

How you cook rice influence the arsenic level

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Sammanfattning

Arsenik kan förekomma i två former, organisk och oorganisk form. Den organiska formen anses inte nämnvärt påverka vår hälsa, medan den oorganiska arseniken klassificeras som toxisk. Arsenik förekommer naturligt i olika halter i berggrunden och därför kan arsenikhalten i grödor ibland vara hög. Eftersom oorganiskt arsenik är cancerframkallande så bör vår exponering för detta vara så låg som möjligt.

Eftersom ris konsumeras mycket och ofta innehåller höga halter av oorganiskt arsenik är det viktigt att vi kan reducera halterna så mycket som möjligt. I denna rapport presenterar vi halterna av oorganiskt arsenik och totala mängden arsenik, oorganisk och organisk, i tolv olika risprover, vanliga märken och inköpta i Uppsala. I studien har vi;

a) Kokat riset i överskott av vatten och därefter analyserat arsenikhalterna i det kokta riset. För att efterlikna hur vi vanligtvis kokar ris i våra kök så har riset kokats i lätt saltat kranvatten i en vanlig kastrull med lock på. Efter kokningens slut har överskottet av vatten hållts av,

b) För att kunna jämföra resultatet med ris som oftast kokas med anpassad vattenmängd, där allt kranvatten kokas in, så har även sådana försök utförts.

Medelhalten av oorganiskt arsenik och totala mängden arsenik i okokt ris var 110 µg/kg respektive 133 µg/kg. I riset som kokats på det sätt som ofta rekommenderas på förpackningarna, med andra ord tillsatt så mycket vatten att det helt och hållet kokas in och inget vatten är kvar efter koktidens slut, här var arsenikhalterna ungefär lika höga som i det okokta riset. Medelhalten av oorganiskt arsenik och totala mängden arsenik i riset som kokats med överskott av kranvatten var betydligt lägre än i det okokta riset, här var halterna reducerade med 40–70 procent.

Även några andra metaller analyserades i de olika proverna. Resultaten visar att nickelhalterna minskade signifikant i riset som kokats i överskott av kranvatten medan uranhalten däremot ökade efter kokningen.

Slutsats: Eftersom arsenik är ett cancerframkallande ämne rekommenderas att koka riset i överskott av vatten som efter kokningen hålls av.

Summary

Inorganic Arsenic, iAs, is a well-known carcinogenic compound. It is therefore important to decrease the exposure of iAs as much as possible. In this work the levels of iAs and total arsenic (totAs) are determined in twelve samples of common rice brands, before and after cooking: i) in a recommended volume of water, and ii) in an extra volume of water which is poured off when the rice is ready to eat. The study mimics the way of cooking rice in the house holds; Ordinary pan has been used, salt has been added, and the tap water at hand has been used. The mean levels of iAs and totAs in unboiled rice were 110 µg/kg and 133 µg/kg respectively. The corresponding mean iAs level in the boiled rice, prepared as recommended with cooking to dryness, was about the same as in the unboiled rice. The mean levels, of iAs and totAs in the rice boiled in an excess amount of water was significantly reduced, between 40-70 percent. Furthermore, also other metals were analysed at the same time, e.g. nickel decreased and uranium increased significantly in the rice boiled in excess of water.

Introduction

Inorganic Arsenic, iAs, is a well-known toxic compound with both carcinogenic and genotoxicity properties. It has been classified as a human carcinogen by WHO, *Group 1* (WHO/IARC, 2012) and it is therefore important to decrease the intake as much as possible. Thus, several agencies including WHO have recommended a maximum level of 10 µg/l of total As, totAs, in drinking water. The European Union, EU, has followed this recommendation and implemented the same maximum level of totAs in drinking water. In January 2016, also foodstuffs containing rice are given different maximum levels for iAs, in EU. In the EU the established levels are between 100 and 300 µg/kg, the lowest level concerns rice destined for the production of food for infants or young children, (EU, 2015/1006).

