



Canadian Food Inspection Agency Agence canadienne
d'inspection des aliments

FOOD SAFETY ACTION PLAN

REPORT

2011-2013 TARGETED SURVEYS - CHEMISTRY

Arsenic Speciation in Selected Foods

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**Special Surveys
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Executive Summary

The Food Safety Action Plan (FSAP) aims to modernize and enhance Canada's food safety system. As a part of the FSAP enhanced surveillance initiative, targeted surveys are used to analyze various foods for specific hazards.

The main objectives of the Arsenic Speciation in Selected Foods targeted survey were to generate baseline surveillance data on the levels of the various forms of arsenic in beverages, fruit products, grain products, rice and rice products and seaweed products available on the Canadian retail market and to compare these levels with data generated from previous FSAP targeted surveys, when possible.

Arsenic is a naturally occurring element found in trace amounts in rock, soil, water and air. The primary routes of human exposure to arsenic are through drinking water and food. The presence of arsenic in food and water is expected as a result of natural accumulation from the environment. Arsenic levels in food are usually low; however, the levels are typically higher in aquatic organisms (such as seaweed, fish and seafood).

Arsenic can exist in both organic and inorganic forms in food; the inorganic forms are widely considered to be of greater toxicological significance to human health. The ratio of inorganic to organic arsenic species can vary widely depending on the source of contamination and the commodities in which it is present. While inorganic arsenic is the predominant species in drinking water, organic arsenic species are the main forms found in aquatic organisms, such as seaweed, fish and seafood. Chronic exposure to inorganic arsenic may lead to a variety of detrimental health effects in humans, including affecting the gastrointestinal tract, kidneys, liver, lungs and skin as well as contributing to the risk of certain cancers.

In total, 2015 samples were collected from Canadian retail stores between April 2011 and March 2013 and analyzed for two inorganic arsenic species, and up to four organic arsenic species. Product types included beverages (bottled waters and juices), fruit products (canned fruits, fruit purees, dried fruit and fruit snacks), grain products (wheat bran and breakfast cereals), rice/rice products (rice grains, flour, bran, noodles/pasta/papers, crackers/cakes, puddings and beverages) and seaweed products (dried seaweeds of various forms). As anticipated, the majority of samples tested (87%) contained a detectable level of one or more arsenic species. Beverages had the lowest prevalence of arsenic, with only 68% of samples containing a detectable level of one or more arsenic species, whereas 100% of seaweed products and rice/rice products tested contained a detectable level of one or more arsenic species. With respect to the levels of inorganic arsenic, beverages had the lowest average levels of inorganic arsenic (3.84 ppb), whereas rice and rice products had the highest average inorganic arsenic concentrations observed (94.19 ppb).

The tolerance for arsenic in fruit juice, fruit nectar, beverages when ready-to-serve and water in sealed containers (other than spring or mineral water) specified in Division 15 of the *Food and Drug Regulations* is outdated and in the process of being reviewed by

Health Canada. Health Canada has proposed lower tolerances for apple juice and bottled water; two apple juice samples tested in the current survey had total arsenic levels greater than the proposed new tolerance for apple juice and none of the water samples contained total arsenic concentrations higher than the proposed lower tolerance for bottled water. There are no other Canadian regulations for arsenic in any of the other foods tested in this survey, so compliance with a numerical standard could not be assessed.

All data generated were shared with Health Canada's Bureau of Chemical Safety for use in performing human health risk assessments. The levels of arsenic in the products tested in this survey were not considered to pose a concern to human health. No product recalls were warranted given the lack of a health concern.

1. Introduction

1.1 Food Safety Action Plan

In 2007, the Canadian government launched a five-year initiative in response to a growing number of product recalls and concerns about food safety. This initiative, called the Food and Consumer Safety Action Plan (FCSAP), aims to modernize and strengthen Canada's safety system for food, health, and consumer products. The FCSAP initiative unites multiple government partners in ensuring safe food for Canadians.

The Canadian Food Inspection Agency's (CFIA's) Food Safety Action Plan (FSAP) is one element of the government's broader FCSAP initiative. The goal of FSAP is to identify risks in the food supply, limit the possibility that these risks occur, improve import and domestic food controls, and identify food importers and manufacturers. FSAP also looks to verify that the food industry is actively applying preventive measures, and that there is a rapid response when/if these measures fail.

Within FSAP, there are 12 main areas of activity, one of which is risk mapping and baseline surveillance. The main objective of this area is to better identify, assess, and prioritize potential food safety hazards through risk mapping, information gathering, and testing of foods from the Canadian marketplace. Targeted surveys are one tool used to evaluate the prevalence and level of a particular hazard in specific foods.

