0.050 mg kg<sup>-1</sup> reported from Finland for brown and white rice [Koivistoinen, 1980]).

The essentiality of chromium is debated. The European Scientific Committee on Food concluded in 1993 that data on essentiality and metabolism were so sparse that nutritional requirements could not be established [SCF 1993]. This view was shared by Kumpulainen who found no convincing indications that Cr is essential [Kumpulainen, 1995], which is similar to the conclusions made in a later Nordic evaluation [NNR 2004]. On the other hand, other national bodies, e.g. U.K [EVM, 2003] and USA [USNAS 2001] have established daily requirements for Cr.

The US National Academy of Science [USNAS, 2001] concluded that an adequate intake of Cr is 0.025 mg day<sup>-1</sup> for women and 0.035 mg day<sup>-1</sup> for men. A similar view is presented in the Nordic Nutrition Recommendations [NNR, 2004]. In the European and Far East WHO Regional Diets rice contributes to on average 0.3 and 8.9 % of the US recommendation, ranges 0.1 -1.2 % and 3.3 – 37 %, respectively (Table 9). Correspondingly, rice in the Swedish diet contributes to 0.5 % (range 0.2 - 2.0 %).

### *Platinum*

There has been concern over potentially increased levels of Pt in foodstuffs since the global use of Pt has increased markedly during the latter third of the twentieth century. This is mainly due to the wide use of Pt as catalyst in vehicle exhaust systems, leading to increased

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3 emission of Pt to the environment. Concern over potentially increased human environmental  
4 exposure has therefore been raised [Vaughan and Florence, 1992; Farago et al., 1998]. Still,  
5 there is limited information on exposure levels and potential health effects in the general  
6 population. From occupational settings it is known that hypersensitivity to platinum salts can  
7 develop, but metallic platinum, which is considered the main form of Pt emitted from  
8 catalytic converters, is non-allergenic [IPCS, 1991].  
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16 The Pt concentration was below the LOD of  $0.0003 \text{ mg kg}^{-1}$  in all samples (data are therefore  
17 not shown in a table), indicating low environmental contamination. Our results were one  
18 order of magnitude lower than that reported in cooked rice purchased on the Australian  
19 market ( $3.48 \mu\text{g kg}^{-1}$  fresh weight) [Vaughan and Florence, 1992]. However, it was considered  
20 possible that during the cooking process Pt might have been added via the cooking water or  
21 the vessels used.  
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### 27 28 *Rubidium*

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30 The Rb concentration in long grain brown rice ranged from  $0.64 - 12 \text{ mg kg}^{-1}$  with a mean of  
31  $6.0 \text{ mg kg}^{-1}$  (Table 8), whereas the white and parboiled white long grain rice had somewhat  
32 lower mean levels. Short grain rice had consistently lower levels. Kelly et al. (2002) reported  
33 a range of  $0.17$  to  $8.82 \text{ mg kg}^{-1}$  in rice from Asia, Europe and USA. It was not shown,  
34 however, whether the results referred to brown or white rice. From Finland it was reported  
35 mean levels of  $1.9 \text{ mg kg}^{-1}$  for brown and  $1.3 \text{ mg kg}^{-1}$  for white rice, respectively  
36 [Koivistoinen 1980].  
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44 Rubidium belongs to the alkali metals. In biological systems Rb resembles potassium and is  
45 therefore used as a marker cation and substitute for  $\text{K}^+$  in studies of the cellular sodium  
46 pump (Zhen et al 2005). Still, it is not known if Rb has a biological role in mammal systems,  
47 and it can be concluded that the literature on this topic is very limited. However, Rb  
48 concentration in blood in humans is reported to be in the same order of magnitude as Cu and  
49 Zn [Bárány et al. 2005], indicating that the bioavailability of Rb in food in general is fairly  
50 high. Recently, correlations between Rb and  $\text{K}^+$  in liver autopsies were reported, suggesting  
51 that Rb might play a biological role in humans [Milman et al. 2006]. Further studies are  
52 needed to clarify if Rb has a nutritional role in human nutrition.  
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## Conclusions

Rice may be a large contributor, covering more than 50% of the RDI for some essential elements, especially Cu, Mn, Se and Zn, if the rice consumption is high. For most elements there were no differences between concentrations in brown vs parboiled white rice. However, the levels of Fe and Mn were significantly higher in brown rice compared to white parboiled rice, indicating that the parboiling process may not be effective in maintaining the high nutritional value by all means. It cannot be ruled out, however, that the differences are due to other parameters like *e.g.* rice variety or production area. Iron deficiency is common worldwide, according to WHO more 30 % of the world's population is anaemic, mainly because of iron deficiency [WHO, 2006]. Therefore it is important that it is further elucidated if brown rice would be a better contributor to daily iron intake than other types of rice.