Arsenic is naturally occurring in the bed rock and released from bed rock sometimes results in high levels in well water and soil. There is a great geographical variation in the occurrence of arsenic and some regions in the world show high levels, e.g. in the South East Asia and regions in South America. Because of high levels in ground water and soil, an elevated arsenic level is found in rice growing in such regions. Not only has the location of the rice production an impact on the arsenic level, but also the variety of rice grown (Kollander and Sundström, 2015). In addition, the way the rice is prepared before consumption has been shown to be important for the final level of iAs in rice ready for consumption.

Rice is a staple food and is much consumed globally, especially by certain population groups. Therefore it is of great importance to decrease the iAs level in often-consumed rice products. Because other species of As have been shown to have toxic properties, e.g. different metabolites, also the occurrence of totAs is of interest, see Hirano et al. (2004). There are different ways of reducing the arsenic level in cooked rice; The first option is to use water that contain low levels of As when boiling the rice in order to prevent a further enrichment of the arsenic in the rice. However, this option might be difficult for people living in arsenic-endemic areas. For people living in regions with low levels of As in water, another way is to boil the rice in excess volume of water which after boiling is discarded. This way of reducing the As level in cooked rice has been demonstrated in the literature (Bae et al., 2002, Carey et al., 2015, Meharg and Zhao, 2012, Mihucz et al., 2010, Naito et al., 2015, Raab et al., 2009, Rahman et al., 2006, Sengupta et al., 2006, Torres-Escribano et al., 2008), but in none of them ordinary tap water together with recommended amount of salt have been used. In this study the intention was to, as much as possible, copy a common way of cooking the rice at home. The use of distilled water and the lack of other ions might overestimate a reduction of iAs due to increased diffusion from the rice into the water. In this article we present and discuss the results of the analyses of both iAs and totAs in rice and compare the effect on the arsenic content in consumption-ready rice after: i) boiling the grains in a volume of tap water adjusted to be totally absorbed after the recommended cooking time, a commonly recommended way of cooking rice, and ii) boiling the rice grains in an extra volume of water which is poured off the pan when the rice is ready to eat. Also the effects on the levels of some other metals in the boiled rice are discussed.

Materials and Methods

Sampling and the procedure for boiling rice

Twelve different brands of rice, of the most common in Sweden, were purchased in some major retailers in the city of Uppsala in Sweden. The tap water used for rinsing and cooking were produced in Uppsala municipality by Uppsala Vatten och Avfall AB. The salt added when boiling the rice was a fine grain household salt from AB Hanson och Möhring, Halmstad, Sweden, a commonly used product in Sweden. From each of the rice packages, three samples, each of 100 gram, were analysed upon the level of iAs, and totAs; a) one sample of raw rice was homogenized without any further preparation, b) one sample, about 100 gram, washed in tap water during 10 seconds, and then boiled in the recommended volume of water, around 0.25 litre, plus a recommended amount of salt added, 1/2 or 1 tea spoon, until all water was absorbed into the rice, and c) one sample, about 100 gram, washed and boiled in extra much tap water, here 1 litre. After the boiling the remaining water was discarded, see Figure 1. Directly after the different ways of cooking, the weight of the boiled rice was documented.



Figure 1. One hundred gram raw rice was put in an ordinary pan of stainless steel. The rice was rinsed in cold tap water during ten seconds and boiled during recommended time, usually 20 minutes, in two different ways; a) until dryness, or b) in an excess of water that was discarded after the boiling was finished. To both a) and b) the recommended amount of salt was added before boiling (1/2 or 1 tea spoon).

Homogenization of rice before and after cooking

The unboiled rice was homogenized using a Retsch GM 200 mill, which has a plastic pan and stainless knife. The boiled rice was homogenized with a Braun food processor with a titanium knife. The homogenized samples were saved in acid-washed plastic vessels until analysis.