Within the current regulatory framework, some commodities (such as meat products) traded internationally and interprovincially are regulated by specific Acts. These are referred to as federally registered commodities. Under the current regulatory framework, non-federally registered commodities encompass 70% of domestic and imported foods that are regulated solely under the *Food and Drugs Act* and the *Food and Drug Regulations*. Targeted surveys are primarily directed towards commodities produced in non-federally registered facilities.

1.2 Targeted Surveys

Targeted surveys are used to gather information regarding the possible occurrence of chemical residues, contaminants, and/or natural toxins in defined food commodities. The surveys are designed to answer specific questions; therefore, unlike monitoring activities, testing of a particular chemical hazard is targeted to commodity types and/or geographical areas.

Due to the vast number of chemical hazards and food commodity combinations, it is not possible, nor should it be necessary, to use targeted surveys to identify and quantify all chemical hazards in foods. To identify food-hazard combinations of greatest potential health risk, the CFIA uses a combination of scientific literature, media reports, and/or a risk-based model developed by the Food Safety Science Committee (FSSC), a group of federal, provincial, and territorial subject matter experts in the area of food safety.

The CFIA regularly monitors a variety of elements, including total arsenic, in various commodities under the National Chemical Residue Monitoring Program (NCRMP) and the Children's Food Project (CFP). Targeted surveys focus mainly on products not monitored under these two programs. The purpose of this targeted survey was to establish baseline data on the levels and forms of arsenic in foods produced in non-federally registered establishments available on the Canadian retail market. The scope of this survey is complementary to the NCRMP and CFP, in that it includes additional commodities not examined under these programs, such as beverages, fruit products, grain products, rice and rice products and seaweed products, as well as examining the proportions of inorganic arsenic present in these products, to allow for more adequate assessment of the potential health concern posed by the levels of arsenic observed in selected foods.

In 2008, the FSSC ranked inorganic arsenic as a priority food contaminant, particularly in seaweed products. Other commodities were included in the survey, such as rice/rice products and grain products as it has been demonstrated that grain based processed products and rice are major contributors to overall dietary exposure to arsenic¹.

1.3 Acts and Regulations

The *Canadian Food Inspection Agency Act* stipulates that the CFIA is responsible for enforcing restrictions on the production, sale, composition, and content of foods and food products as outlined in the *Food and Drugs Act* and the *Food and Drug Regulations*.

Health Canada establishes the health-based standards for levels of chemical residues and contaminants in food sold in Canada. Certain standards for chemical contaminants in food appear in the Canadian *Food and Drug Regulations*, where they are referred to as tolerances. Tolerances are established as a risk management tool and generally only for foods that significantly contribute to the total dietary exposure. There are also a number of maximum levels that do not appear in the regulations and are referred to as standards, which are available on Health Canada's website².

Currently there is a tolerance in Table 1 of Division 15 of the *Food and Drug Regulations* for total arsenic of 100 ppb for fruit juice, fruit nectar, beverages when ready-to-serve and water in sealed containers (other than mineral water or spring water). However, this tolerance is in the process of being reviewed by Health Canada. In 2014, Health Canada publicly consulted on a proposal to lower the tolerances for arsenic in apple juice and bottled water³. Specifically, new, lower tolerances for total arsenic of 10 ppb in both apple juice and the apple juice portion of any juice blend or drink as well as bottled waters (including mineral and spring waters), were proposed. Although these regulatory amendments were proposed after the sampling and analysis of the samples for the current targeted survey, they are presented here to give context and perspective to the arsenic concentrations detected herein.

Health Canada's proposed lower tolerances are for total arsenic and are more protective of human health than the existing tolerances. Different species of arsenic have variable toxicity, with the inorganic forms being considered to be of greater toxicological significance to human health than organic arsenic compounds⁵. To support Health Canada's ongoing regulatory amendments for arsenic in foods, the CFIA has quantified various arsenic species, including inorganic arsenic. These data have been considered by Health Canada in the development of updated regulations for arsenic in foods that are protective of human health.

All foods sold in Canada must be compliant with section 4(1)(a) of the *Food and Drugs Act*, which states that no person shall sell an article of food that has in or on it a poisonous or harmful substance. In the absence of applicable Canadian tolerances or standards, elevated levels of arsenic in specific foods may be assessed by Health Canada on a case-by-case basis using the most current scientific data available to determine if there is a potential human health concern. Follow-up actions are initiated in a manner that reflects the magnitude of the health concern. Actions may include further analysis, notification of the producer or importer, follow-up inspections, additional directed sampling, and recall of products.