Although in line with rare previous reports, the mean concentration of Rb in rice was remarkably high, considering that Rb has no known function in the human body.

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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 for chromium.

Wavelength	Slit	Ash temp °C	Atomize temp.°C	Sample volume	Diluent volume
357.9 nm	0.7 Low	700	2200	10 µl	10 µl

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Table 3. ICP-MS operating conditions.

Parameter	ELAN6000 (quadrupole)
ICP Power (W)	1100 <sup>1</sup>
Nebuliser gas flow rate (L/min)	0.70 <sup>1</sup>
Lens setting	AutoLens
Nebuliser type	Glass concentric
Interface cones	Nickel
<i>MS Acquisition setting</i>	
Dwell time (msec)	70
Number of sweeps/reading	1
Number of readings/replicate	55
Number of replicates	1
Scan mode	Peak hopping
Detector	Dual
Isotopes monitored	<sup>82</sup> Se, <sup>85</sup> Rb, <sup>103</sup> Rh, <sup>195</sup> Pt,

<sup>1</sup>Optimised 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<sup>-1</sup> dry wt.

	Element	n	Found mean	Certified value
NIST SRM Rice flour 1568a	Cr	2	<0.021	-
	Cu	2	2.3	2.4
	Fe	2	5.4	7.4
	Mn	2	24.4	20
	Zn	2	21.0	19.4
	Se	1	0.3	0.38
	Rb	1	7.01	6.14
	Pt	1	<0.003	-
NRCC DORM-2 Dogfish muscle	Se		1.75	1.4
	Rb		5.78	-
	Pt		<0.0003	-

Table 5. Results from proficiency tests for certain metals. Potato powder in mg kg<sup>-1</sup> dry wt, canned fish in mg kg<sup>-1</sup> fresh wt.

PT-provider	Round, date	Test sample	Metal	Found result	Assigned value	z-score
NFA	T-6, 2001-11	Potato powder	Cu	2.87	2.83	+0.1
NFA	T-6, 2001-11	Potato powder	Mn	3.78	3.88	-0.3
FAPAS <sup>2</sup>	18-32, 2004-09	Canned fish	Se	0.519	0.539	-0.2

<sup>1</sup> National Food Administration, Uppsala, Sweden

<sup>2</sup> FAPAS Secretariat, Central Science Laboratory, York, UK

Table 6. Concentration of Cr in different types of rice on the Swedish market in mg kg<sup>-1</sup> fresh weight.

Results in bold indicate mean values

				Cr		
Type	Other information	Imported from	n	Mean	Min	Max
<b>Long grain (<i>Indica</i>)</b>						
Brown		Not known	2	0.006	0.005	0.007
Parboiled brown		Not known	2	0.024	0.015	0.033
		USA	3	0.006	0.004	0.009
Brown mean			7	<b>0.011</b>	<b>0.004</b>	<b>0.033</b>
White	Asian	Thailand	1	< 0.003		
	Basmati	India/Pakistan	5	0.016	0.007	0.028
	Jasmin	Thailand	7	0.006	0.003	0.010
	Ecological Jasmin	Thailand	1	< 0.003		
White mean			14	<b>0.009</b>	< <b>0.003</b>	<b>0.028</b>
Parboiled white	Instant	Not known	2	0.003	0.003	0.004
		Not known	2	0.012	0.011	0.013
		USA	10	0.009	0.005	0.017
	Ecological	Italy	2	0.004	0.004	0.005
		USA/Italy	1	0.003		
Parboiled white mean			17	<b>0.007</b>	<b>0.003</b>	<b>0.017</b>
Parboiled white	Wild rice mix	Not known	2	0.010	0.009	0.010
		USA	1	0.015		
Wild rice mix mean			3	<b>0.011</b>	<b>0.009</b>	<b>0.015</b>
<b>Short grain (<i>Japonica</i>)</b>						
Brown	Ecological	Australia/Italy	1	0.004		
White	Instant flakes	Not known	2	< 0.003		
		Not known	2	0.005	< 0.003	0.008
		USA	1	< 0.003		
	Ecological	Italy	1	< 0.003		
White mean			6	< <b>0.003</b>		<b>0.008</b>
Parboiled white	Avorio	Not known	1	< 0.003		
<b>Grand mean</b>			<b>49</b>	<b>0.008</b>	< <b>0.003</b>	<b>0.033</b>