Instruments and material

The coded samples were analysed of inorganic arsenic in the laboratory of the Swedish National Food Agency by HPLC-ICPMS (high performance liquid chromatography-inductively coupled plasma mass spectrometry), equipped with a strong anion exchange column. Detection at mass to charge ration (m/z) 75 with an Agilent 7700x ICP-MS directly connected to the column. All material used was acid-washed and all reagents are of analysis quality or better. For further information, see Kollander and Sundström (2015).

The analysis of totAs and other elements was performed by ALS Scandinavia AB, Luleå, using high resolution ICP-MS (HR-ICP-MS, ELEMENT XR, Thermo Scientific). All samples were analysed using two different instruments to safeguard the results. To increase sensitivity to arsenic, methane gas was added to the sample flow. The limit of detection for arsenic was 1.7 $\mu\text{g}/\text{kg}$, calculated as 3 times the standard deviation for blank sample ($n=11$). Quality control of the analytical method was performed by analysing CRM NIST 1547 Peach Leaves. For further information, see Engström et al. (2004).

Analytical method for iAs

The method, prEN 16082, used for the analysis of iAs in this work was selected for testing as European standard by the European Committee for Standardisation CEN. The method is accredited in accordance with ISO/IEC 17025 for inorganic arsenic, for rice and rice products, among others within the range 1-25 000 $\mu\text{g}/\text{kg}$. The limit of detection (LOD) is between 1 and 3 $\mu\text{g}/\text{kg}$ depending on how much the sample is diluted before analysis and whether the sample is wet or dry. The expanded uncertainty is ± 26 per cent (coverage factor $k=2$) and is calculated on the basis of the reproducibility in testing of the method in CEN, as well as the laboratory's own results from participating in proficiency tests and analysis of reference material.

Evaluation of data

To facilitate the comparison between unboiled and boiled rice, the results presented for the boiled rice was corrected for the weight of absorbed water during cooking. This was performed by weighing the rice before and after cooking. Generally 100 gram of rice was boiled from each brand. The weight of the rice boiled in an excess amount of water was mostly higher than the weight of the rice boiled to dryness, about 325 gram and about 280 gram respectively.

The one tailed Student t-test has been used in the calculations.

Results

Total and inorganic arsenic

The levels of iAs in the twelve samples of unboiled rice ranged from 35 to 270 (mean 110) $\mu\text{g}/\text{kg}$ and the levels of totAs from 50 to 274 (mean 133) $\mu\text{g}/\text{kg}$. The corresponding mean iAs level in the boiled rice, prepared as recommended with cooking to dryness, was as expected about the same as in the unboiled rice after correction of the increase in weight from absorbed water. The mean levels, of iAs and totAs in the rice boiled in an excess amount of water was, however, significantly reduced, $p < 0.001$. In all rice the reduction was between 40-70 percent for both iAs and totAs. The levels ranged from 9 to 79 (mean 32) μg iAs/kg rice and from 30-119 (mean 34) μg totAs/kg, see Table 1 and Figure 2 a, b. The iAs level in tap water used in this study was below 1 $\mu\text{g}/\text{L}$. The levels in the discarded water varied between 3 and 12 $\mu\text{g}/\text{L}$ with an average of 9 $\mu\text{g}/\text{L}$. From four of the rice samples (A, B, K and L), the iAs level was analysed. The results correspond well to the reduction in the rice with 40 to 70 percent compared to the respective unboiled rice.

Table 1. The content of inorganic arsenic, iAs, and total arsenic, totAs, in twelve different brands of rice (A – L). Hundred gram of rice was boiled in two ways, either boiled to dryness (all water absorbed by the rice) or boiled with an excess of water that was discarded after the cooking.

