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Part I – A Survey of Inorganic Arsenic

Inorganic Arsenic in Rice and Rice Products on the Swedish Market 2015

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Contents

Preface

The Swedish National Food Agency works in the interests of the consumer for safe food, good drinking water, fair practices in the food trade and good eating habits.

The European Food Safety Authority (Efsa) has assessed along with many other international authorities, that arsenic is a substance that should be avoided as much as possible. The Swedish National Food Agency has been working for many years mapping the sources of consumers' consumption of arsenic. Rice and rice products represent one third of the total exposure to arsenic in Sweden.

In 2013, the Swedish National Food Agency investigated the arsenic content in a selection of products intended for children. The results of the investigation also led to several companies subsequently working to reduce the arsenic content in their products. This project is part of the Swedish National Food Agency's work to map the occurrence of arsenic in various foods and to investigate the intake of arsenic from various types of food. It is also part of work on a more long-term objective, to induce rice producers to work more actively to ensure that the rice raw material has a lower arsenic content and in this way reduce consumers' intake of arsenic.

With effect from 1 January 2016, maximum levels are being introduced for inorganic arsenic in rice and certain rice products within the European Union (EU) and in the longer term also globally (CODEX Alimentarus[1]). As a result of the maximum levels being introduced, it will be possible to take control measures for inorganic arsenic in rice and rice products. Since 2014, the Swedish National Food Agency has been accredited for analysing inorganic arsenic in foods and will perform such testing. The analytical method (prEN16802) will become the European standard for analysis of inorganic arsenic in 2016. The European Commission is also encouraging its member states to collect as much data as possible during 2015 and 2016 on arsenic in all types of food, including foods where there is no stated maximum level. The purpose is to better be able to assess the risks of arsenic in various foods in the EU's inner market and to be able to set relevant maximum levels for arsenic.

The occurrence of arsenic in food is due to both natural causes and human activity, such as mining. Arsenic is an element that occurs naturally in various concen-

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[1] Codex Alimentarus is an international organisation that was created in 1963 by the UN bodies FAO and WHO for the purpose of producing international standards for safe foods, integrity in food handling and free trade in foods.

trations in bed-rock and sediments. In areas with minerals that contain arsenic, the arsenic can be dissolved out into the surrounding ground water and in this way become available to plants, animals and people.

Arsenic is found in many different chemical compounds and these are normally divided into two main groups: organic and inorganic arsenic. The inorganic form is carcinogenic and is considered to be the more toxic form for humans. A food may contain both forms at the same time. Ground water that contains arsenic contains mainly the inorganic form, while the organic form of arsenic dominates in marine fish and shellfish. Rice is one of the foods that contains the highest amount of inorganic arsenic, as well as some organic arsenic.

This investigation intends to answer the questions:

- How much inorganic arsenic is found in the rice and rice products that are available on the market in Sweden?
- What is the average intake of inorganic arsenic in children and adults?
- Is there a risk that people with coeliac disease have a higher intake of inorganic arsenic, since replacement products are often based on rice?
- Is the content of inorganic arsenic in rice dependent on how the rice is prepared before consumption?
- Are the new maximum levels for inorganic arsenic in rice at the right levels, i.e. do they adequately protect consumers to a too high inorganic arsenic exposure?
- Does the Swedish National Food Agency need to give advice about the consumption of rice and rice products, and if so what?

This report, the Swedish National Food Agency's report serial number 16/2015 *Inorganic Arsenic in Rice and Rice Products on the Swedish Market 2015,* consists of three parts.

- *A Survey of Inorganic Arsenic in Rice and Rice Products: Part1,* reports on the content of inorganic arsenic that is found in rice and rice products on the Swedish market. This section of the report also describes how the preparation of rice can affect the inorganic arsenic content.
- *Risk Assessment: Part 2* describes the risks that inorganic arsenic can lead to, with the aid of scenario analyses and with the application of the Swedish National Food Agency's so-called Risk Thermometer.

Based on the two scientific sub-reports concerning the survey and risk assessment, as well as on other scientific literature, consideration was then given as to whether, and which, measures could be taken to reduce consumers' intake of inorganic arsenic. Other relevant factors have also been included in this assessment, for example whether it is possible for consumers to follow a given advice about consumption of rice and rice products, how such advice may be perceived, how it can be applied by the target groups, what opportunities exist for testing and whether the consequence of a measure is in proportion to the risk and benefit of a specific food.

- *Risk Management: Part 3* reports on the considerations and assessments that resulted in the measures that the Swedish National Food Agency considers to be justified in order to manage the occurrence of inorganic arsenic in rice and rice products and to reduce exposure to inorganic arsenic in both the short and long term.

The purpose of the report is to clearly show the Swedish National Food Agency's reasons for the measures that have been decided upon.

Swedish National Food Agency, 25 September 2015

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Definitions and abbreviations

ALARA	“as low as reasonably achievable” - a procedure for setting the maximum level for the toxic substance that is as low as possible in practice without shutting off parts of trade on the global market.
As(V)	Pentavalent arsenic, which is included in arsenate. Arsenate and arsenite represent the main components of what is called inorganic arsenic in food.
As(III)	Trivalent arsenic, which is included in arsenate. Arsenate and arsenite represent the main components of what is called inorganic arsenic in food.
BfR	Bundesintitut für Risikobewertung – The German Federal Institute for Risk Assessment
CEN	Comité Européen de Normalisation – European Committee for Standardisation
CRM	Certified reference material
Efsa	European Food Safety Authority
EU	European Union
HPLC	High performance liquid chromatography
ICP-MS	Inductively coupled plasma mass spectrometry
HR-ICPMS	High resolution ICP-MS
LOD	Limit of detection - the lowest concentration of a substance that an analytical method can detect.
NMKL	Nordisk Metodikkommitté för Livsmedel - Nordic Committee on Food Analysis
PT	Proficiency test
RSD	Relative standard deviation
WHO	World Health Organization
Whole grain rice	Equivalent to brown rice or husked rice, in Swedish “Fullkornsris”

Country abbreviations that appear in the report

BE	Belgium
CZ	Czech Republic
DE	Germany
DK	Denmark
EG	Egypt
GB	Great Britain
GR	Greece
IN	India
IN/PK	India/Pakistan
IT	Italy
KH	Cambodia
NL	The Netherlands
PK	Pakistan
PL	Poland
SE	Sweden
TH	Thailand

Summary

Inorganic arsenic is a substance that must be avoided as far as possible according to the European Food Safety Authority (Efsa). Inorganic arsenic often occurs in rice, however. The Swedish National Food Agency has therefore surveyed the occurrence of inorganic arsenic in a selection of rice and rice products that were on sale in Swedish supermarkets in spring 2015.

A total of 102 products were included in the survey. None of these had an inorganic arsenic content that exceeded the maximum levels that will come into force in the EU with effect from 1 January 2016.

The 102 products included 63 rice (basmati, jasmine, long-grain, round-grain, whole grain), 11 rice cakes, 9 fresh rice porridges, 6 breakfast cereals, 5 rice drinks, 4 gluten-free breads, 3 noodles and 1 gluten-free pasta. The products include brands from the large food producing chains, as well as less common brands and organic products. The average (min–max) content in the dry rice products (n = 88) was 67 (3–322) µg/kg. General findings:

- Rice cakes (n = 11) have the highest level of inorganic arsenic, with an average of 152 µg/kg (maximum 322 µg/kg).
- Whole grain rice and raw rice (n = 9) have the next-highest level with an average of 117 µg/kg (maximum 177 µg/kg).
- Basmati rice (n = 17, average 63 µg/kg) and jasmine rice (n = 18, average 69 µg/kg) had a significantly lower inorganic arsenic content than other types of rice.
- The gluten-free breads contain lower levels of arsenic than rice cakes, with an average of 42 µg/kg.

For the fresh rice porridges (n = 9), which apart from the rice itself had a water content of 60-90 per cent, the average content was 14 (10–17) µg/kg, and for the rice drinks (n = 6) 8 (5–10) µg/kg.

The study included 18 organic products. The results showed that there was no significant difference in arsenic content between organic and conventionally produced products. Neither could any difference be detected on the basis of country of origin.

To investigate whether preparation and cooking affected the inorganic arsenic content, a further six different types of rice were analysed before cooking, after rinsing, after cooking where all the water was absorbed and after cooking where cooking water was left and discarded. Rinsing before cooking did not reduce the inorganic arsenic content. On the other hand, the content was reduced by between

40 and 70 per cent if the rice was cooked with an excess of water, compared with when all the cooking water was absorbed.

In order to estimate the general intake of inorganic arsenic in the Swedish population, analyses were also made of food samples that were included in the Swedish National Food Agency's earlier study, Market basket 2010, which were only analysed for total arsenic. The highest levels of inorganic arsenic were found in the following food groups (average content (min–max) in µg/kg): Fish 13 (10–21), Cereals 11 (4–15), Sugar and similar 5 (< 2–12) and Fruit 3 (< 2–7). In the food groups Meat, Egg, Dairy, Cooking fat, Bakery, Soft drinks, Vegetables and Potatoes, the level of inorganic arsenic was in most cases below the detection limit of 1–2 µg/kg (in wet and dry samples respectively).

Introduction

There has been interest in studying arsenic in rice and rice products, among other foods, at the Swedish National Food Agency for many years and there are also many international publications on the subject. The Swedish National Food Agency has performed studies and directed surveys on rice (Jorhem 2008), rice-based baby food (Eneroth 2011) and baby food (Öhrvik 2013), but arsenic has also been included in more general studies such as Market basket 2010. Other countries have also performed comprehensive studies of arsenic in rice and rice products. Examples include Fødevarestyrelsen 2013 (Denmark), BfR 2015 (Germany), Food Standards Agency 2007 (Great Britain), U.S. Food and Drug Administration 2013 (USA) and Torres-Escribano 2008 (Spain).

There is still a great need for further content data regarding the occurrence of arsenic in its various forms in food. This applies especially to the occurrence of so-called inorganic arsenic. Inorganic arsenic consists mainly of arsenite (AsIII) and arsenate (AsV) and these are considered to be the most toxic of the different arsenic compounds that exist (Efsa 2009). Many of the surveys that have been performed covered only the total content of arsenic. The surveys that have been performed on products on the Swedish market where inorganic arsenic was considered covered only a limited number of products: 49 and 30 respectively (Jorhem 2008 and Eneroth 2011).

The European Union (EU) is encouraging its member states to gather as much data as possible on inorganic arsenic in all types of food during 2015 and 2016 (Commission Recommendation on the monitoring of arsenic in food, SANTE/10258/2015, European Commission 2015). The purpose is to be better able to assess the risks of arsenic in various foods and to be able to set relevant new maximum levels for arsenic. With effect from 1 January 2016, maximum levels are being introduced for inorganic arsenic in rice in the EU and in the longer term also globally (CODEX Alimentarus[2]). The maximum levels adopted in the EU are listed in Table 1. As a result of maximum levels being introduced, it will be possible to carry out control for inorganic arsenic in rice and products that contain rice.

Previously, there has only been a maximum level for total arsenic content in drinking water (10 µg arsenic per litre of drinking water, SLV FS 2001:30). There are established methods for analysing the total content of arsenic in food, such as

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[2] Codex Alimentarus is an international organisation that was created in 1963 by the UN bodies FAO and WHO for the purpose of producing international standards for safe foods, integrity in food handling and free trade in foods.

NMKL method 186 and EN 15763. At present there is no adopted standard for determining the level of inorganic arsenic in food, but the European Committee for Standardisation (CEN) is working on one.

On behalf of CEN, the Foodstuffs Institute at Denmark Technical University (DTU) has developed the relevant method (prEN 16802) and the Swedish National Food Agency, in collaboration with DTU, has set this method up in its own laboratory. In 2013, the Swedish National Food Agency and 14 other laboratories in Europe and the USA took part in the testing of this method, so as to determine if it was appropriate as a standard. The results were satisfactory (Sloth 2013) and it is anticipated that the method for analysis of inorganic arsenic in food will be approved as standard in the EU and will be available for commercial laboratories to purchase in 2016.

Table 1. The maximum levels for inorganic arsenic in food that are introduced in the Commission's regulation 1881/2006 and that will be applied with effect from 01/01/2016.

	Foodstuff	Maximum level, mg/kg wet weight	Maximum level, µg/kg wet weight
3.5	**Arsenic (inorganic)**[(50) (51)]		
3.5.1	Non-parboiled milled rice (polished or white rice)	0.20	200
3.5.2	Parboiled rice and husked rice	0.25	250
3.5.3	Rice waffles, rice wafers, rice crackers and rice cakes	0.30	300
3.5.4	Rice destined for the production of food for infants and young children [(3)]	0.10	100

[(50)] Sum of As(III) and As(V).
[(51)] Rice, husked rice, milled rice and parboiled rice according to Codex Standard 198-1995
[(3)] Scientific Opinion on Arsenic in Food. The Efsa journal, vol. 7 (2009):10; article number 1351.

The future CEN standard for inorganic arsenic in rice and rice products is used in this study. The Swedish National Food Agency has been accredited by SWEDAC (the Swedish Board for Accreditation and Conformity Assessment) for the performance of analyses according to this method since March 2014. The accreditation means that analyses are performed in a quality-assured manner and with quality-assured results.

So as to be able to better estimate the general intake of inorganic arsenic from food in the Swedish population, and not just from rice and rice products, food samples from the above-mentioned survey Market basket 2010 have also been analysed in this project using the same analytical method. These samples have previously been analysed with regard to total arsenic content and with the aid of conversion factors (Efsa 2009) an approximate inorganic arsenic content was obtained (Market basket 2010). This approximate content was suspected of overestimating the content of inorganic arsenic and a real analysis of inorganic arsenic was desirable.

The analyses performed in most surveys published by the Swedish National Food Agency and others have been performed on “raw” food, i.e. without any form of cooking. The reason for this is that it makes for easier comparison with other surveys and reduces the preparatory handling of samples. However, the content of substances found in “raw” foods may be changed by various types of cooking. This means that an analysis result from a “raw” food will not always reflect the levels that will be consumed when eating the food. It is also interesting to investigate whether using a particular type of cooking can affect the content in the food. For this reason, we have also investigated in this project how the level of inorganic arsenic in rice is affected depending on how it is cooked.

Material and method

Selection and sampling of rice and rice products

A selection of rice and rice products was bought in various food stores in Uppsala, Halmstad and Västerås and via the internet during the period March-April 2015. The selection was made with the aim of covering the large supermarket chains' own brands, as well as other well-known brands on sale in many different stores and also organic products. A number of individual random samples of rice were also bought from smaller specialist shops. In the larger stores, rice products were also bought that were intended for consumers with food allergies/coeliac disease.

A total of 102 different products were bought, made up of 63 rice ((basmati, jasmine, long-grain, round-grain, whole grain), 11 rice cakes, 9 fresh rice porridges, 6 breakfast cereals, 5 rice drinks, 4 gluten-free breads, 3 noodles and 1 gluten-free pasta. At least 1 kg of all products was bought from at least 2 packs of the same product. This is in accordance with the commission's directive (EC) 333/2007) for controls pursuant to current legislation. Exceptions were made, however, for two types of rice in 5 kg packs and for one rice in a 10 kg pack. For these, only one pack of each product was purchased.