Table 7. Concentration of Cu, Fe, Mn and Zn in different types of rice on the Swedish market in mg kg<sup>-1</sup> fresh weight. Results in bold indicate mean values

Type	Other information	Imported from	n	Cu			Fe			Mn			Zn		
				Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
<b>Long grain (Indica)</b>															
Brown		Not known	2	2.1	2.0	2.2	9.0	8.2	9.7	45	39	51	21	19	23
Parboiled brown		Not known	2	2.5	2.2	2.8	14	10	18	42	39	45	21	20	23
		USA	3	2.0	2.0	2.2	8.7	7.4	11	40	22	52	18	13	20
Brown mean			7	<b>2.2</b>	<b>2.0</b>	<b>2.8</b>	<b>10</b>	<b>7.4</b>	<b>18</b>	<b>42</b>	<b>22</b>	<b>52</b>	<b>20</b>	<b>13</b>	<b>23</b>
White	Asian	Thailand	1	0.77			1.9			12			15		
	Basmati	India/Pakistan	5	2.1	1.6	2.5	3.8	2.0	5.7	9.0	8.7	9.5	17	16	17
	Jasmin	Thailand	7	1.2	0.92	1.5	1.8	1.0	3.4	10	9	12	17	15	17
	Ecological Jasmin	Thailand	1	0.99			1.3			11			18		
White mean			14	<b>1.5</b>	<b>0.77</b>	<b>2.5</b>	<b>2.5</b>	<b>1.0</b>	<b>5.7</b>	<b>10</b>	<b>9</b>	<b>12</b>	<b>17</b>	<b>15</b>	<b>18</b>
Parboiled white	Instant	Not known	2	1.6	1.6	1.6	2.9	2.7	3.1	8.0	7.3	8.8	8.8	8.6	9.0
		Not known	2	2.8	2.6	2.9	4.1	4.1	4.2	7.0	6.6	7.3	6.6	6.0	7.2
		USA	10	2.1	1.7	2.4	5.2	3.6	8.6	13	6.4	18	12	5.0	15
	Ecological	Italy	2	1.5	1.4	1.5	2.2	2.2	2.2	7.8	7.6	7.9	9.5	9.4	9.5
		USA/Italy	1	1.7			2.3			12			10		
Parboiled white mean			17	<b>2.0</b>	<b>1.4</b>	<b>2.9</b>	<b>4.3</b>	<b>2.2</b>	<b>8.6</b>	<b>11</b>	<b>6.4</b>	<b>18</b>	<b>10</b>	<b>5.0</b>	<b>15</b>
Parboiled white	Wild rice mix	Not known	2	3.9	3.9	3.9	6.7	6.6	6.8	9.4	8.5	10	18	17	18
		USA	1	2.9			9.2			20			20		
Wild rice mix mean			3	<b>3.6</b>	<b>2.9</b>	<b>3.9</b>	<b>7.5</b>	<b>6.6</b>	<b>9.2</b>	<b>13</b>	<b>8.5</b>	<b>20</b>	<b>18</b>	<b>17</b>	<b>20</b>
<b>Short grain (Japonica)</b>															
Brown	Ecological	Australia/Italy	1	1.6			10			39			19		
White	Instant flakes	Not known	2	1.6	1.3	1.9	1.6	1.6	1.7	8.1	7.3	9.0	16	15	16
		Not known	2	2.0	1.6	2.3	2.6	1.5	3.7	15	10	20	18	17	19
		USA	1	1.9			3.3			16			12		
	Ecological	Italy	1	1.1			1.2			7.3			12		
White mean			6	<b>1.7</b>	<b>1.1</b>	<b>2.3</b>	<b>2.2</b>	<b>1.2</b>	<b>3.7</b>	<b>11</b>	<b>7.3</b>	<b>20</b>	<b>15</b>	<b>12</b>	<b>19</b>
Parboiled white	Avorio	Not known	1	1.7			3.0			7.7			11		
Grand mean			49	<b>1.9</b>	<b>0.77</b>	<b>3.9</b>	<b>4.7</b>	<b>1.0</b>	<b>18</b>	<b>16</b>	<b>6.4</b>	<b>52</b>	<b>15</b>	<b>5.0</b>	<b>23</b>