Id	Sort	Country of origin	Unboiled rice ($\mu\text{g}/\text{kg}$)		Boiled to dryness ($\mu\text{g}/\text{kg}$)*	Boiled in excess of water ($\mu\text{g}/\text{kg}$)*	
			iAs	totAs	iAs	iAs	totAs
A	Jasmine	Thailand	35	50	31	9	30
B	Whole grain	Greece	114	130	103	35	50
C	Whole grain	EU	74	100	70	24	30
D	Jasmine	Thailand	53	88	54	23	47
E	Long-grain, parboiled	Thailand	101	127	99	26	38
F	Whole grain ecologic, red rice	Italy	270	274	-	79	119
G	Jasmine	Thailand	57	118	52	33	72
H	Jasmine	not specified	61	117	55	19	55
I	Long-grain, parboiled	Thailand	98	129	100	25	51
J	Long-grain, parboiled	Greece	136	152	130	37	43
K	Whole grain	Greece	235	181	132	43	63
L	Brown rice	EU	90	127	89	30	53

* The results are corrected for the weight increase of the rice caused by the absorption of water during the boiling, i.e. all results are given for "unboiled dry rice".

iAs in rice, before and after boiling.

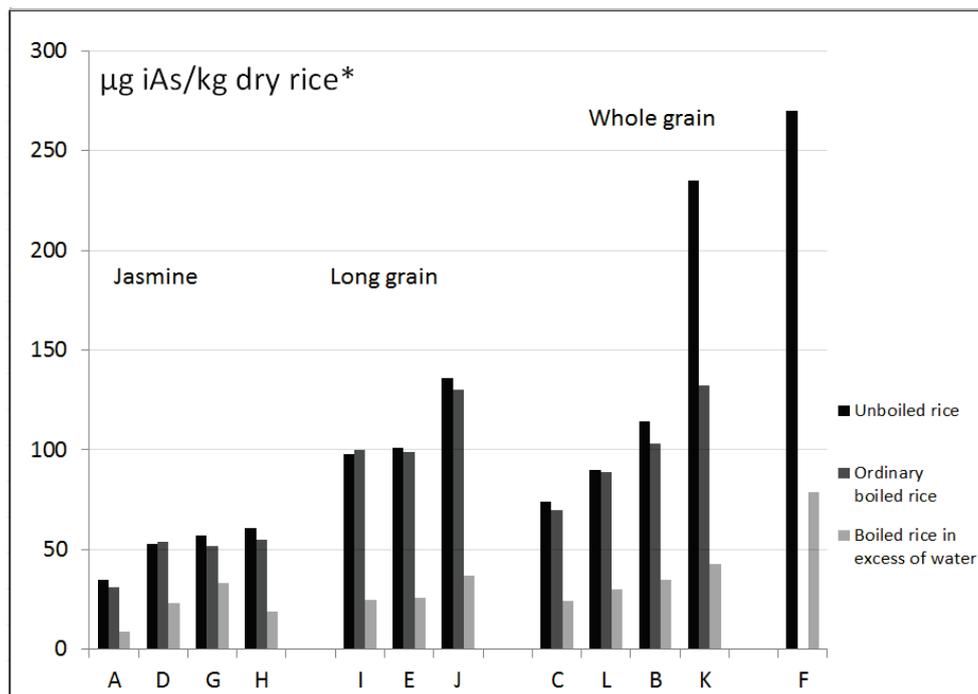


Figure 2 a. The concentrations of inorganic arsenic, iAs, in different brands of rice (A–L); Unboiled, boiled to dryness, and boiled in excess of water that was discarded after cooking.

* The concentrations are adjusted for the increase in weight after boiling, i.e. corrected to give the concentrations in dry unboiled rice. See Table 1 for more information about the different sorts of rice.

totAs in rice, before and after boiling.