Table 2 lists the number of products in the different categories. For more detailed information about products, brands, shops etc., see Appendix 1. Note that all information is taken from the various products' own packs. For many products, the origin of the rice is not stated, only the country in which the product is produced. No further attempt has been made to trace the origin of the rice in these products. The purpose of this study has primarily been to survey the content of inorganic arsenic in rice and rice products that are on sale in the Swedish market and not to link content with country of origin.

Sample preparation of rice and rice products

Sample preparation for the products purchased varied depending on the form in which the product is sold and how large the pack was. All procedures had the following in common:

- 150 ml homogenised sample was saved for analysis in acid-washed plastic jars.
- The mills were cleaned between samples by homogenising a decilitre of the next rice sample and then discarding this.

Rice, rice noodles and gluten-free pasta were homogenised using a Retsch Ultra Centrifugal Mill ZM 100 which includes a stainless pan and a 4 mm titanium sieve. Rice cakes, various types of rice bread and breakfast cereals were homogenised using a large food processor (Foss Homogenizer 2094) with a stainless pan and stainless knife. Fresh rice products were homogenised in a Braun food processor with a titanium knife.

Table 2. Number of products in each product category. For more detailed information about products, brands, shops etc., see Appendix 1.

Product category	Number
Bread	4
Drinks	5
Porridge	7
Cakes	11
Breakfast cereals	6
Rice porridge snack	2
Noodles	3
Pasta	1
Rice	63
Total	**102**

Rice type	Number
Basmati	17
Whole grain	7
Jasmine	18
Long-grain	4
Long-grain and wild rice	1
Long-grain rice, parboiled	9
Risotto	2
Round-grain	2
Raw rice	2
Instant rice	1
Number of rice	**63**

Rice

Samples were taken slightly differently depending on how large the pack was:

- 1 kg and less: The entire pack was mixed in a Petri dish without homogenising.
- 2 kg: The pack was agitated and a small quantity poured out. The pack was agitated again and then half the pack was poured into a large Petri dish. The procedure was repeated for the second pack. The rice sample was mixed in a Petri dish without homogenising.

- 4-5 kg: Samples were taken from 4-5 different levels by pouring a part quantity of the rice into a Petri dish. The rice sample was mixed in the Petri dish without homogenising.
- 10 kg (only one pack): Samples were taken at five levels, 1 dl at each level. Homogenising was then performed on 5 dl of rice and then 1.5 dl was taken out as a sample and saved in acid-washed plastic jars.

Rice noodles
The rice noodles were divided in the middle. Half the packet was broken off and crushed into small pieces in the pack and in a Petri dish. Homogenising was performed on 5 dl of each of the rice noodles.

Gluten-free pasta
The entire pack was mixed in a Petri dish without homogenising. Homogenising was performed on 5 dl of pasta.

Crispbread and crisp rice cakes
Half of each piece in the pack was homogenised in two stages and mixed in a Petri dish after homogenisation.

Rice cakes
Every second cake was removed from the pack and homogenised in two stages and mixed in a Petri dish after homogenisation. If the pack contained an odd number of cakes, half the last cake was taken.

Breakfast cereals
The pack was agitated and half of each pack was homogenised in two stages and mixed in a Petri dish after homogenisation.

Rice bread
The entire content of the pack was homogenised.

Rice porridge and rice porridge snacks
The entire pack was mixed in a Petri dish without homogenising. Jam from the porridge snacks was saved in a separate plastic jar and analysed separately.

Rice drinks
The pack was agitated and poured into a 3-litre beaker. After stirring the samples were poured into acid-washed plastic jars.

The effect of cooking on the arsenic content of rice

A further eight rices of different brands comprising ordinary rice, jasmine rice (different kinds), whole grain rice and so-called red rice were purchased in three different stores in Uppsala. The purpose was to analyse the content of inorganic arsenic in the rice after rinsing and cooking. One pack of each brand of rice was purchased for this purpose.

Sample preparation of rice before cooking
A 100 gram sample was taken directly from the pack of each rice for analysis of uncooked rice. This dry rice was homogenised using a Retsch GM 200 mill, which has a plastic pan and stainless knife. A further 100 gram sample of each rice was taken to study the effect of rinsing the rice before cooking. To these samples was added 10 dl of cold tap water (Uppsala public supply); the rice was stirred with a plastic spoon for ten seconds and the water was poured out. Homogenising of the rinsed rice was performed using a Braun food processor with a titanium knife. Both rinsed rice and rinse water were saved in acid-washed plastic jars for analysis.

Sample preparation of rice after cooking
Three further samples of 100 grams each were taken of each rice for cooking. All the rice samples were rinsed as above before cooking. One of the samples was cooked according to the instructions on the respective pack. The amount of tap water that was recommended was 2-3 dl per 100 grams of rice and the rice was cooked until dry, i.e. when all the water was gone. Two of the samples were cooked with an excess of water (9 dl per 100 grams). After the recommended cooking time, the water was poured off and saved for analysis. The cooked rice was homogenised with a Braun food processor with a titanium knife. To each cooking trial was added ½ or 1 teaspoon of table salt (Falksalt, fine grain household salt, AB Hanson och Möhring, Halmstad).

Content of inorganic arsenic in other foods

In the Swedish National Food Agency's survey Market basket 2010, samples of various food groups were analysed for nutrients, minerals and contaminants. The contaminants tested for included total arsenic content, but not inorganic arsenic. The samples (homogenates of various products in each food group) were prepared in spring and autumn 2010 and have since been kept frozen (-20°C).

The various homogenates consisted of foods from five supermarkets in Uppsala (COOP, ICA, Willys, Hemköp and Lidl). From each supermarket except Lidl, a low-price alternative and a normal-price alternative of each food had been taken. The different food groups were called Meat, Egg, Dairy, Cereals, Cooking fat, Vegetables, Potatoes, Fish, Fruit, Sugar and similar, Bakery and Soft drinks. Table 3 shows which foods are included in each food group.

The proportions of each food in each food group are based on sales statistics and corresponded to 90 per cent of the food consumption of an average consumer in Sweden. For the food groups Fruit, Vegetables and Potatoes, products were also purchased in autumn 2010. A total of 118 homogenates were defrosted for analysis of inorganic arsenic in this study.

Table 3. The analysed food samples' (homogenates') content and classification in different food groups (Market Basket 2010).

Homogenate number	Food group	Included foods
1	Cereal products	flour, grain, corn flakes, pasta, bread (including rice 7 per cent by weight)
2	Pasteries	cakes, buns, pizza, biscuits
3	Meat	meat products, beef, lamb, chicken, processed meat
4	Fish	fish products, fresh and frozen, fish in cans, shellfish (11 per cent by weight)
5	Dairy products	milk, yoghurt, cheese, cream, cottage cheese
6	Egg	fresh eggs
7	Fat	butter, margarine, mayonnaise, cooking oil
8	Vegetables	root vegetables, fresh, frozen, canned
9	Fruit	fresh, frozen, canned, juice, squash, nuts
10	Potatoes	fresh, mashed potato powder, French fries, crisps
11	Sugar sweets	granulated, honey, sweets, ketchup, ice cream, sauces, dressing
12	Beverages	soft drinks, mineral water, beer

Analysis of inorganic arsenic by HPLC-ICPMS

Instruments and material

Analysis of inorganic arsenic was performed by HPLC-ICPMS (high performance liquid chromatography – inductively coupled plasma mass spectrometry) in the Swedish National Food Agency's laboratory. An HPLC from Agilent (1260) with a strong anion exchange column (Dionex Ionpac AS7, 25 cm, id 4.6 µm, particle size 4 µm and precolumn Dionex Ionpac AG7, 4 cm, id 4.6 µm, particle size 4 µm) was used to separate the different arsenic compounds in the sample. 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.

Analytical method

The method (prEN 16082) used 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 by SWEDAC (method number at the Swedish National Food Agency is SLV K2-m 413.2) for inorganic arsenic for rice and rice products among others within the range 1-25 000 µg/kg. The limit of detection (LOD) is between 1 and 3 µg/kg depending on how much the sample is diluted before analysis and whether the sample is wet or dry.

The method's LOD fulfils the requirements for use in testing maximum levels within the EU since the maximum levels that apply for inorganic arsenic vary between 100 and 300 µg inorganic arsenic per kg and the LOD may be a maximum one tenth of the limit (EU 333/2007), which means 10-30 µg/kg. The correctness of the method has been tested by participation in international proficiency tests (PT) for rice, among other samples, and with the aid of repeated analysis of certified rice reference material (Table 4). 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 analysis of PTs and reference material.

Analysis of total arsenic content by HR-ICPMS

The total content of arsenic in the samples was analysed 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 µg/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. The value obtained was 61 µg/kg with RSD 3 per cent (n=2), certified value 60 +/- 18 µg total As/kg. An internal reference material, Vetemjöl Special (In-house RM), was analysed and gave a result of 4.97 µg total As/kg with RSD 6.3 per cent (n=6); the guideline value is 4.62 +/- 0.92 µg/kg (obtained from tests during 1.5 years' routine analysis). The method is the same as for ALS accredited analysis for this type of sample, but with less dilution of the samples. Further information about the method may be found in Engström et al (2004).

Table 4. Quality control for analysis of inorganic arsenic in rice flour according to standard prEN 16802.

Type of control	Sample type	Our result µg/kg	RSD %	Certified /assigned value mg/kg	Z-score
2013 BRL Interlaboratory Comparison Study for Arsenic Speciation in Food and Juice	White rice flour	36 (n=3)	8.5	30	0.72
	Brown rice flour	45 (n=3)	4.7	39	0.82
2013 CEN, testing of analytical method prEN 16802	White rice flour	85 (n=3)	0.7	73 +/- 6	
	Whole grain rice flour	52 (n=3)	2.3	47* +/- 0.5	
Own control					
Sinlac rice porridge, Inhouse RM	White rice flour	22 (n=19)	15	-	
NMIJ White rice flour 7503-a, RM231	White rice flour	76 (n=20)	6.6	84.1** +/- 0.3	
Rice flour, NIST 1568a, RM173	White rice flour	104 (n=2)	1.5	*94**** +/- 14	
IRMM Wheat IMEP-112, RM232	Wheat flour	154 (n=20)	6.8	169 +/- 25	

* The whole grain rice is a CRM, FAPAS T07151QC, and the stated certified value of this is 39.0 (24.6 – 53.4) mg inorganic arsenic/kg.
** The total of the certified contents of As(V) 13.0 +/-0.9 and As(III) 71.0 +/-0.3 mg/kg.
*** This CRM is not certified for inorganic arsenic but in the literature this average value is reported for inorganic arsenic based on a total of 39 publications (Tyson 2013) with RSD=14 %.

Results

Overall results for rice and rice products

A general result for each product category is given in Table 5 and then in more detail under each heading below. In general it can be said that the dry rice products have higher content levels (average content 67 µg/kg, n=88) than the fresh products (average content 14 µg/kg, n=9). In Rice drinks the average content was 8 µg/kg (maximum 10 µg/kg, n = 6). Rice cakes have the highest measured levels of inorganic arsenic with an average of 152 µg/kg (maximum 322 µg/kg).

Eighteen of the products in the survey were labelled as organic. It was not possible to show any significant difference in the levels of inorganic arsenic in organic and conventionally produced products (Wilcoxon´s signed-rank test).

Table 5. Summarised results for inorganic arsenic in the surveyed rice and rice products.

	Content of inorganic arsenic in products on sale, µg/kg				
Product category	**Number**	**Average**	**Median**	**Min**	**Max**
DRY RICE PRODUCTS					
Breakfast cereals	6	52	54	25	91
Bread	4	42	44	22	56
Rice cakes	11	152	139	86	322
Pasta	1	3	3	3	3
Noodles	3	70	75	55	80
Rice	63	80	72	30	177
FRESH RICE PRODUCTS					
Drinks	5	8	9	5	10
Porridge snack, ready to eat	2	16	16	15	16
Porridge, ready to eat	7	12	12	10	17

Dry rice products and rice

The results for dry rice products and rice are shown in Figure 1. None of the products analysed exceeded the maximum levels which begin to apply in EU with effect from 1 January 2016. One rice cake gave a value above the limit of 300 µg/kg, but allowing for measurement uncertainty (+/- 26 per cent) the content was juridically considered to be below the limit.

Rice, rice types, country of origin

Inorganic arsenic content in relation to rice type

The average content of inorganic arsenic in all the rice types analysed was 80 µg/kg. The lowest level measured was 30 µg/kg and the highest 177 µg/kg. Figure 2 shows the contents grouped by type. In general, it can be said that a large proportion of the whole grain rice has an inorganic arsenic content among the higher levels, while basmati rice and jasmine rice have a significantly lower content of inorganic arsenic than the other rice types (Mann Whitney rank sum test, boxplot Figure 3).

Content in relation to country of origin

Among the rice where the pack stated the country of origin, 28 were from Asia, 15 from Europe and 1 from Africa (Figure 4). Almost a third of the rice (19 of 63) did not state the country of origin on the pack. From the rice analysed, no significant differences can be seen based on country of origin (Kruskal-Wallis test). Neither is there any significant difference if we exclude whole grain products, which generally contain more inorganic arsenic, from the test.