Table 8. Concentration of Se and Rb in different types of rice on the Swedish market in mg kg<sup>-1</sup> fresh weight. Results in bold indicate mean values

Type	Other information	Source	n	Se			Rb		
				Mean	Min	Max	Mean	Min	Max
<b>Long grain (<i>Indica</i>)</b>									
Brown		Not known	2	0.2	0.1	0.2	4.6	2.6	6.6
Parboiled brown		Not known	2	0.3	0.2	0.4	8.8	5.3	12
		USA	3	0.2	<0.1	0.3	5.0	0.64	7.5
Brown mean			7	<b>0.2</b>	<b>&lt;0.1</b>	<b>0.4</b>	<b>6.0</b>	<b>0.64</b>	<b>12</b>
White	Basmati	India/Pakistan	4	0.2	0.1	0.2	2.2	1.2	4.1
	Jasmin	Thailand	5	< 0.1			4.2	4.0	4.6
	Ecological Jasmin	Thailand	1	0.2			5.5		
White mean			10	<b>0.1</b>	<b>&lt;0.1</b>	<b>0.2</b>	<b>3.6</b>	<b>1.2</b>	<b>5.5</b>
Parboiled white	Instant	Not known	2	< 0.1			0.50	0.47	0.53
		Not known	1	0.2			5.7		
		USA	6	0.2	<0.1	0.3	4.8	0.43	6.9
	Ecological	Italy	2	< 0.1			1.5	1.4	1.6
		USA/Italy	1	< 0.1			1.1		
Parboiled white mean			12	< <b>0.1</b>		<b>0.3</b>	<b>3.3</b>	<b>0.43</b>	<b>6.9</b>
Parboiled white	Wild rice mix	Not known	2	< 0.1			0.69	0.69	0.70
		USA	1	0.3			5.4		
Wild rice mix mean			3	< <b>0.1</b>		<b>0.3</b>	<b>2.3</b>	<b>0.69</b>	<b>5.4</b>
<b>Short grain (<i>Japonica</i>)</b>									
Brown	Ecological brown	Australia/Italy	1	< 0.1			1.2		
White	Instant flakes	Not known	2	< 0.1			0.62	0.57	0.67
		Not known	2	< 0.1			1.1	0.33	1.9
		USA	1	< 0.1			0.77		
	Ecological	Italy	1	< 0.1			0.38		
White mean			6	< <b>0.1</b>			<b>0.76</b>	<b>0.33</b>	<b>1.9</b>
Parboiled white	Avorio	Not known	1	< 0.1			0.85	0.85	0.85
Rice, grand mean			40	<b>0.1</b>	<b>&lt;0.1</b>	<b>0.4</b>	<b>3.3</b>	<b>0.33</b>	<b>12</b>

Table 9. The contribution of consumption of rice in relation to Recommended Dietary Intake [NNR, 2004] except where otherwise indicated. The calculations are made using the average and min-max concentration values reported in Tables 6, 7 and 8.

	% RDI mean (range)		
	Consumption of rice, gram day <sup>1</sup>		
	15 Sweden <sup>1</sup>	9 Europe <sup>2</sup>	278 Far East <sup>2</sup>
Copper	4.1 (1.7 – 8.4)	2.5 (1.0 – 5.1)	77 (31 – 156)
Iron	0.6 (0.1 – 2.3)	0.3 (0.1 – 1.3)	11 (2.3 – 41)
Manganese <sup>4</sup>	2.4 (1.4 – 7.8)	1.4 (0.6 – 4.7)	44 (18 – 145)
Selenium	3.8 (3.8 – 15)	2.3 (2.3 – 9.0)	70 (70 – 278)
Zinc	3.2 (1.1 – 4.9)	1.9 (0.7 – 2.9)	59 (21 – 91)

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

<sup>2</sup> average consumption of raw rice according to GEMS/Food Regional Diets (WHO, 2003).

<sup>3</sup> [FNB, 2001 ]

<sup>4</sup> [SCF, 2003 ]