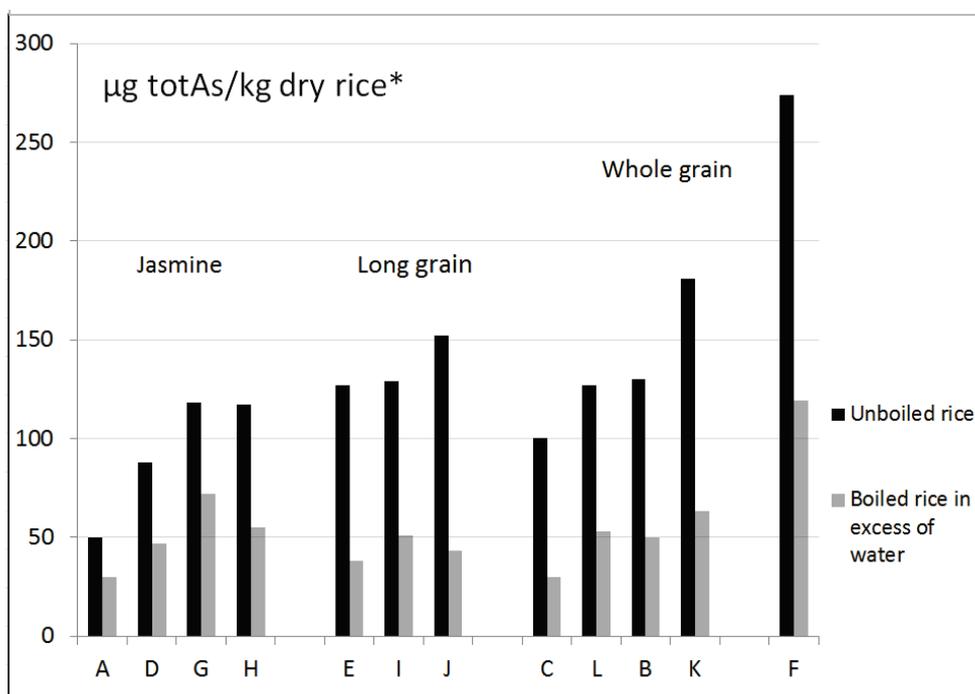


Figure 2b. The content of total arsenic, totAs, in different brands of rice (A – L); Unboiled and boiled in excess of water that was discarded after cooking.

* The arsenic concentrations are adjusted for the increase in weight after boiling, i.e. corrected to give the concentrations in dry unboiled rice.

Other toxic elements

The rice samples were also analysed regarding other toxic elements, e.g. cadmium (Cd), mercury (Hg), nickel (Ni), lead (Pb) and uranium (U). Hg and Ni were only analysed in rice B, H and E. The levels of Hg and Pb were 1 to 4 and 3 to 10 $\mu\text{g}/\text{kg}$ in unboiled rice respectively, while the level of Cd spread over a wider range 2 to 30 $\mu\text{g}/\text{kg}$ in unboiled rice. None of these elements showed any significant difference between the levels in unboiled rice and the two boiling methods. When boiling the rice in an excess of water the levels of Ni decreased significantly ($p < 0.05$). The original level of Ni varied between 250 and 460 $\mu\text{g}/\text{kg}$ in unboiled rice and after the boiling in excess of water the level was reduced 70 percent (Figure 3). On the contrary the levels of U increased in the rice after boiling. The tap water used in the study has a documented high level of U, about 30-40 $\mu\text{g}/\text{L}$, which was reflected in the boiled rice. The U-level in the boiled rice increased from below 1 $\mu\text{g}/\text{kg}$ to the same level as in the tap water.

Ni in rice, before and after boiling.