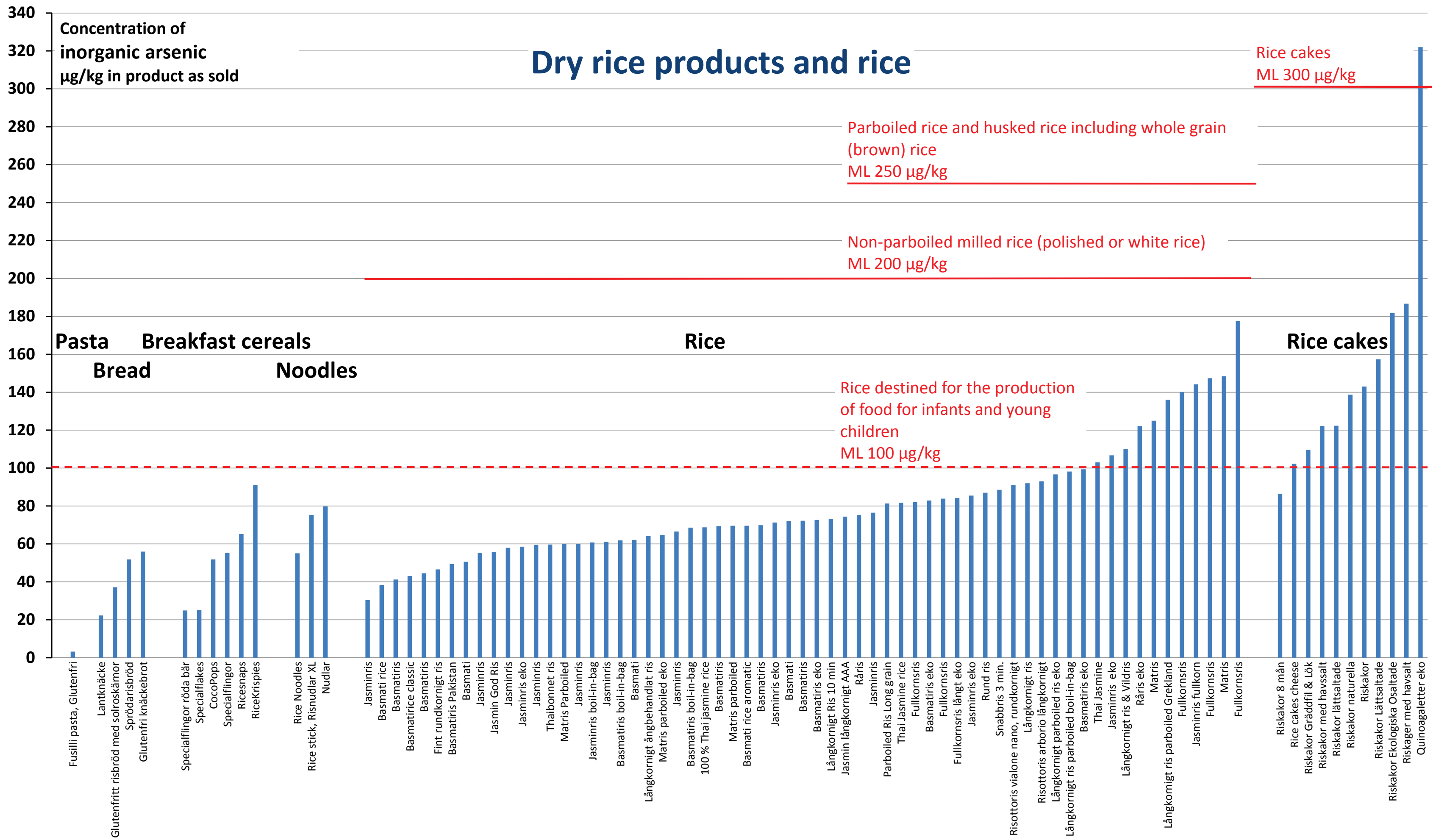

Figure 1. Content of inorganic arsenic in the dry rice and rice products included in the survey. The products are sorted by group and listed in order of their inorganic arsenic content. The maximum level (ML) for inorganic arsenic is marked with red lines (applies from 1 January 2016).

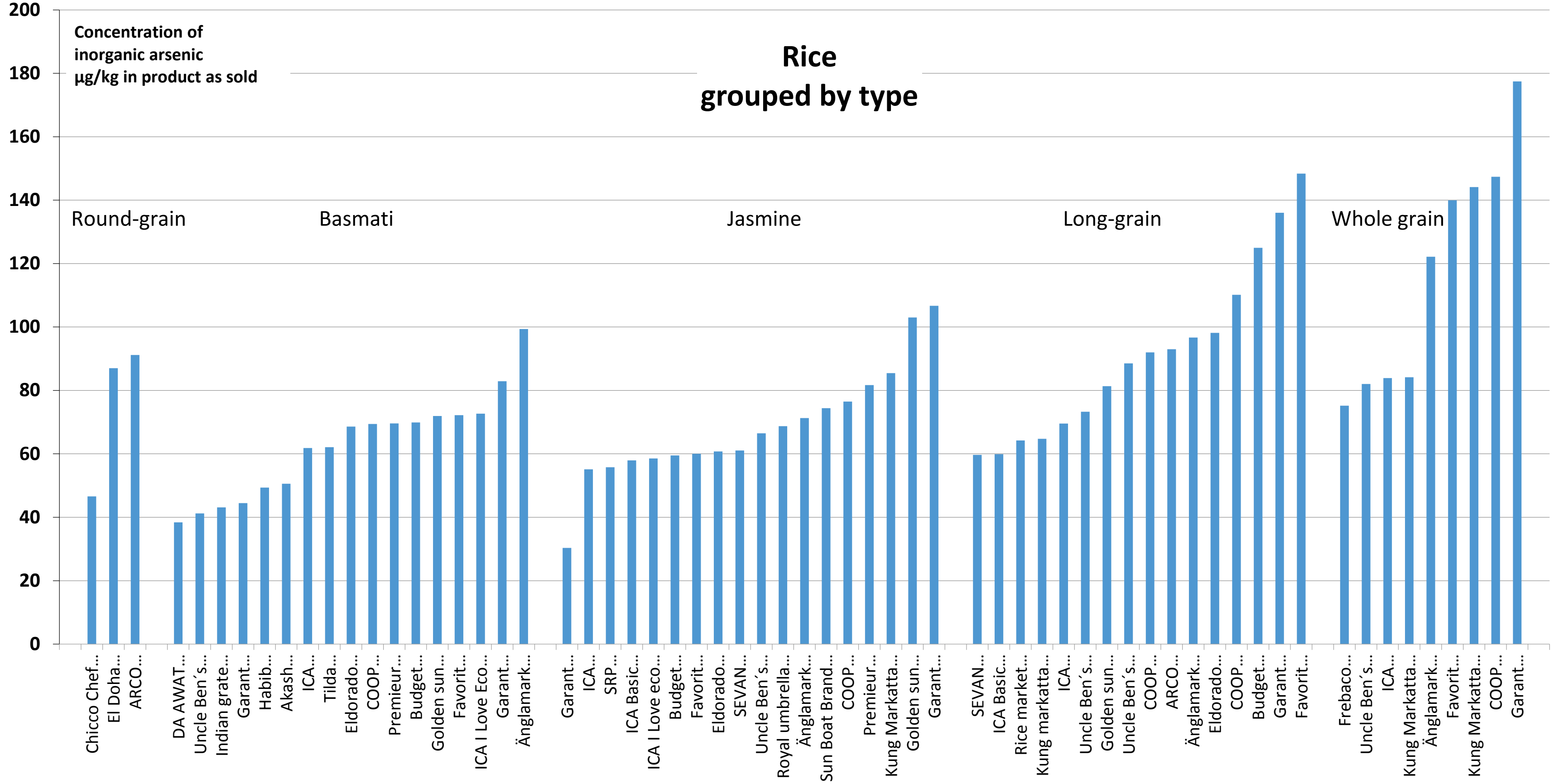

Figure 2. Content of inorganic arsenic in rice grouped by type and listed in order of their inorganic arsenic content. In the long-grain rice group, 14 out of 16 are parboiled. Rice from SEVAN and ARCO are not parboiled. For more information about the different rice types, see Appendix 1.

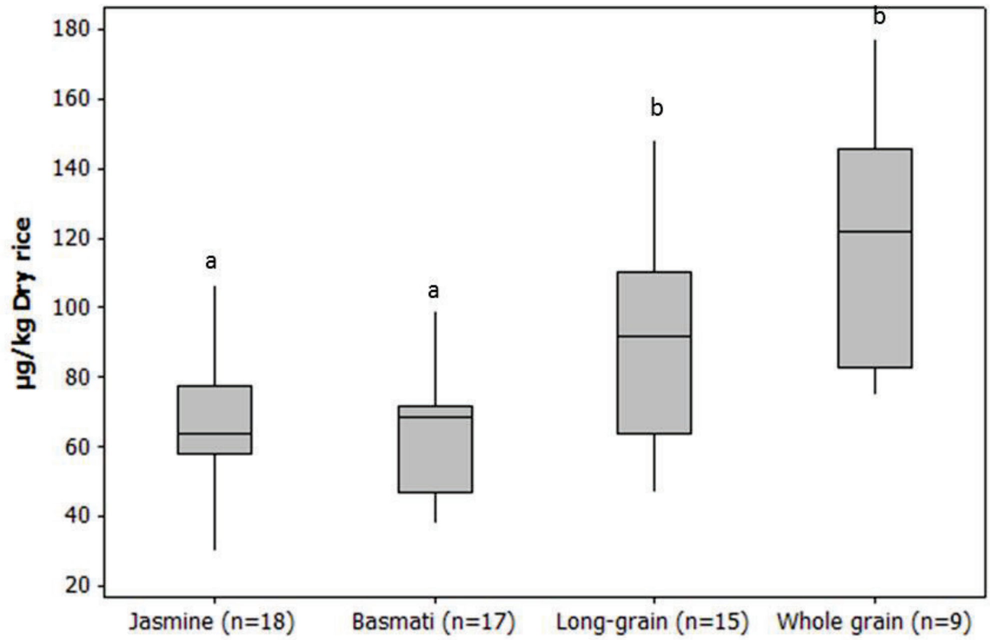

Figure 3. Content of inorganic arsenic in rice grouped by type and listed in order of their inorganic arsenic content. Different letters indicate significantly different levels. Mann Whitney rank sum test.

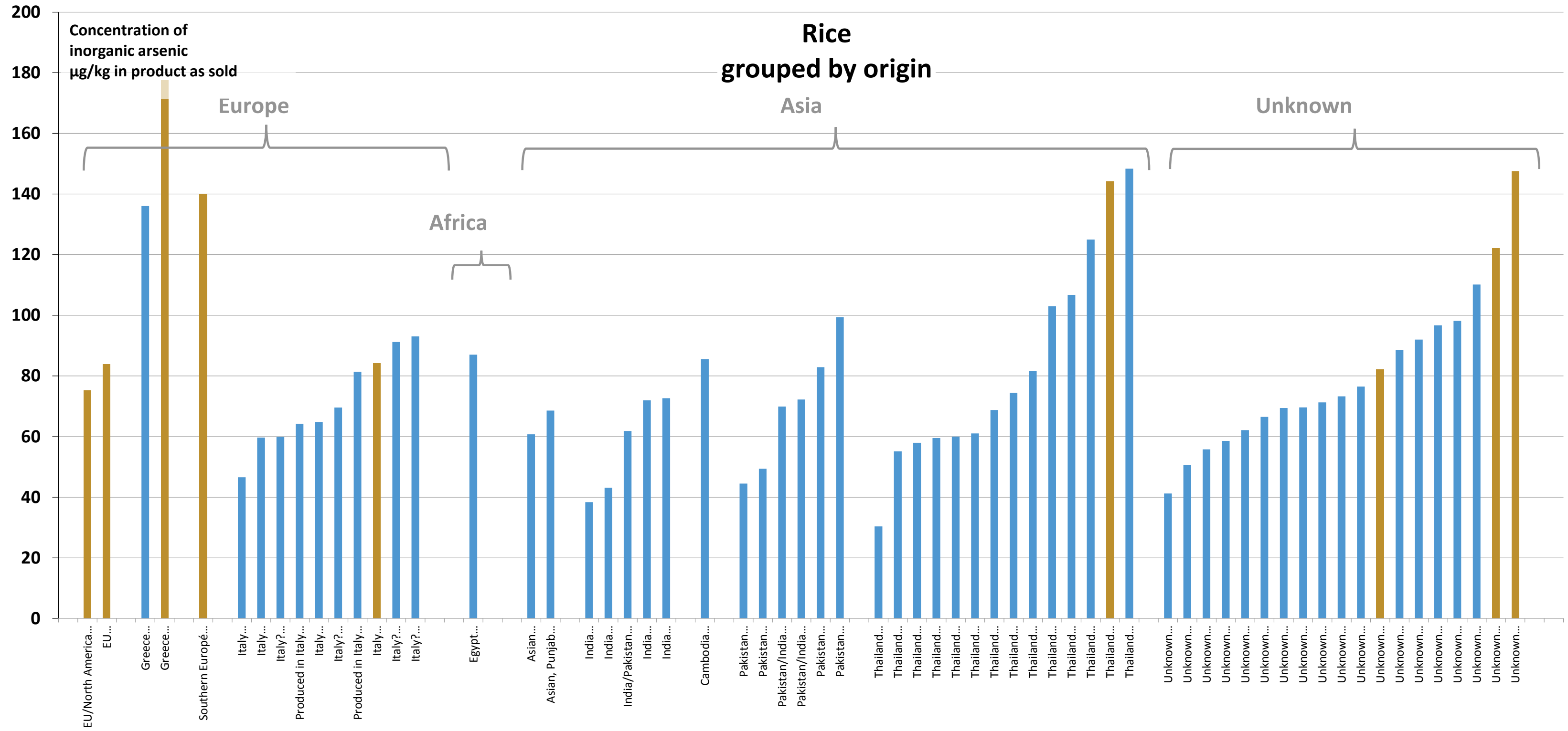

Figure 4. Content of inorganic arsenic in rice grouped by country of origin and listed in order of their inorganic arsenic content. Whole grain rice and raw rice are marked with a brown bar.

Rice-based bread and rice cakes

The rice-based bread group included 3 hard types and one soft. These were found on the supermarket shelves for food allergies/coeliac disease. Compared with the 11 rice cakes analysed, levels are lower in the products intended for gluten-intolerant consumers (Figure 5). The average level in the rice cakes is 152 µg inorganic arsenic/kg compared with 42 µg/kg for the rice-based bread.

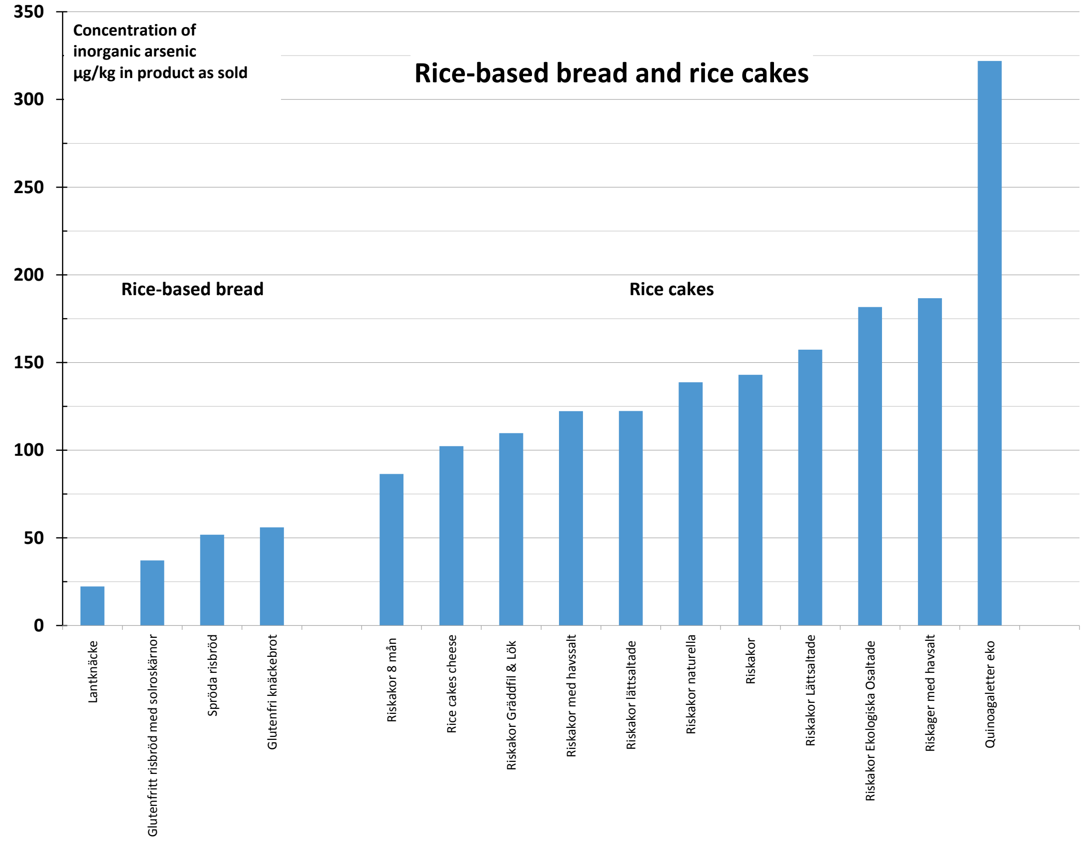

Figure 5. Content of inorganic arsenic in rice-based bread and rice cakes. The products are sorted by group and listed by increasing order of their inorganic arsenic content.