2. Survey Details

2.1 Arsenic

Arsenic is a naturally occurring element that can be found in the Earth's crust. Arsenic may be released into the air, water and/or soil through natural erosion/leaching or through man-made activities. Historically, arsenic has been used in pharmaceuticals, wood preservatives, agricultural chemicals, mining applications, metallurgical, glass-making and semiconductor industries⁴. Arsenic is generally found in combination with other elements or substances to form different compounds. There are two types of arsenic compounds: inorganic and organic. Inorganic arsenic species are considered to be of greater toxicological significance to human health than the organic forms of arsenic and have been associated with long term health effects⁵. Long term exposure to inorganic arsenic has been shown to affect the gastrointestinal tract, kidneys, liver, lungs and skin⁶. Inorganic arsenic compounds have been classified as carcinogenic to humans and organic arsenic compounds, dimethylarsinic (DMA) and monoethylarsonic acid (MMA), have been classified as possibly carcinogenic to humans by the International Agency for Research on Cancer (IARC)⁴.

The primary route of arsenic exposure for the general population is through the consumption of food and water⁵. The average dietary intake of total arsenic for Canadians ranges from 0.51 to 0.97 µg/kg body weight/day⁷, and it has been estimated that inorganic arsenic comprises 20-40% of the total dietary arsenic intake for the average North American individual⁸.

The amount and forms of arsenic found in foods is dependent on a number of factors such as food type, growing conditions, and processing techniques. Arsenic is expected to be present at very low levels in food as a result of natural accumulation from the environment. Both organic and inorganic arsenic may be present in foods. Seafood (fish, crustaceans and seaweed) has been shown to contain high levels of arsenic⁵, but the predominant forms of arsenic found in these items are organic species that are considered to be of less concern to human health⁶. A scientific report published by the European Food Safety Authority (EFSA) cited grain-based processed products as the main contributor to dietary exposure of inorganic arsenic, with other notable sources being rice, milk and dairy products and drinking water¹.

2.2 Rationale

In 2014, Health Canada proposed revisions to the tolerances for total arsenic in fruit juices, nectars, beverages when ready-to-serve and water in sealed containers³. These revisions serve to align safety-based standards with concentrations that are as low as reasonably achievable, while considering existing Canadian drinking water quality guidelines, and with the new action level for arsenic in apple juice established by the US Food and Drug Administration (FDA)⁹.

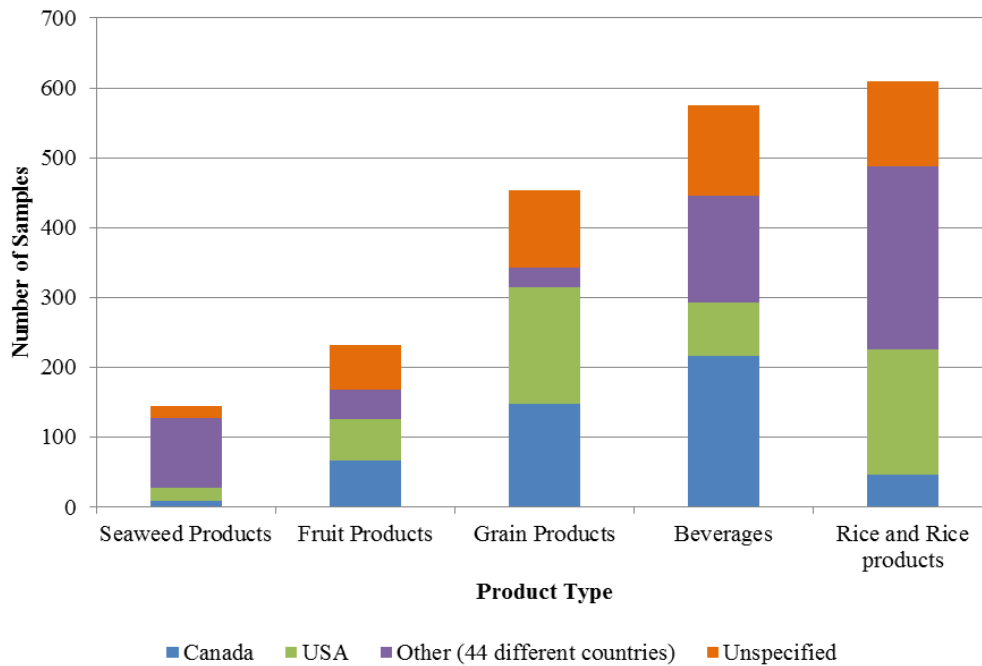
The CFIA's regular monitoring activities do not target inorganic arsenic. The CFIA's National Chemical Residue Monitoring Program (NCRMP) examines levels of total arsenic in registered commodities (such as meat, milk, fresh fruits and vegetables, etc.), but has not examined speciated arsenic, nor has it examined the types of processed products examined in the current survey. The CFIA's Children's Food Project (CFP) has examined the levels of total arsenic (but not speciated arsenic) in certain types of processed products targeted at infants and children. Products examined under the CFP include processed rice products and processed fruit and vegetable products. As such, there was a need for surveillance data on the presence and levels of total arsenic as well as the various forms of arsenic, specifically levels of inorganic arsenic, in grain products, rice and rice products, fruit products, bottled water, and seaweed products of domestic and imported origin. This information may be used by Health Canada's Bureau of Chemical Safety (BCS) in future health risk assessments conducted on arsenic exposure, and in support of proposed changes to arsenic tolerances.