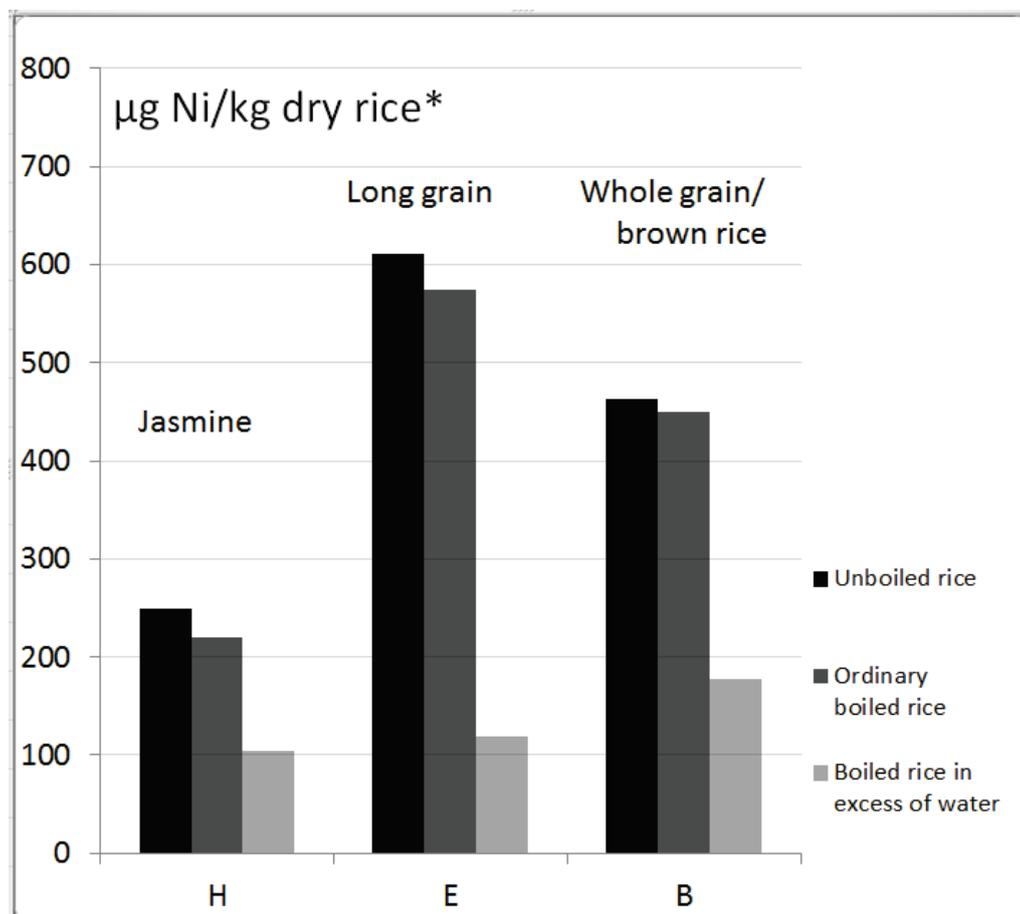


Figure 3. The concentration of Ni, in three different brands of rice (B,E,H); Unboiled, boiled to dryness, and boiled in excess of water that was discarded after cooking.

* The concentrations are adjusted for the increase in weight after boiling, i.e. corrected to give the concentrations in unboiled dry rice.

Quality of the results

The results from these kinds of experiments are always subjected to errors originating from the sample preparation and the analytical measurement. The measurement uncertainty is rather straight forward to estimate from repeated measurements of reference materials on different occasions. For the results presented the measurement uncertainty varies between 20 and 30 percent. However, it is more difficult to estimate the error originating from the sample preparation, especially for the boiled rice. There could be small differences in how “dry” or wet the rice is when all water has been absorbed by the rice after the cooking time is finished. Also when discarding the excess of water after cooking, there could be a slight difference in how much of the water is left with the rice, i.e. the wetness of rice could differ. These small differences will affect the results although the intention always has been to follow the exactly the same procedure for every sample.

Discussion

We have studied how two ways of cooking rice influence the levels of As and some other toxic elements in the rice ready to eat. We have followed the most common way to cooking rice, at least in the Nordic countries, i.e. boiling the rice in an ordinary pan containing salted tap water, which contain a low As level, here below $<1\mu\text{g/l}$. The two different ways of cooking are; a) the water volume was totally absorbed by the rice during the recommended boiling time, which is often stated in the recipe on the packages, b) boiling the rice in an excess volume of tap water which is discarded after the boiling time by simply tilting the pan against the lid (Figure 1). The result is obvious, two thirds of As, both totAs and iAs, migrate from the rice grains into the boiling water when an excess of water is used. The results also show that the mineral content in this tap water do not prevent migration of As out from the grains into water.