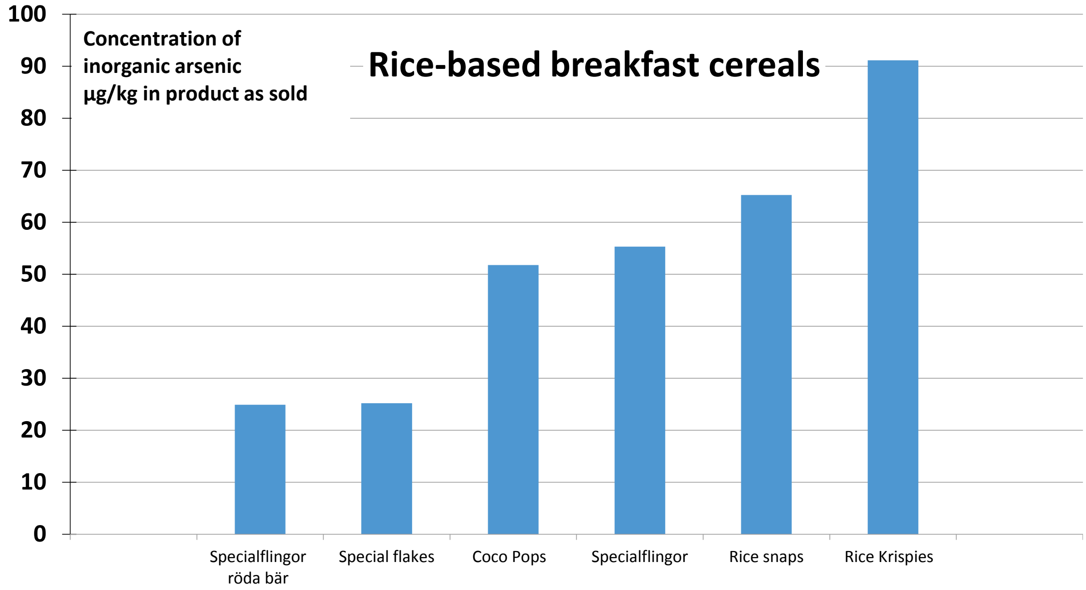

Figure 6. Content of inorganic arsenic in rice-based breakfast cereals.

Rice breakfast cereals
The average content of rice breakfast cereal was 52 µg inorganic arsenic/kg and the levels vary from 20 to almost 100 µg/kg. See Table 5 and Figure 6.

Fresh rice products and rice drinks

Of the 9 fresh rice porridge products that were analysed, 7 were of the rice porridge type and 2 were so-called rice porridge snacks. The average contents were 12 and 16 µg/kg respectively (Table 5 and Figure 7). Since there were only two rice porridge snacks, no general conclusions can be drawn. The rice porridge snacks also included separately packed strawberry jam, which was analysed separately. The inorganic arsenic content in the strawberry jam was 2-3 µg/kg.

The rice drinks contain between 5 and 10 µg inorganic arsenic per kg. The density of one of the rice drinks was measured as 1.04 g/ml (n=6) (ID No. 8). See Table 5 and Figure 7.

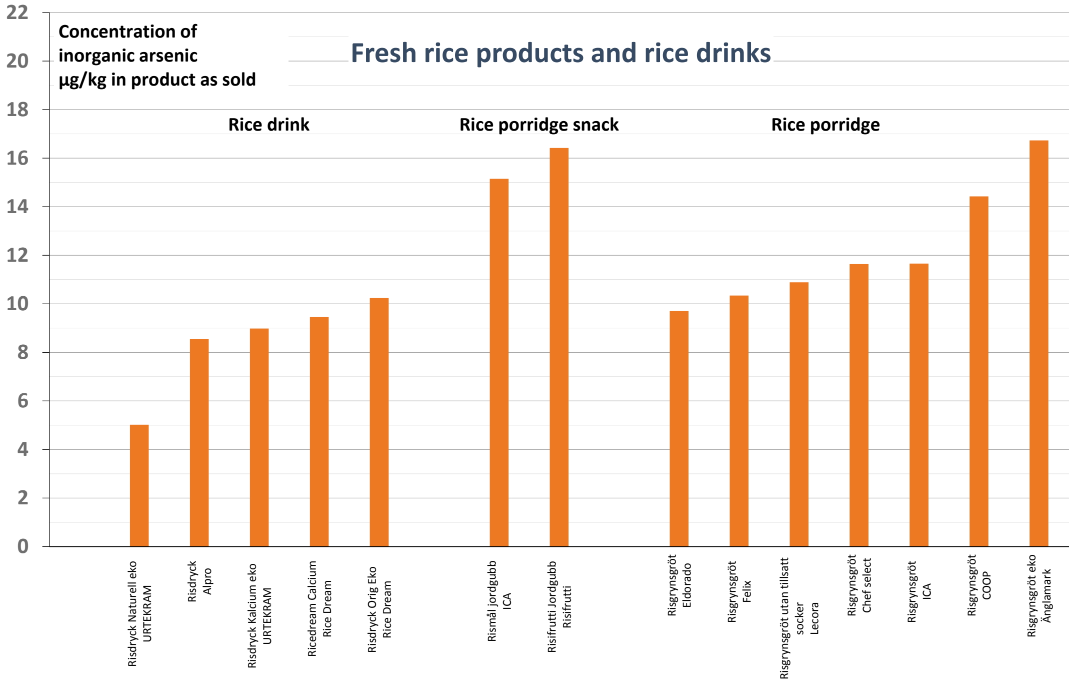

Figure 7. Content of inorganic arsenic in fresh rice products and rice drinks. The products are sorted by group and listed in order of their inorganic arsenic content. The rice porridge snacks also included separate strawberry jam, which contained 2-3 µg inorganic arsenic/kg.

Total content of arsenic in rice and rice products

The total content of arsenic is shown in Figure 8 and in Appendix 1 together with the content of inorganic arsenic. The measurements of total content from the two different HR-ICP-MS instruments are in good agreement. In rice drinks and rice porridge, the proportion of organic arsenic is less than in rice and rice cakes. In rice, the proportion of inorganic arsenic varies between 33 and 91 per cent (average 67 per cent, n=63) and in rice cakes between 20 and 98 per cent (average 76 per cent). Figure 9 a) and b) shows examples of results (chromatogram) from HPLC-ICP-MS analysis of rice cakes with high (Figure 9a) and low proportions of inorganic arsenic. For rice cakes with the lowest proportion of inorganic arsenic, only 20 per cent, it can clearly be seen that the proportion of *organic* arsenic is large (the peak to the left in the chromatogram, Figure 9 b).

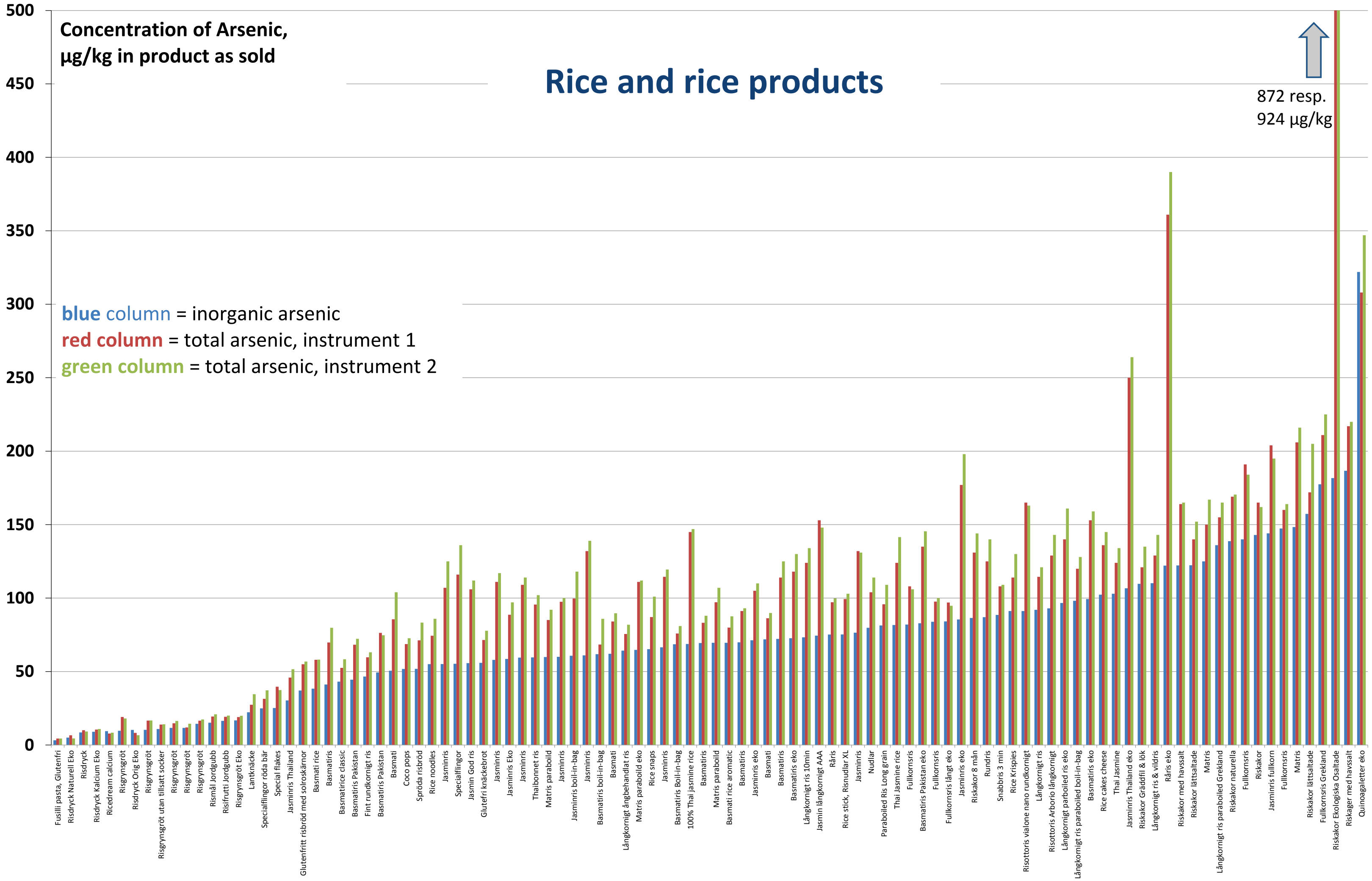

Figure 8. Content of both inorganic (blue bar) and total arsenic (red and green bar). Note that the measured total content for rice cake (ID No. 11) is off the scale. Measured values 872 and 924 µg/kg. Total content of arsenic is measured by ALS Scandinavia AB in Luleå using HR-ICPMS.

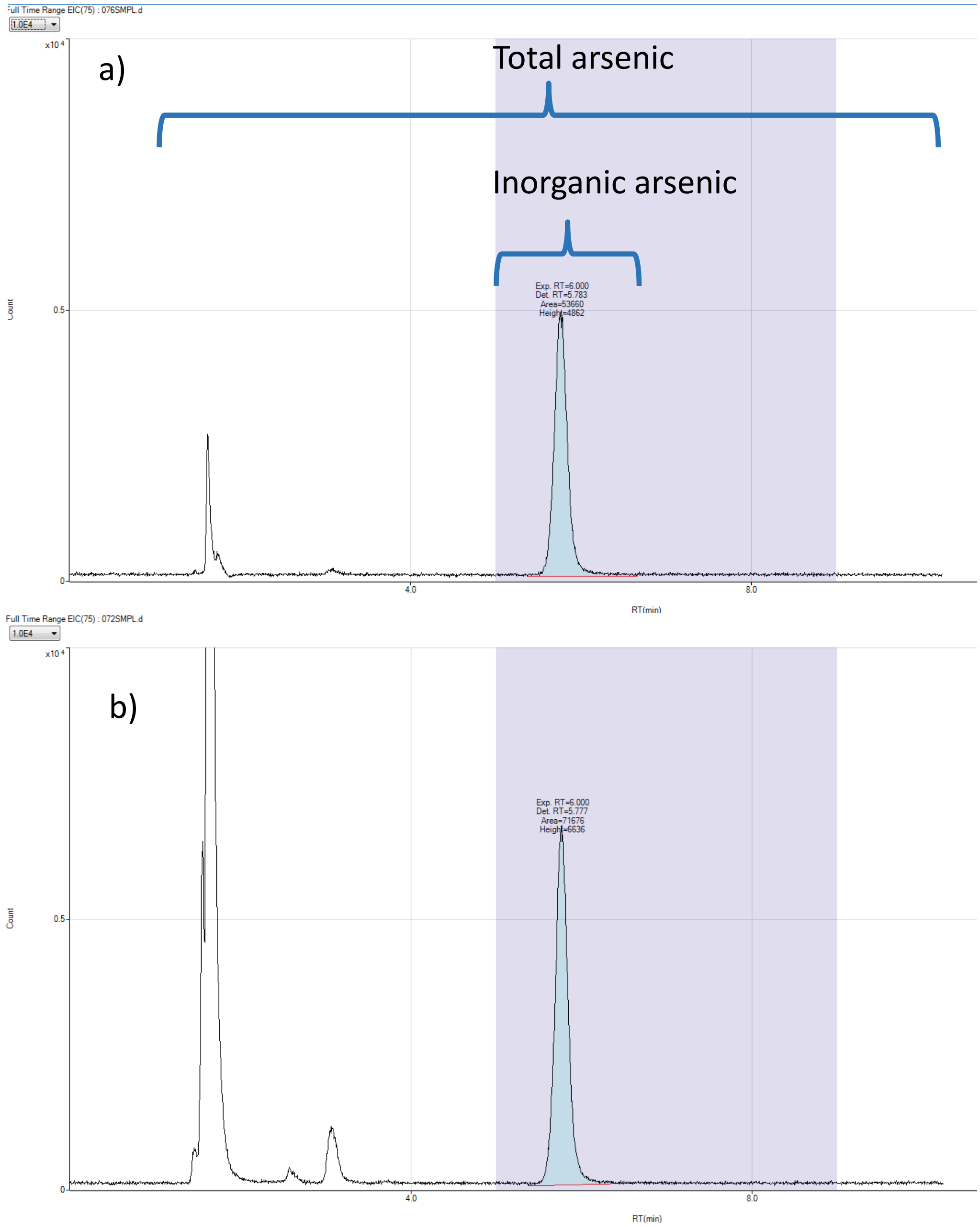

Figure 9. a) Chromatogram of analysis of rice cake (ID No. 15) with high proportion of inorganic arsenic, 87 per cent, corresponding to a content of 143 µg inorganic arsenic/kg. b) Chromatogram of rice cake (ID No. 11) containing a high level of total arsenic, 900 µg/kg. The inorganic arsenic content is 182 µg/kg, corresponding to a proportion of 20 per cent.