2.3 Sample Distribution

In this survey, a total of 2015 samples were collected from grocery and specialty stores in 11 Canadian cities between April 2011 and March 2013. The 2015 samples collected included 485 domestically produced products, 1086 imported products and 444 products of unspecified origin, meaning the country of origin could not be confirmed based on the available information recorded during sampling. It is important to note that the products sampled often contained the statement "packaged in Country X", "imported for Company A in Country Y" or "manufactured for Company B in Country Z", and though the labelling meets the intent of the regulatory standard, it does not specify the true origin of

the product ingredients. Only those products labelled with a clear statement of “Product of”, “Prepared in”, “Made in”, “Processed in”, and “Manufactured by” were considered as being from a specific country of origin.

The distribution of samples by country of origin (as recorded by the sampler or indicated on the label) is presented in Figure 1 to provide a general sense of the origin of products sampled.



*Unspecified refers to those samples for which country of origin could not be determined from the label or sample information.

Figure 1 - Distribution of samples by country of origin

2.4 Method Details

Survey samples were analyzed by a CFIA laboratory which is ISO17025 accredited for food testing. The laboratory used a method that quantifies inorganic (in the form of As^{3+} and As^{5+}) and organic arsenic forms (arsenobetaine (AsB), arsenocholine (AsC), monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA)) in food by High Performance Liquid Chromatography-Inductively Coupled Plasma Mass Spectrometry (LC-ICP-MS) (see Table 1).

Table 1 - Arsenic species examined in the current targeted survey

Species	Form	Synonym	Chemical formula	IARC Classification
As ³⁺	Inorganic	Arsenious acid, Arsenite	As(OH) ₃	carcinogenic to humans (Group 1)
As ⁵⁺	Inorganic	Arsenic acid, Arsenate	H ₃ AsO ₄	carcinogenic to humans (Group 1)
AsC	Organic	Arsenocholine	C ₅ H ₁₄ AsBr O	not classifiable as to their carcinogenicity to humans* (Group 3)
AsB	Organic	Arsenobetaine	C ₅ H ₁₁ AsO ₂	not classifiable as to their carcinogenicity to humans* (Group 3)
MMA	Organic	Monomethylarsinic acid	CH ₃ AsO ₃ N a	possibly carcinogenic to humans (Group 2B)
DMA	Organic	Dimethylarsinic Acid, Cacodylic acid	C ₂ H ₇ AsO ₂	possibly carcinogenic to humans (Group 2B)

*available toxicological data suggests that arsenocholine and arsenobetaine are not as toxic to human health as inorganic arsenic

All results are reported as elemental arsenic (rather than the organic species, e.g. arsenobetaine is C₅H₁₁AsO₂ and is reported as the As concentration only). The limits of detection (LOD) for all product types tested are presented in Table 2. It should be noted that other arsenic species may be present in the sample; however, this method is applicable for the species mentioned above. It should also be noted that for seaweed products, due to method limitations, it was only possible to quantify four of the six arsenic species outlined in Table 2.