Our result points in the same direction as some earlier published results from similar studies, (Bae et al., 2002, Carey et al., 2015, Mihucz et al., 2010, Naito et al., 2015, Raab et al., 2009, Rahman et al., 2006, Sengupta et al., 2006, Torres-Escribano et al., 2008). However, these studies have followed a variety of procedures, and it may be difficult to strictly compare the results. For example in some of studies, distilled water have been used (Carey et al., 2015, Mihucz et al., 2010, Naito et al., 2015, Raab et al., 2009, Sengupta et al., 2006, Torres-Escribano et al., 2008) and in other cases distilled water spiked with different high levels of As (Sengupta et al., 2006, Torres-Escribano et al., 2008). Also the use of tap water containing high amounts of As (some hundred $\mu\text{g/L}$) has been presented (Bae et al., 2002, Rahman et al., 2006). The rice has been cooked in ordinary pans, in different types of percolators and in rice cookers. In our study we have used the cooking procedure the majority of the consumers in Sweden would use, and probably consumers in other countries as well. Taken as a whole it is evident; if the As level in the tap water is far below the As level in the unboiled rice, the rice boiled in an excess of water will contain less As after cooking compared to the rice boiled to dryness. Furthermore, the results indicate that irrespective of the sort of rice or the initial As level, the final concentrations after boiling is about the same in the different samples, see Figure 2a, b. How much it will decrease, depends probably on the volume of water used, (Carey et al., 2015). They showed that the more water is used the more the As level in rice will decrease.

Could only rinsing with water before cooking the rice decrease the concentration of As? In order to follow what is often recommended on the recipe on the packages, before boiling, we rinsed the twelve rice samples in a large volume of cold tap water during ten seconds. Some samples of the rinsing waters were analysed, but the results did not show any significant decrease of the content of As (data not shown). However, in some other studies, a more extended rinsing showed significantly decreased levels of As (Mihucz et al., 2007, Sengupta et al., 2006, Raab et al., 2008). Our result, showing no decrease, probably depends on the short duration of the rinsing and perhaps on a lower temperature of the water used.

It could be expected that also other water soluble ions and molecules, for example some vitamins, minerals and toxic metals, will migrate between the rice grains and surrounding water. Among the metals that are classified as toxic metals, we analyzed Cd, Hg, Ni, Pb and U. Of these metals the U level increased in rice, reaching about the same level as in tap water. Concerning Ni the result is the opposite, Ni showed a significant decrease while boiling the rice in an excess of water. In a scientific opinion about Ni in food, EFSA, The European Food Safety Agency, established that the current dietary exposure raises concern for certain consumers in Europe, (EFSA, 2015). The reproductive and developmental effects are the most critical. Therefore, it is satisfying to note that Ni easily can be lowered by simply cooking the rice in excess of water. Our result is strengthening by earlier data published by Mihucz et al. (2010). They showed that Ni is migrating from the rice grain into the water after carefully rinsing and also after boiling in deionized water.

Our results and data from other published studies show, irrespective of the content of other metals present in tap water, that boiling rice in water reduces the As content. The tap water used in our study contained low levels of As and therefore it was possible to get rid of some of the As in the rice. In comparison with other carcinogenic compounds that we are exposed to via food, the health risk of inorganic arsenic is high. Among average and high level consumers in Europe the extra cancer risk is calculated to 1 percent (EFSA, 2009). Therefore it is recommended that dietary exposure to inorganic arsenic should be reduced. Our study demonstrates that the way of cooking rice in the house hold could easily decrease our exposure of As.

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5. Evaluation of the Nordic Nutrition Recommendations 2012 – Results from an external evaluation of the Nordic Nutrition Recommendations 2012 project and suggested improvements on the structure and process for a future revision by J Ahlin.
6. Riskprofil – Livsmedel som spridningsväg för antibiotikaresistens av M Egervärn och J Ottoson.
7. How you cook rice influence the arsenic level by L Abramsson-Zetterberg, B Sundström and B Kollander.