The effect of cooking on the arsenic content of rice

The average content of inorganic arsenic in the dry rice taken directly from the pack was 71 (35-114) µg/kg (n=7, excluding red rice) and the content in the tap water used for rinsing and cooking was less than 1 µg/kg. The table salt used in cooking contained 4 µg arsenic/kg salt, which means that as a maximum it can add less than 1 µg arsenic per kg cooked rice. The quantity of red rice purchased was only sufficient for the rinse trial and cooking trial with excess water.

Rinsing rice before cooking

No significant difference could be seen in the content of inorganic arsenic (n=8) before and after 10 seconds rinsing with tap water (Student t-test, $p>0.05$). When the rice was allowed to stand for two hours in the cold rinsing water, the level decreased but the number of samples (n=2) was too low to draw any conclusion from the result.

Cooking in all the water and with excess water

The content of inorganic arsenic decreased significantly when the rice was cooked with an excess of water, which was poured out after the cooking time (Student t-test, $p=0.004$). The average level for rice cooked with an excess of water was 24 µg/kg dry rice, while the average level of inorganic arsenic in rice where all the water was cooked in was 68 µg/kg dry rice. Cooking the rice in the tap water did not change the content of inorganic arsenic compared with the original value before cooking. The rice increased approximately equally in weight regardless of the quantity of water used in cooking. All the reported concentrations are corrected for weight increase because of absorption of water during cooking. For one jasmine rice and for whole grain rice, a double test was made of cooking with excess water. These double tests gave comparable results. Figure 10 shows the results for the various rices. The results show that when cooking with excess water, the content of inorganic arsenic in the cooked rice decreased by 40 to 70 per cent.

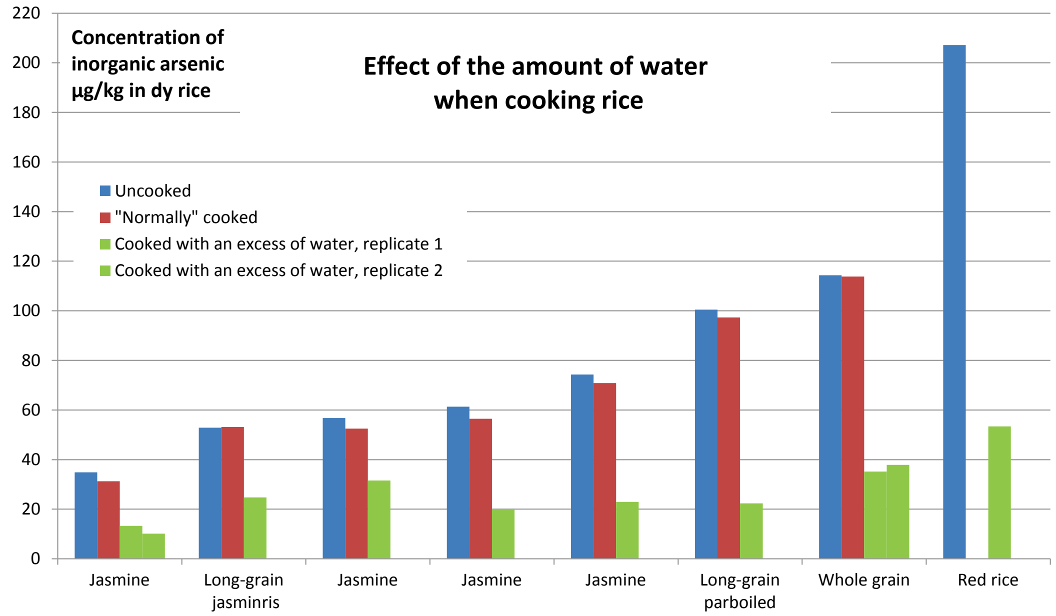

Figure 10. Content of inorganic arsenic in uncooked rice (blue bar), in rice cooked dry (normally cooked rice, red bar) and in rice cooked with an excess of water that is then discarded (green bar). For the cooked rice, the content is calculated back to "dry rice", i.e. corrected for absorption of water during cooking. Red rice was only cooked with excess water.

Content of inorganic arsenic in other foods

The highest levels of inorganic arsenic were found in the food groups Fish (10-21 µg/kg), Cereals (4-15 µg/kg), Fruit (< 2-7) and Sugar and similar (2-12 µg/kg). For the other food groups, most levels were below the limit of detection (1-3 µg/kg). See Table 6. The proportion of inorganic arsenic to total arsenic could only be calculated in the food groups Fish, Cereal, Fruit and Sugar and similar, since these obtained quantifiable results in the Market Basket analysis of total arsenic content (Market Basket 2010). The proportion of inorganic arsenic for Fish was less than 1 per cent in all 9 samples, while the average in the other food groups was between 50 and 100 per cent. Total arsenic content in Fish was between 1000 and 4000 µg/kg, hence the low proportion of inorganic arsenic.

Table 6. Results of analysis of inorganic arsenic in homogenates of different food groups from Market Basket 2010. The food was purchased from COOP (C), ICA (I), Willys (W), Hemköp (H) and Lidl (L). One low-price alternative (1) and one normal-price alternative (2) of each food from each supermarket chain had been purchased, except for Lidl were there was only the low-price alternative.

Sample and food group	Inorganic arsenic µg/kg	Sample and food group	Inorganic arsenic µg/kg
C1:4 Fish	13	C1:9 Fruits	< 2
C2:4 Fish	20	C2:9 Fruits	3
I1:4 Fish	21	I1:9 Fruits	2
I2:4 Fish	11	I2:9 Fruits	3
W1:4 Fish	10	W1:9 Fruits	7
W2:4 Fish	14	W2:9 Fruits	2
H1:4 Fish	11	H1:9 Fruits	2
H2:4 Fish	10	H2:9 Fruits	2
L1:4 Fish	11	L1:9 Fruits, autumn	2
C1:1 Cereal products	11	LH1:9 Fruits, autumn	< 2
C2:1 Cereal products	12	C1H:9 Fruits, autumn	3
I1:1 Cereal products	12	I1H:9 Fruits, autumn	2
I2:1 Cereal products	13	H1H:9 Fruits, autumn	4
W1:1 Cereal products	7	C1:8 Vegetables	< 1
W2:1 Cereal products	8	C2:8 Vegetables	< 1
H1:1 Cereal products	4	I1:8 Vegetables	< 1
H2:1 Cereal products	15	I2:8 Vegetables	< 1
L1:1 Cereal products	14	W1:8 Vegetables	< 1
C1:11 Sugar and sweets	2	W2:8 Vegetables	3
C2:11 Sugar and sweets	4	H1:8 Vegetables	3
I1:11 Sugar and sweets	2	H2:8 Vegetables	< 1
I2:11 Sugar and sweets	3	L1:8 Vegetables	2
W1:11 Sugar and sweets	4	C1H:8 Vegetables, autumn	1
W2:11 Sugar and sweets	12	I1H:8 Vegetables, autumn	2
H1:11 Sugar and sweets	3	W1H:8 Vegetables, autumn	2
H2:11 Sugar and sweets	7	H1H:8 Vegetables, autumn	2
L1:11 Sugar and sweets	3	LH1:8 Vegetables, autumn	2
Food groups with most results below the limit of detection.			
Pasteries	< 3	Egg	< 2
Potatoes	< 3	Dairy products	< 1
Meat	< 2	Beverages	< 1
Fat	< 2		

Discussion

Content levels in rice

Arsenic is a substance that must be avoided as far as possible according to the European Food Safety Authority (Efsa 2009). The purpose of the introduction of maximum levels for inorganic arsenic, is to decrease the consumers' exposure of inorganic arsenic. At the same time, the introduction of maximum levels set on the ALARA (as low as reasonably achievable) principle should not affect trade on global markets to any great extent (maximum around 10 per cent). The purpose of the maximum levels is to force down the levels of inorganic arsenic in rice by influencing producers and importers to work towards achieving rice types that contain lower levels. The maximum levels in the EU are constantly reconsidered so that they can be lowered so as to further reduce the population's exposure. The current maximum levels for rice are between 100 and 250 µg/kg depending on the type of rice. Whole grain and parboiled rice have a maximum level of 250 µg/kg and in this survey the highest measured level of inorganic arsenic was 177 µg/kg. For white and polished rice the maximum level is 200 µg/kg and the highest measured level was 129 µg/kg. It is remarkable that none of the 102 products investigated, which contained relatively high levels of inorganic arsenic, exceeded the new maximum levels. This is an indication that the maximum levels should be set at lower levels so as to fulfil their purpose of forcing down inorganic arsenic levels in rice. Based on the results of our survey, a maximum level set according to the ALARA principle, in which 10 per cent of products exceed the maximum level, could be 100 µg inorganic arsenic/kg for white and polished rice, and 150 µg/kg for whole grain and parboiled rice.

Many newly published and older studies of inorganic arsenic in rice and rice products show similar results. In a study by Pétursdóttir et al 2014, all 44 rices and rice products analysed had levels below the proposed maximum levels. The products were bought in ordinary shops in Aberdeen, Great Britain. Surveys in Denmark in 2013 show that the average and median content levels for 81 samples of white rice were 68 and 67 µg inorganic arsenic/kg respectively and the highest measured value was 220 µg/kg, i.e. barely over the proposed maximum level of 200 µg/kg (Fødevarestyrelsen 2013).

A further example where none of the proposed maximum levels for rice was exceeded is a study by Torres-Escribano et al, which analysed rice sold in Spain in 2007. Of a total of 39 products, 25 were cultivated in Spain and the others were from Asia (5), Italy (5), North America (3) and France (1). The average content for all rice investigated, including 14 samples of brown rice, was 114 +/- 46 µg/kg dry weight, with the highest measured value 253 µg/kg for one brown rice, or in other words precisely at the maximum level of 250 µg/kg for husked rice (including brown and whole grain rice) and parboiled rice.

On behalf of the Food Standards Agency, Meharg 2007 compiled literature on the content of arsenic in rice, both total content and various chemical forms of arsenic including inorganic arsenic. A large number of the results come from the University of Aberdeen, where rice and rice products have been analysed over several years. In Meharg's summary of data, the level of inorganic arsenic in rice seldom exceeds the maximum level of 250 µg/kg. Total arsenic content, on the other hand, can be considerably higher. In white rice produced in the USA, the average total arsenic content was 250 µg/kg (n=174) while Spanish (n=51), Japanese (n=26) and French (n=21) rice all showed an average content of 190 µg/kg. In America, the Food and Drug Administration (FDA) has also performed extensive analysis of rice. Also, in these data (FDA 2013), none of the rices exceeds the European maximum levels for inorganic arsenic in white rice, 200 µg/kg, nor in husked, whole grain and parboiled rice, 250 µg/ kg. On the other hand there is a high proportion of rice that should not be used for baby food since the content exceeds the maximum level for inorganic arsenic in baby food of 100 µg/kg.

Efsa's 2014 summary of European intake of inorganic arsenic via food reports results of analysis of inorganic arsenic in 706 samples of rices. The average content for these rices was 110 µg/kg and the 95th percentile 200 µg/kg. For so-called brown rice (n=94) and parboiled rice (n=70) the 95th percentile was at 250 and 234 µg/kg respectively, which should be compared to the maximum level of 250 µg/kg. The average value was 153 and 117 µg inorganic arsenic/kg respectively. The number of analysis results reported to Efsa for inorganic arsenic is small (about 3,000 results) in comparison with the number of results reported for total arsenic content (about 100,000). To increase the statistical basis in the intake figures for inorganic arsenic, Efsa uses general conversion factors to convert the content of total arsenic to inorganic arsenic. For rice, the assumption is that inorganic arsenic makes up 70 per cent of the total arsenic content, which is comparable with the average value we found in our survey (67 per cent). Thus for the total of 1,112 rices analysed, this gives an average and median of almost 140 and 110 µg inorganic arsenic/kg rice respectively and a 95th percentile of 360 µg/kg. Efsa mentions in the report from 2014 that this conversion of total arsenic content to inorganic gives an uncertainty in the results. This uncertainty is confirmed by our survey, where the range in the proportion of inorganic arsenic in the different rice types was from 30 to 90 per cent. Thus analysing the content of inorganic arsenic rather than using conversion factors gives a safer result.

The results of the studies mentioned above are compiled in Table 7, where average, minimum and maximum content, as well as the 95th percentile, are given for inorganic arsenic in rice and rice products. In this table the white rice group also includes parboiled rice and since parboiled rice often has a higher content of inorganic arsenic, this gives a higher average than would have been the case for untreated white rice alone. In the legislation, parboiled rice is separated from other white rice and has a higher maximum level of 250 µg/kg, instead of the 200 µg/kg that applies for white rice.

Table 7. Summary of some European surveys of inorganic arsenic in rice and rice products.The maximum levels (ML) are included.

			Inorganic arsenic content µg/kg		
Source	**Year**	**n**	**Average**	**Min**	**Max**
White rice all types*				***ML***	***200 (250*)***
Meharg[1]	2007	45	88	10	(220)
Torres-Escribano et al[2]	2007	16	85		
BfR, Germany[3]	2010-11	74	101		*(200**)*
Födevarestyrelsen[4]	2013	81	68	9	(220)
Pétursdóttir et al[5]	2014	75	84		
Efsa 2014[6]	2014	189	89		
Swedish National Food Agency	2015	54	74	30	(148)
Whole grain rice, brown rice and raw rice				***ML***	***250***
Torres-Escribano et al[2]	2007	18	144		
BfR, Germany[3]	2010-11	6	141		*231***
Födevarestyrelsen[4]	2013	15	160	38	550
Pétursdóttir et al[5]	2014	12	116		
Efsa 2014[6]	2014	94	153		*250***
Swedish National Food Agency	2015	9	117	75	177
Rice cakes and rice biscuits				***ML***	***300***
BfR, Germany[3]	2010-11	51	260		*425***
Födevarestyrelsen[4]	2013	27	230	140	350
Signes-Pastor et al[7]	2014	97	106		
Swedish National Food Agency	2015	11	152	86	322
Breakfast products and cereals				***No ML***	
Födevarestyrelsen[4]	2013	14	85	< 2	250
Signes-Pastor et al[7]	2014	53	84		
Swedish National Food Agency	2015	6	52	25	91

*In several studies this also includes parboiled rice, which often contains higher levels of inorganic arsenic. All stated maximum values in the table are for parboiled rice. The maximum level for parboiled rice is 250 µg/kg.
**Represents the 95th percentile in the survey.
[1] Meharg, A.A., Levels of arsenic in rice – literature review, Food Standards Agency contract C101045, UK 2007. Note that this publication refers to analysis of “rice”, unspecified.
[2] Torres-Escribano, Silvia , Mariana Leal , Dinoraz Vélez * and Rosa Montoro, Environ. Sci. Technol., 2008, 42 (10), pp 3867–3872.
[3] BfR 2015, Arsenic in Rice and Rice Products, BfR Opinion No. 018/2015 of 24 June 2014
[4] Fødevarestyrelsen 2013, Inorganic arsenic in rice and rice products, CONTROL RESULTS 2013, Project number 2009-20-64-00159[3] Efsa 2014.
[5] Pétursdóttir, A.H., Friedrich, N., Musil, S., Raab, A., Gunnlaugsdóttir, H., Krupp, E.M., Feldmann, J., Analytical Methods, 2014, 6, 5392-5396.
[6] Efsa Journal 2014;12(3):3597. Dietary exposure to inorganic arsenic in the European population.
[7] Signes-Pastor, Antonio J., Manus Carey, Andrew A. Meharg, Food Chemistry, Article in press 2014.

With the published data that exists for levels of inorganic arsenic in rice and rice products on the European market, it can be stated that the maximum levels that begin to apply in the EU with effect from 1 January 2016 should be a third to a half lower according to the ALARA principle.

No difference in arsenic content depending on country of origin in this study

Of the 63 different rices included in this study, no significant difference could be seen in the level of inorganic arsenic depending on which country the rice came from. This can be explained partly by the fact that a third of the rice has an unknown origin and partly by the fact that for some countries only one rice was analysed. Also, the arsenic content in rice from the same country can vary depending on local variations of bed rock and other cultivation conditions. Some of the rice studied was whole grain rice, which often contains more arsenic than white rice, regardless of country of origin. However the purpose of this study was to survey levels in the rice that can be bought in the Swedish market (2015) not to survey levels depending on country of origin.

Jasmine rice and basmati rice contain lower levels

Almost a third of the rice investigated was jasmine or basmati rice and the inorganic arsenic content was significantly lower in these types compared with the others. The low level in basmati rice is confirmed in other studies, such as Kuramata et al (2013) and Food and Drug Administration (2013), which also shows lower levels for jasmine rice.

Organic rice does not have lower levels

The fact that the organic rice products contain the same levels of inorganic arsenic as conventionally cultivated ones is an expected result. Rice absorbs arsenic from the ground and water and this absorption is dependent on the rice type itself and content in the soil rather than on whether the rice is produced organically or not. The more arsenic there is in the ground where the rice is growing, the more arsenic there will be in the rice grain (see for example Meharg 2012). Arsenic is found in the ground and water all over the world, although the level varies greatly depending on the type of bed rock. In some cases, human influence has contributed to increased levels, for example through the use of pesticides that contain arsenic and with certain types of mining. The pesticides that were previously used have now been phased out in many parts of the world, but there are still places where levels are high following extensive historical use, including in parts of the USA where cotton was previously grown (Williams 2007). In the EU there is no maximum level for arsenic content in soil for organic cultivation. On the contrary, so-called extended transition to organic agriculture can be introduced if there is a suspicion that the ground is contaminated with products that are not approved for organic production (regulation (EC) No. 889/2008). In the case of import of organic food from countries outside the EU, either the country must be approved for export to the EU or the control body that inspects the products outside the EU must be approved (regulation (EC) No. 1235/2008).

Rice cakes have the highest levels

Among the 10 rice and rice products with the highest levels of inorganic arsenic, 7 were rice cakes (out of 11 rice cakes surveyed). The rice cakes analysed in this survey contained levels corresponding approximately to those in the survey performed in 2013 by Fødevarestyrelsen in Denmark. The levels were, however, somewhat lower with an average value of 139 µg/kg (n=11) in our study and 220 µg/kg (n=27) in the Danish one. Fødevarestyrelsen's lowest reported level was 140 µg/kg while three rice cakes in our study had significantly lower levels. The lowest measured level was 86 µg/kg and these rice cakes (ID No. 17) were specifically intended for children aged 8 months and above. This is half of the average content of 152 µg/kg in our study.

Rice drinks - lower levels than in previous studies

The rice drinks contain between 5 and 10 µg inorganic arsenic per kg (n=5). This is somewhat lower than in the survey performed by the Swedish National Food Agency in 2011-2013 (Öhrvik 2013) in which levels were between 18 and 30 µg/kg (n=2). One of the products (ID No. 8) was analysed in both studies and the level in this study is 50 per cent lower. More comprehensive studies are needed before any real conclusion is drawn about a possible general reduction of the level of inorganic arsenic in rice drinks.

Cooking affects the level of arsenic in rice

The results for rice samples from the cooking study have not been included in the results reported above and in Appendix 1. This is because the sampling procedure was different. In the survey, sampling of rice and rice products has been done as far as possible in accordance with the commission's directive (EC) 333/2007 for controls pursuant to current legislation, while only one pack per rice type was purchased for the cooking test. The cooking trial was to study the effect of cooking on arsenic levels in each rice type and therefore no more packs of the same rice type were bought.

The cooking trial was performed in the same way as rice can be prepared in the home, i.e. with tap water and with salt added. The salted water contained less than one µg arsenic per litre. The trial showed that the level of inorganic arsenic decreases significantly when the rice is cooked with excess water that is then poured off. Our results are confirmed by similar studies. The method in the various studies differs, but all of them show that the arsenic content of the rice decreases when the rice is cooked with excess water that contains no or unmeasurable levels of arsenic (Carey 2015, Raab 2009, Rahman 2006, Sengupta 2006, Victor 2010). In some of these studies, deionised water was used in the trial (Carey 2015, Raab 2009, Sengupta 2006, Victor 2010). It is highly probable that deionised water gives a greater migration of ions from rice to water than when tap water is used. This leads in turn to a greater reduction in arsenic content in the cooked rice. Migration of arsenic between rice and water can occur in both directions. In cases where arsenic content is greater in the cooking water, the arsenic content is higher in the cooked rice than before cooking (Rahman 2006, Sengupta 2006, Bae 2002). This is an important aspect for geographical areas where the arsenic content of the water used for cooking is high.

In our study, the arsenic content did not measurably change when the rice was rinsed in cold water before cooking. Other studies have shown, however, that repeated rinsing of various types of rice can lower the arsenic content to a varying degree, as a maximum up to approximately 20 per cent (Raab 2009, Sengupta 2006, Naito 2015).

In three of the eight rice samples, the total arsenic content and some other metals were analysed before and after cooking. In these three samples, the total arsenic content followed the same pattern as inorganic arsenic, i.e. the level is reduced when the rice is cooked with an excess of water that is then poured out. The results indicate that cobalt, molybdenum and nickel are also reduced. Cadmium is also reduced somewhat, although to a lesser extent. Considerably more tests would be needed, however, to clarify the effect of cooking on these other metals (no data are presented in this report).

Rice contains a number of water-soluble vitamins, including niacin equivalents and vitamin B6. It can be assumed that the content of these could be reduced when the rice is cooked with excess water that is then poured out. The contribution of rice to the daily intake of these vitamins, however, is about three per cent of the daily requirement (Amcoff 2012) so the loss when cooking with excess water is not tangible.

Levels in other foods - fish and grain products contain the most arsenic

Analysis of samples from Market Basket 2010, show that Fish and Cereals (grain products) are the two food groups with the highest levels of inorganic arsenic, with an average content of just over 10 µg/kg (see Table 3 for a summary of the Fish and Cereal samples).

The results for the Fish food group, which includes various fish products and shellfish, correspond to the Swedish National Food Agency's analyses of inorganic arsenic in individual samples of herring, mackerel, cod and shellfish muscle (unpublished data). Levels in these fish samples represent some few µg inorganic arsenic/kg while levels in shellfish muscle are between 10 and 80 µg/kg. A major Norwegian/Danish study reported levels of inorganic arsenic in more than 900 individual fish samples (Julshamn 2012). All the samples had levels below 6 µg/kg while total arsenic content is often high (more than 1,000 µg/kg). Shellfish may have varying levels of inorganic arsenic from a few µg/kg to several mg/kg depending on the species of shellfish and where it comes from (see for example Sloth 2008, Zmozinski 2015).

The results for the Cereal food group correspond to other surveys of the foods included in the Cereal group. Pasta, bread and flour together account for almost 80 per cent of the content in the sample, while the proportion of rice is 7 per cent. The contribution of rice to the inorganic arsenic content in this food group is relatively substantial since the level is higher (average 80 µg/kg) than in the other products. For example, a survey of 105 pasta products on the Swedish market in 2014 showed that total arsenic content varied between 4 and 21 µg/kg, with an average of 10 µg/kg (Kollander 2015). No analysis was made of inorganic arsenic in the pasta but literature on the subject shows that similar levels are obtained and that arsenic in wheat consists of practically 100 per cent inorganic arsenic (Zhao 2010, Cubadda 2010, Raber 2012).

Because the inorganic arsenic content in samples from Market Basket 2010 has now been determined, the intake calculations for inorganic arsenic are considerably improved. This is because the measured content can be used instead of, as previously, using theoretical conversion factors to estimate the level of inorganic arsenic from the total content. For example, Efsa's standard value (Efsa 2009) for fish of 100 µg inorganic arsenic/kg fish was previously used; this is at least 10 times higher than the actual value. Another reason why better intake calculations can now be made is that the limit of detection for inorganic arsenic is lower than that for total arsenic. For example the limit of detection for total arsenic in analysis of cereals was 30 µg/kg, while that for inorganic arsenic in this survey was 3 µg/kg. The Market Basket samples have been kept frozen (-20°C) until autumn 2014, when they were defrosted for analysis of inorganic arsenic. Previous studies have shown that storage at –20°C does not affect the relationship between inorganic and organic arsenic in food (see for example Dahl 2010, Pizarro 2003).

The Swedish National Food Agency is now planning its next market basket survey, Market basket 2015. Analysis of inorganic arsenic will also be performed on these samples.

Conclusions

Arsenic is a substance that should be avoided as far as possible. By setting as low a maximum level as possible, the idea is that consumers can be protected as far as possible from toxic substances without the maximum level preventing more than 10 per cent of trade on the global market. None of the 102 products surveyed had a content of inorganic arsenic that exceeded the maximum levels that will come into force with effect from 1 January 2016. This is remarkable, because the maximum levels are set for the purpose of forcing down levels in rice sold on the European market. If no maximum levels are exceeded, there is no incentive for producers and importers to seek other rice types and rice products with lower levels.

In general it can be stated that the rice cakes have the highest levels of inorganic arsenic, followed by whole grain and raw rice. Basmati and jasmine rice have a significantly lower inorganic arsenic content than other types of rice. Fresh rice products such as rice porridge, rice porridge snacks and rice drinks contain inorganic arsenic in corresponding quantities when converted to dry rice.

The results showed that there was no significant difference in arsenic content between organic and conventionally cultivated products in terms of occurrence of inorganic arsenic. Neither can any difference in arsenic content be found in this study due to the country of origin of the rice.

The inorganic arsenic content can be reduced by 40 to 70 per cent if the rice is cooked with an excess of water, compared with cooking until the rice is dry of water.

The food groups with the highest levels of inorganic arsenic were Fish and Cereals. In the food groups Meat, Egg, Dairy, Cooking fat, Bakery, Soft drinks, Vegetables and Potatoes, the level of inorganic arsenic was below the limit of detection for the analytical method.

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References

Amcoff E., Edberg A., Enghardt Barbieri H., Lindroos AK., Nälsén C., Pearson M., Warensjö Lemming E., Riksmaten – vuxna 2010–11. Livsmedels- och näringsintag bland vuxna i Sverige. Swedish National Food Agency, Uppsala (2012)

Bae M., Watanabe C., Inaoka T., Sekiyama M., Sudo N., Bokul M.H., Ohtsuka R., Arsenic in cooked rice in Bangladesh. Lancet. 2002 Dec 7; 360(9348):1839-40. Erratum in: Lancet. 2002 Mar 22; 361(9362):1060.

BfR 2015, Arsenic in Rice and Rice Products, BfR Opinion No. 018/2015 of 24 June 2014.

Carey M., Jiujin X., Gomes Farias J., Meharg A.A., Rethinking Rice Preparation for Highly Efficient Removal of Inorganic Arsenic Using Percolating Cooking Water. PLoS One. 2015 Jul 22; 10(7)

Commission Recommendation on the monitoring of arsenic in food, SANTE/10258/2015, European Commission 2015.

Cubadda, F., Ciardullo, S., D'Amato, M., Raggi, A., Aureli, F., Carcea M., Arsenic contamination of the environment-food chain: a survey on wheat as a test plant to investigate phytoavailable arsenic in Italian agricultural soils and as a source of inorganic arsenic in the diet, J Agric Food Chem. 2010 Sep 22;58(18):10176-83.

Dahl, L., Molin, M., Amlund, H., Meltzer, H. M., Julshamn, K., Alexander, J., Sloth, J. J., Stability of arsenic compounds in seafood samples during processing and storage by freezing, Food Chem. 123 (2010) 720.

Efsa Journal 2009; 7(10):1351, Efsa Panel on Contaminants in the Food Chain (CONTAM); Scientific Opinion on Arsenic in Food.

Efsa Journal 2014; 12(3):3597. Dietary exposure to inorganic arsenic in the European population.

EC regulation 333/2007 - laying down the methods of sampling and analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuffs.

ECregulation 834/2007 - on organic production and labelling of organic products.

EC regulation 889/2008 - on organic production and labelling of organic products.
EC regulation 1235/2008 - detailed rules for implementation of Council Regulation (EC) No 834/2007 as regards the arrangements for importing organic products from third-party countries.

EN15763 Foodstuffs - Determination of trace elements - Determination of arsenic, cadmium, mercury and lead in foodstuffs by inductively coupled plasma mass spectrometry (ICP-MS) after pressure digestion.

Eneroth, Å., ”Sammanställning av kartläggning av oorganisk arsenik i risbaserad barnmat”, unpublished report No. 892/2011, Swedish National Food Agency 2011.

Engström E., Stenberg A., Senioukh S., Edelbro R., Baxter D.C., Rodushkin, I., Multi-elemental characterization of soft biological tissues by inductively coupled plasma–sector field mass spectrometry. Analytica Chimica Acta. 521(2):123-135 (2004)

Food and Drug Administration 2013, Analytical Results from Inorganic Arsenic in Rice and Rice Products Sampling, USA, September 2013.

Food Standards Agency 2007. Survey of metals in weaning foods and formulae for infants - Additional information on inorganic arsenic and methyl mercury levels. Food Surveillance Information Sheet 03/07, UK 2007.

Fødevarestyrelsen 2013, Uorganisk arsen i ris og risprodukter, KONTROLRESULTATER 2013, Project number 2009-20-64-00159.

Jorhem, L., Åstrand, C., Sundström, B., Baxter, M., Stokes, P., Lewis, J., Grawe, K.P., Elements in rice from the Swedish market: Part 1. Cadmium, lead and arsenic (total and inorganic), Food Additives and Contaminants, March 2008; 25(3): 284–292.

Julshamn, K., Nilsen, B., Frantzen, S., Valdersnes, S., Maagea, A., Nedreaas, K., Sloth, J., Total and inorganic arsenic in fish samples from Norwegian waters, Food Additives and Contaminants: Part B, Vol. 5, No. 4, December 2012, 229–235.

Kollander, B., Pettersson, J., Roduskhin, I., Analysis of cadmium, arsenic, lead, molybdenum, selenium and iron in pasta products by high resolution ICP-MS, presented at the European Conference on Plasma Spectrochemistry, Münster, Germany, February 2015.

Kuramata, M., Abe1, T., Kawasaki, A., Ebana, K., Shibaya, T., Yano, M., Ishikawa, S., Genetic diversity of arsenic accumulation in rice and QTL analysis of methylated arsenic in rice grains. Rice 2013, 6:3.

Market Basket 2010 – chemical analysis, exposure estimation and health-related assessment of nutrients and toxic compounds in Swedish Market basket, Swedish National Food Agency report serial number 7/2012, Uppsala, 2012.

Meharg, A.A., Levels of arsenic in rice – literature review, Food Standards Agency contract C101045, UK 2007.

Meharg, A.A., Zhao, F-J., Arsenic and Rice, Springer Dordrecht Heidelberg London New York, 2012. ISBN: 978-94-007-9655-3.

Mihucza, V.G., Silversmitc, G., Szalókid, I., de Samberc, B., Schoonjansc, T., Tatára, E., Vinczec, L., Virága, I., Yaoe, J., Záraya, G., Removal of some elements from washed and cooked rice studied by inductively coupled plasma mass spectrometry and synchrotron based confocal micro-X-ray fluorescence. 2010. Food Chemistry, 121, 290-297.

Naito S., Matsumoto E., Shindoh K., Nishimura T.. Effects of polishing, cooking, and storing on total arsenic and arsenic species concentrations in rice cultivated in Japan. Food Chem. 2015 Feb 1;168:294-301.

NMKL 186, Trace elements - As, Cd, Hg, Pbin food. Determination by ICP-MS after pressure digestion, NMKL 2007.

Pétursdóttir, A.H., Friedrich, N., Musil, S., Raab, A., Gunnlaugsdóttir, H., Krupp, E.M., Feldmann, J., Hydride generation ICP-MS as a simple method for determination of inorganic arsenic in rice for routine biomonitoring, Analytical Methods, 2014, 6, 5392-5396.

Pizarro, I., Gómez, M., Cámara, C., Palacios, M. A., Arsenic speciation in environmental and biological samples Extraction and stability studies, Anal. Chim. Acta 495 (2003) 85.

prEN 16802 Foodstuffs - Determination of elements and their chemical species - Determination of inorganic arsenic in food of marine and plant origin by anion exchange HPLC-ICP-MS following waterbath extraction. CEN 2015.

Raab A., Baskaran C., Feldmann J., Meharg A.A., Cooking rice in a high water to rice ratio reduces inorganic arsenic content. J Environ Monit. 2009 Jan;11(1):41-4.

Raab, A.,Feldman, J., Meharg, A.A., Levels of arsenic – the effects of cooking. Food Standards Agency contract C01049, UK 2009.

Raber, G., Stock, N., Hanel, P., Murko, M., Navratilova, J., Francesconi, K.A., An improved HPLC–ICPMS method for determining inorganic arsenic in food: Application to rice, wheat and tuna fish, Food Chemistry 134 (2012) 524–532.

Rahman, M.A., Hasegawa, H., Rahman, M.A., Rahman, M.M., Miah, M.A., Influence of cooking method on arsenic retention in cooked rice related to dietary exposure. Sci Total Environ. 2006 Oct 15; 370(1):51-60. Epub 2006 Jul 11.

Sengupta, M.K., Hossain, M.A., Mukherjee, A., Ahamed, S., Das, B., Nayak, B., Pal A., Chakraborti D. Arsenic burden of cooked rice: Traditional and modern methods. Food Chem Toxicol. 2006 Nov; 44(11):1823-9. Epub 2006 Jun 28.

Sloth, J., (2013), Determination of inorganic arsenic in food of marine and plant origin – report from collaborative trial, manuscript.

Sloth, J., Julshamn, K., Survey of Total and Inorganic Arsenic Content in Blue Mussels (Mytilus edulis L.) from Norwegian Fiords: Revelation of Unusual High Levels of Inorganic Arsenic, J.Agri.Food Chem., 56. 1269-1273 (2008)

Signes-Pastor, A.J., Carey, M., Meharg, A.A., Inorganic arsenic in rice-based products for infants and young children. Food Chemistry 191, 128–134 (2015)

Torres-Escribano, S., Leal, M., Vélez, D., Montoro, R., Total and Inorganic Arsenic Concentrations in Rice Sold in Spain, Effect of Cooking, and Risk Assessments, Environ. Sci. Technol., 2008, 42 (10), 3867–3872.

Tyson, J., The Determination of Arsenic Compounds: A Critical Review, Analytical Chemistry, Volume 2013 (2013), Article ID 835371, 24 pages.

Williams, P.N., Raab, A., Feldmann, J., Meharg, A.A., Market basket survey shows elevated levels of As in South Central U.S. processed rice compared to California: consequences for human dietary exposure. Environ Sci Technol. 2007 Apr 1; 41(7):2178-83.

Zhao, F.J., Stroud, J.L., Eagling, T., Dunham, S.J., McGrath, S.P., Shewry, P.R., Accumulation, distribution, and speciation of arsenic in wheat grain. Environ Sci Technol. 2010 Jul 15; 44(14):5464-8.

Zmozinski, A.V., Llorente-Mirandes, T., López-Sánchez, J.F., da Silva, M.M., Establishment of a method for determination of arsenic species in seafood by LC-ICP-MS, Food Chemistry 173 (2015) 1073–1082.

Öhrvik, V., Engman, J., Kollander, B., Sundström, B., Contaminants and minerals in foods for infants and young children. Part 1: Analytical results, Swedish National Food Agency report series 1/2013, Uppsala, 2013.

Appendix 1. Products included in this project and analysis results.

Information from packs and content of inorganic arsenic and total arsenic. For the latter, two separate measurements have been made for the same samples. Measurement uncertainty in the analysis results is approximately +/- 30 % and the limit of detection 1-3 µg/kg. Note that the origin of the product is not always stated on the pack.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best be-fore	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Instr.2
Basmati rice classic	**1**	Indian grate	1 kg	1		No D-1400 (CB AD BE) (033-B-GAG-020), 'MAR 2014	Feb 17	IN	Rice	Basmati rice	**43**	**53**	**58**
100 % Thai jasmine rice	**2**	Royal umbrella	5 kg	2		NL 05 00539 291057 Lot:7564	end Octo-ber 2016	TH	Rice	Jasmine rice	**69**	**145**	**147**
Rice stick, Risnudlar XL	**3**	--	400 g	3	Item No. 5141 - 30*400g		30-09-2016	TH	Noodles		**75**	**99**	**103**
Risifrutti Jordgubb	**4**	Risifrutti	175 g	6	Jam analysed separately Only rice		16-04-2015 H 12:35	-	Rice porridge snack		**16**	**19**	**20**
Jordgubbssylt	**4S**	Risifrutti			Jam		--	-	Jam in rice porridge snack		**2**	**-**	**-**
Rismål jordgubb	**5**	ICA	175 g	6	Jam analysed separately Only rice		04. 05. 2015 059 L494 08:18	-	Rice porridge snack		**15**	**19**	**21**
Jordgubbsylt	**5S**	ICA			Jam			-	Jam in rice porridge snack		**3**	**-**	**-**
Risdryck	**6**	Alpro	1 l	2		M522815:25 02 000	21.09.15	-	Drinks		**9**	**10**	**9**
Ricedream Calcium	**7**	Rice Dream	1 l	2		308 08:16:14 M1	03.11.2015	-	Drinks		**9**	**8**	**8**
Risdryck Orig Eko	**8**	Rice Dream	1 l	4		302 08:14:55 M1	29.10.2015	-	Drinks		**10**	**8**	**7**
Spröda risbröd	**9**	OLDA	65 g	16		3010	2016	-	Bread		**52**	**71**	**83**

Appendix 1 continued. Products included in this project and analysis results.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best be-fore	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Instr.2
Glutenfri knäckebrot	**10**	Wasa	275 g	4	Rice flour, maize flour	Co2304375 10:32	31.12.2015 L12	-	Bread		**56**	**72**	**78**
Riskakor Ekologiska Osaltade	**11**	Friggs	130 g	8	Raw rice, raw materials non-EU	B2	12012016	-	Rice cakes		**182**	**872**	**924**
Quinoagaletter eko	**12**	URTEKRAM	100 g	10	Whole grain rice 90 %, quinoa 7 % unhusked sesame seeds	23 02 2015	23 11 2015	-	Rice cakes		**322**	**308**	**347**
Riskakor lättsaltade	**13**	ICA I love eco	100 g	10		08:43A1NL 008	08-01-2016	-	Rice cakes		**122**	**140**	**152**
Riskakor Gräddfil & Lök	**14**	ICA	130 g	8	Whole grain rice	15 006 22:48 C2	08 10 15	-	Rice cakes		**110**	**121**	**135**
Riskakor	**15**	ICA Basic	100 g	10	Rice	13:29 B1NL 019	19-01-2016	-	Rice cakes		**143**	**165**	**162**
Lantknäcke	**16**	Semper	230 g	5	Includes rice flour		02 10 2015	-	Bread		**22**	**27**	**35**
Riskakor 8 mån	**17**	Hipp	40 g	10	Rice, whole grain rice	14 336 15:15 C5	03 11 15	-	Rice cakes		**86**	**131**	**144**
Coco Pops	**18**	Kellogg´s	375 g	3	Rice	44 23:08 MC	3 different best before dates: 17 01 16, 16 01 16, 09 12 15	-	Breakfast cereals		**52**	**69**	**73**
Rice Krispies	**19**	Kellogg´s	375 g	3	Rice, puffed and roasted	44 02:36 MC	21 01 16	-	Breakfast cereals		**91**	**114**	**130**
Specialflingor röda bär	**20**	ICA	375 g	3	Rice, whole grain wheat	013 19:06	14.01.2016	Prod. DE	Breakfast cereals		**25**	**31**	**37**
Rice Noodles	**21**	Santa Maria	250 g	4		14374 3ZD3	13-12-2016	-	Noodles		**55**	**74**	**86**
Fusilli pasta, Gluten-fri	**22**	Semper	500 g	2	Maize-rice starch	L5034C(D34) 00:12	03-02-2017		Pasta		**3**	**4**	**4**
Fullkornsris	**23**	Uncle Ben´s	1 kg	2			12 01 16 B	-	Rice	Whole grain rice	**82**	**108**	**106**

Appendix 1 continued. Products included in this project and analysis results.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best before	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Total arsenic µg/kg Instr.2
Jasminris	**24**	Uncle Ben´s	1 kg	2			06 08 17 B	-	Rice	Jasmine rice	**66**	**115**	**120**
Basmatiris	**25**	Uncle Ben´s	1 kg	2			17 07 17 C	-	Rice	Basmati rice	**41**	**70**	**80**
Långkornigt Ris 10 min	**26**	Uncle Ben´s	1 kg	2			06 08 17 C	-	Rice	Long grain rice	**73**	**124**	**134**
Snabbris 3 min.	**27**	Uncle Ben´s	350 g	3			22 07 16 B	-	Rice	Long grain rice	**89**	**108**	**109**
Jasminris	**28**	ICA	2 kg	2		255776/928 A5E1400366 (44) BV 071 WD 05 00366 08/01/58 04 11:19:57	17-jan	TH	Rice	Jasmine rice	**55**	**107**	**125**
Basmatiris boil-in-bag	**29**	ICA	500 g	2		13:25	2026-01-17	IN/PK	Rice	Basmati rice	**62**	**68**	**86**
Matris parboiled eko	**30**	Kung markatta	750 g	2			23-01-2017	IT	Rice	Normal rice	**65**	**111**	**112**
Jasminris	**31**	ICA Basic	2 kg	2		246409/643 A5E1400366(37) 071 WD 0500366 01.12.57 04 13:11:00	Dec 16	TH	Rice	Jasmine rice	**58**	**111**	**117**
Matris Parboiled	**32**	ICA Basic	2 kg	2		LO42D	82 016	IT?	Rice	Long grain rice	**60**	**85**	**92**
Råris	**33**	Frebaco	600 g	2			5022016	EU/ North America	Rice	Whole grain rice	**75**	**97**	**100**
Basmatiris eko	**34**	ICA I love eco	1 kg	2				IN	Rice	Basmati rice	**73**	**118**	**130**
Matris parboiled	**35**	ICA	1 kg	2		L041D	82 016	IT?	Rice	Long grain rice	**70**	**97**	**107**
Jasminris eko	**36**	ICA I love eco	1 kg	2		10:26 21603	02 02 2016 L8	-	Rice	Jasmine rice	**59**	**89**	**97**
Risgrynsgröt	**37**	Felix	500 g	2		18:30 M4061	14 04 2015	-	Porridge		**10**	**17**	**17**
Risgrynsgröt	**38**	ICA	500 g	2		03.03.2015	04.04.2015	-	Porridge		**12**	**12**	**15**

Appendix 1 continued. Products included in this project and analysis results.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best before	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Total arsenic µg/kg Instr.2
Risgrynsgröt utan tillsatt socker	**39**	Lecora	500 g	2		Lot 4853	31032015	-	Porridge		**11**	**14**	**14**
Basmatiris Pakistan	**40**	Habib	2 kg	2		WF4295D13:03	Oct 2016	PK	Rice	Basmati rice	**49**	**76**	**75**
Basmatiris boil-in-bag	**41**	Eldorado	500 g	2		Y22 15:10	72 016	IN/PK	Rice	Basmati rice	**69**	**76**	**81**
Basmatiris eko	**42**	Garant	1 kg	2		15.034 194 14	30 FEB 2017	PK	Rice	Basmati rice	**83**	**135**	**146**
Basmatiris	**43**	Garant	1 kg	2		15. 023. 237 14	30-jan-17	PK	Rice	Basmati rice	**44**	**68**	**72**
Jasminris boil-in-bag	**44**	Eldorado	500 g	2		Y08 18:58	72 016	Asian	Rice	Jasmine rice	**61**	**100**	**118**
Jasminris eko	**45**	Garant	1 kg	2		15. 043 258 14	Feb 17	TH	Rice	Jasmine rice	**107**	**250**	**264**
Jasminris	**46**	Garant	1 kg	2		15. 049. 256 14	30. FEB.2017	TH	Rice	Jasmine rice	**30**	**46**	**52**
Fullkornsris	**47**	Garant	1 kg	2	Unpolished long grain rice	14. 348. 1. 235 14	30-dec-16	GR	Rice	Whole grain rice	**177**	**211**	**225**
Långkornigt ris parboiled boil-in-bag	**48**	Eldorado	500 g	2		Z09 06:16	62 016	-	Rice	Long grain rice	**98**	**120**	**128**
Långkornigt ris parboiled Grekland	**49**	Garant	1 kg	2		14 352 212 14	30-dec	GR	Rice	Long grain rice	**136**	**155**	**165**
Riskakor Lättsaltade	**50**	Garant	130 g	8	Raw rice	15 028 1835 C3	29 01 16	IT	Rice cakes		**157**	**172**	**205**
Risdryck Kalcium eko	**51**	URTEKRAM	1 l	2		260 00:52:03 M2	17. 09. 2015 0	-	Drinks		**9**	**11**	**11**
Risdryck Naturell eko	**52**	URTEKRAM	1 l	2		302 05:09:49 M1	29. 10. 2015 0	-	Drinks		**5**	**7**	**4**
Jasminris eko	**53**	Kung Markatta	500 g	2			31-10-2016	KH	Rice	Jasmine rice	**85**	**177**	**198**
Fullkornsris långt eko	**54**	Kung Markatta	750 g	2			06-11-2016	IT	Rice	Whole grain rice	**84**	**97**	**95**
Risottoris vialone nano rundkornigt	**55**	ARCO	1 kg	2	No Swedish labelling	LOT14RN	19 11 16	IT?	Rice	Risotto rice	**91**	**165**	**163**
Risottoris arborio långkornigt	**56**	ARCO	1 kg	2	No Swedish labelling	LOT14SB	27 11 16	IT?	Rice	Risotto rice	**93**	**129**	**143**
Risgrynsgröt eko	**57**	Änglamark	500 g	2		20-02-2015	03-04-2015	-	Porridge		**17**	**19**	**20**

Appendix 1 continued. Products included in this project and analysis results.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best before	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Instr.2
Risgrynsgröt	**58**	COOP	1 kg	2		03.03.2015	04.04.2015	-	Porridge		**14**	**17**	**17**
Långkornigt ris & Vildris	**59**	COOP	1 kg	2	15% wild rice 85% long grain rice without husk	16 20	S 17 05 2016	-	Rice	Long grain rice	**110**	**129**	**143**
Långkornigt ris	**60**	COOP	2 kg	2		05 02	W 23 06 2016	-	Rice	Long grain rice	**92**	**115**	**121**
Basmatiris eko	**61**	Änglamark	1 kg	2		L31LOT:23114M 13:00	28.01.2016	PK	Rice	Basmati rice	**99**	**153**	**159**
Basmatiris	**62**	COOP	2 kg	2		16 46 U23	62 016	-	Rice	Basmati rice	**69**	**83**	**88**
Jasminris eko	**63**	Änglamark	1 kg	2		L31LOT:21603 11:56	02.02.2016	-	Rice	Jasmine rice	**71**	**105**	**110**
Jasminris	**64**	COOP	2 kg	2		07 04 W	28 06 2016	-	Rice	Jasmine rice	**76**	**132**	**131**
Råris eko	**65**	Änglamark	1 kg	2		LOT:22437 13:13 L31,12 month before best before	29.01.2016	-	Rice	Whole grain rice	**122**	**361**	**390**
Långkornigt parboiled ris eko	**66**	Änglamark	1 kg	2		LOT:23063M 08:50 L31	28.01.2016	-	Rice	Long grain rice	**97**	**140**	**161**
Riskakor med havssalt	**67**	Änglamark	100 g	10	Raw rice	YAR9C, '12-01-2015	12-01-2016	-	Rice cakes		**122**	**164**	**165**
Risgrynsgröt	**68**	Eldorado	1 kg	2			20-04-2015	-	Porridge		**10**	**19**	**18**
Risgrynsgröt	**69**	Chef select	1 kg	2		05-03-2015	06-04-2015	-	Porridge		**12**	**15**	**16**
Basmati	**70**	Golden sun	1 kg	2		Wo. 48749 13:45	30-11-2016	IN	Rice	Basmati rice	**72**	**86**	**90**
Basmati rice aromatic	**71**	Premieur	500 g	2		L34 22200 17:14	22-04-2016	-	Rice	Basmati rice	**70**	**80**	**88**
Parboiled Rice Long grain	**72**	Golden sun	2 kg	2		L 09/10/16 05:19 6	2009-10-16	Manuf. IT	Rice	Long grain rice	**81**	**96**	**109**
Thai Jasmine rice	**73**	Premieur	500 g	2		L 34 22205 20:10	20-04-2016	TH	Rice	Jasmine rice	**82**	**124**	**142**
Thai Jasmine	**74**	Golden sun	1 kg	2	Long grain		1930-01-17	TH	Rice	Jasmine rice	**103**	**124**	**134**

Appendix 1 continued. Products included in this project and analysis results.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best before	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Total arsenic µg/kg Instr.2
Jasminris fullkorn	**75**	Kung Markatta	500 g	2			23-01-2017	TH	Rice	Whole grain rice	**144**	**204**	**195**
Fullkornsris	**76**	ICA	1 kg	2		L014D072016	07-2016	EU	Rice	Whole grain rice	**84**	**98**	**100**
Långkornigt ångbehandlat ris	**77**	Rice market	1 kg	2		L350D 06 2016	06-2016	Prod. IT	Rice	Long grain rice	**64**	**76**	**82**
Fullkornsris	**78**	COOP	1 kg	2		U03 06 2016 00:53	03-06-2016	-	Rice	Whole grain rice	**147**	**160**	**164**
Nudlar	**79**	BÁN PHO'THU'O'NG HANG	400 g	3			03-06-2016	TH	Noodles		**80**	**104**	**114**
Riskager med havsalt	**80**	DK:Gamle Mölle	125 g	8	Brown rice	133.6 10:11	07-05-2016	-	Rice cakes		**187**	**217**	**220**
Rice cakes cheese	**81**	Snacky Cracky	120 g	9	Rice	10:22A3NL 352	18-10-2015	Manuf. NL	Rice cakes		**102**	**136**	**145**
Riskakor naturella	**82**	COOP	100 g	10	Raw rice	JBR9C, 09-02-2015	09-02-2016	-	Rice cakes		**139**	**169**	**171**
Specialflingor	**83**	Eldorado	500 g	2		344 13:53	10-12-2015	Prod. DE	Breakfast cereals		**55**	**116**	**136**
Special flakes	**84**	COOP	500 g	2		14-11-2014 08:33	15-11-2015	-	Breakfast cereals		**25**	**40**	**37**
Rice snaps	**85**	Crownfield	500 g	2		6561576 348 17:33	14-12-2015		Breakfast cereals		**65**	**87**	**101**
Glutenfritt risbröd med solroskärnor	**86**	PEMA	375 g	2	Whole grain rice, millet, buckwheat, maize	L142460759	28-04-2015	Prod. DE	Bread		**37**	**55**	**57**
Jasminris	**87**	SEVAN	5 kg	2				TH	Rice	Jasmine rice	**61**	**132**	**139**
Jasmin God Ris	**88**	SRP	10 kg	1		19-02-2015	02-2017	-	Rice	Jasmine rice	**56**	**106**	**112**
Jasmin långkornigt AAA	**89**	Sun Boat Brand	10 kg	1	Thai hom mali rice	Lot 18M1?	28-06-2016	TH	Rice	Jasmine rice	**74**	**153**	**148**
Basmati	**90**	Akash	5 kg	2		L10 B/B Nov 2016 14322 18:57, 01-11-2016	01-11-2016	-	Rice	Basmati rice	**51**	**86**	**104**

Appendix 1 continued. Products included in this project and analysis results.

Product	ID	Brand	Weight of pack	Number of packs	Comments	Batch and/or packing day	Best before	Origin	Group	Subgroup	Inorganic arsenic µg/kg	Total arsenic µg/kg Instr.1	Instr.2
Basmati	**91**	Tilda	4 kg	2		L10 B/B Nov 2016 14323 03:33, 01-11-2014	01-11-2016	-	Rice	Basmati rice	**62**	**84**	**90**
Jasminris	**92**	Budget	2 kg	2		51	2012-12-16	TH	Rice	Jasmine rice	**59**	**109**	**114**
Matris	**93**	Budget	2 kg	2	Parboiled, long grain from 2 batches	0049; 0050	20-11-2016; 11-12-16	TH	Rice	Long grain rice	**125**	**150**	**167**
Basmatiris	**94**	Budget	2 kg	2	Polished rice	L9 10:26 LOT 22619	2012-06-16	PK/IN	Rice	Basmati rice	**70**	**91**	**93**
Jasminris	**95**	Favorit	1 kg	2	Thai hom mali rice		21-02-2016;14-08-2016	TH	Rice	Jasmine rice	**60**	**98**	**100**
Basmatiris	**96**	Favorit	1 kg	2		L12 22608 11:18	01-06-2016	PK/IN	Rice	Basmati rice	**72**	**114**	**125**
Matris	**97**	Favorit	1 kg	2	Long grain parboiled rice		19-09-2016	TH	Rice	Long grain rice	**148**	**206**	**216**
Rund ris	**98**	El Doha	1 kg	2		11-2014	11-2016	EG	Rice	Round rice	**87**	**125**	**140**
Fint rundkornigt ris	**99**	Chicco Chef	1 kg	2			1-GIU (June)-16; 13-LUG (July)-16	IT	Rice	Round rice	**47**	**60**	**63**
Basmati rice	**100**	DA AWAT	1 kg	2		LOT (A1) 90015494, 18/07/2014 22:58	06/2016	IN	Rice	Basmati rice	**38**	**58**	**58**
Thaibonnet ris	**101**	SEVAN	1 kg	2	Slightly less sticky		14-LUG (July)-16	IT	Rice	Long grain rice	**60**	**96**	**102**
Fullkornsris	**102**	Favorit	2 kg	2		L9 12:54 LOT 22658; L9 16:05 LOT 22658	11-06-16; 16-06-16	Southern Europe	Rice	Whole grain rice	**140**	**191**	**184**

Rapporter som utgivits 2014

1. Exponeringsuppskattningar av kemiska ämnen och mikrobiologiska agens – översikt samt rekommendationer om arbetsgång och strategi av S Sand, H Eneroth, B-G Ericsson och M Lindblad.
2. Fusariumsvampar och dess toxiner i svenskodlad vete och havre – rapport från kartläggningsstudie 2009-2011 av E Fredlund och M Lindblad.
3. Colorectal cancer-incidence in relation to consumption of red or precessed meat by PO Darnerud and N-G Ilbäck.
4. Kommunala myndigheters kontroll av dricksvattenanläggningar 2012 av C Svärd, C Forslund och M Eberhardson.
5. Kontroll av bekämpningsmedelsrester i livsmedel 2011 och 2012 av P Fohgelberg, A Jansson och H Omberg.
6. Vad är det som slängs vid utgånget hållbarhetsdatum? – en mikrobiologisk kartläggning av utvalda kylvaror av Å Rosengren.
7. Länsstyrelsernas rapportering av livsmedelskontrollen inom primärproduktionen 2012 av L Eskilson och S Sylvén.
8. Riksmaten – vuxna 2010-2011, Livsmedels- och näringsintag bland vuxna i Sverige av E Amcoff, A Edberg, H Enghart Barbieri, A K Lindroos, C Nälsén, M Pearson och E Warensjö Lemming.
9. Matfett och oljor – analys av fettsyror och vitaminer av V Öhrvik, R Grönholm, A Staffas och S Wretling.
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14. Kommuners och Livsmedelsverkets rapportering av livsmedelskontrollen 2013 av L Eskilsson och M Eberhardson.
15. Rapport från workshop 27-28 november 2013. Risk- och sårbarhetsanalys – från jord till bord. Samman-fattning av presentationer och diskussioner.
16. Risk- och nyttovärdering av nötter – sammanställning av hälsoeffekter av nötkonsumtion av J Bylund, H Eneroth, S Wallin och L Abramsson-Zetterberg.
17. Länsstyrelsernas rapportering av livsmedelskontrollen inom primärproduktionen 2013 av L Eskilson, S Sylvén och M Eberhardson.
18. Bly i viltkött – ammunitionsrester och kemisk analys, del 1 av B Kollander och B Sundström, Livsmedelsverket, F Widemo, Svenska Jägareförbundet och E Ågren, Statens veterinärmedicinska anstalt.

    Bly i viltkött – halter av bly i blod hos jägarfamiljer, del 2 av K Forsell, I Gyllenhammar, J Nilsson Sommar, N Lundberg-Hallén, T Lundh, N Kotova, I Bergdahl, B Järvholm och P O Darnerud.

    Bly i viltkött – riskvärdering, del 3 av S Sand och P O Darnerud.

    Bly i viltkött – riskhantering, del 4 av R Bjerselius, E Halldin Ankarberg och A Kautto.
19. Bra livsmedelsval baserat på nordiska näringsrekommendationer 2012 av H Eneroth, L Björck och Å Brugård Konde.
20. Konsumtion av rött kött och charkuteriprodukter och samband med tjock- och ändtarmscancer – risk och nyttohanteringsrapport av R Bjerselius, Å Brugård Konde och J Sanner Färnstrand.
21. Kontroll av restsubstanser i levande djur och animaliska livsmedel. Resultat 2013 av I Nordlander, B Aspenström-Fagerlund, A Glynn, A Törnkvist, T Cantillana, K Neil Persson, Livsmedelsverket och K Girma, Jordbruksverket.
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23. The Risk Thermometer – a tool for comparing risks associated with food consumption, draft report by S Sand, R Bjerselius, L Busk, H Eneroth, J Sanner Färnstrand and R Lindqvist.
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1. Spannmål, fröer och nötter -Metaller i livsmedel, fyra decenniers analyser av L Jorhem, C Åstrand, B Sundström, J Engman och B Kollander.
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11. Bra livsmedelsval för barn 2-17 år – baserat på nordiska näringsrekommendationer av H Eneroth och L Björck.
12. Kontroll av restsubstanser i levande djur och animaliska livsmedel. Resultat 2014 av I Nordlander, B Aspenström-Fagerlund, A Glynn, A Törnkvist, T Cantillana, K Neil Persson, Livsmedelsverket och K Girma, Jordbruksverket.
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    Inorganic Arsenic in Rice and Rice Products on the Swedish Market 2015. Del 2 – Risk Assessment by S Sand, G Concha, L Abramsson and V Öhrvik.

    Inorganic Arsenic in Rice Products on the Swedish Market 2015. Del 3 – Risk Management by E Halldin Ankarberg, P Fohgelberg, K Gustafsson, H Nordenfors and Bjerselius.

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