Table 2 - Limits of detection (LODs) for arsenic species in the current targeted survey

Arsenic Species	LOD (ppb) in Rice, Rice Products and Grain Products	LOD (ppb) in Fruit Products	LOD (ppb) in Beverage Products	LOD (ppb) in Seaweed Products
AsC	0.39	0.52	0.06	N/A
AsB	0.41	0.23	0.08	N/A
DMA	0.70	0.36	0.04	5.0
MMA	0.98	0.58	0.09	13.0
As³⁺	0.68	0.66	0.08	10.0
As⁵⁺	4.80	2.67	0.13	10.0

N/A = these species are not currently detectable by the arsenic speciation method used

2.5 Limitations

The current targeted survey was designed to provide a snapshot of the levels of speciated arsenic in selected foods available for sale in Canada and had the potential to highlight commodities that warranted further investigation. This survey cannot distinguish between arsenic originating from natural sources or environmental contamination. The limited sample size represents a small fraction of the products available to Canadian consumers. Therefore, care must be taken when interpreting and extrapolating these results. As stated in the previous section, the analytical method used in this study can only quantify up to six of the arsenic species outlined above, and may not quantify all forms of arsenic present, making comparison of this data with arsenic concentrations derived using other analytical methodologies imprudent. Regional differences, impact of product shelf-life, packaging and storage conditions, or cost of the commodity on the open market were not examined in this survey.

3. Results and Discussion

3.1 Overview of Survey Results

Arsenic is a naturally occurring element found in trace amounts in rock, soil, water and air. The presence of arsenic in food and water is expected as a result of natural accumulation from the environment. Arsenic levels in food are usually low; however, the levels are typically higher in aquatic organisms (such as seaweed, fish and seafood).

Under the 2011-2013 Arsenic Speciation in Selected Foods Targeted Survey, 2015 samples collected at the Canadian retail level and analyzed for arsenic. The distribution of samples by product type and the number of samples with a detectable level of one or more arsenic species is presented in Figure 2. Seaweed and rice/rice products had the highest occurrence of arsenic, with 100% of samples containing a detectable level of one

or more arsenic species. Grain products, fruit products and beverages had lower occurrences with 96%, 72% and 68% of products, respectively, containing a detectable level of one or more arsenic species.

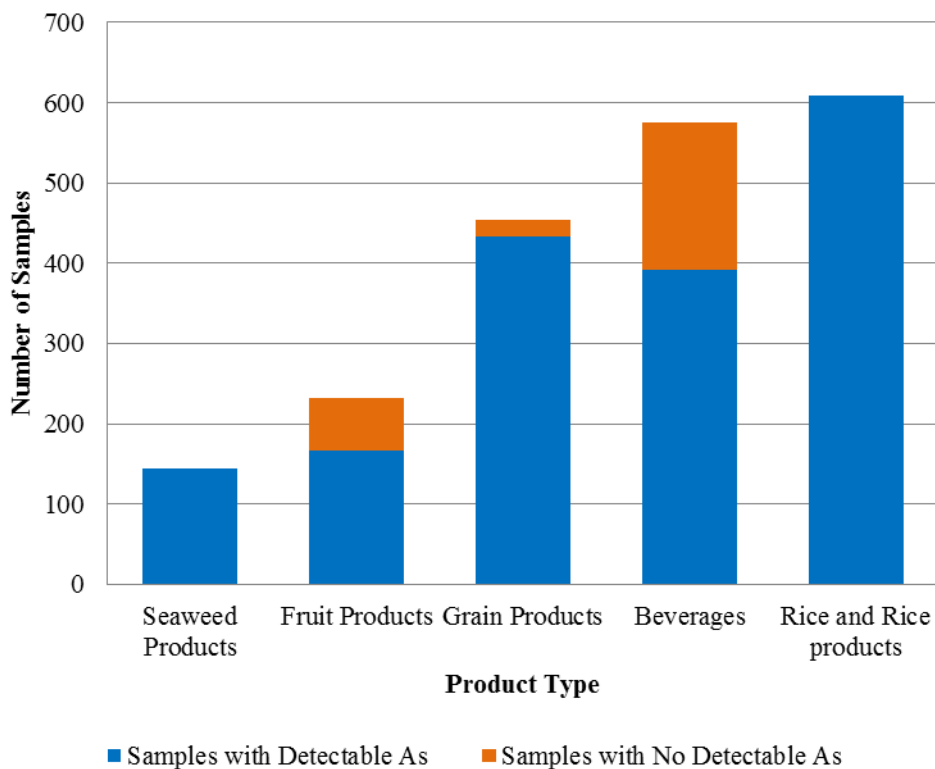


Figure 2 - Distribution of samples by product type

Overall 87% of samples tested contained a detectable level of one or more arsenic species. The concentrations of total arsenic (calculated as the sum of the arsenic species investigated) quantified in individual samples ranged from 0.08 parts per billion (ppb) in infant cereal to 1815.3 ppb in dried seaweed. Figure 3 illustrates the range of total arsenic and inorganic arsenic (calculated as the sum of the two inorganic species As^{3+} and As^{5+}) concentrations detected in survey samples. Only samples with a detectable level of one or more arsenic species are displayed.

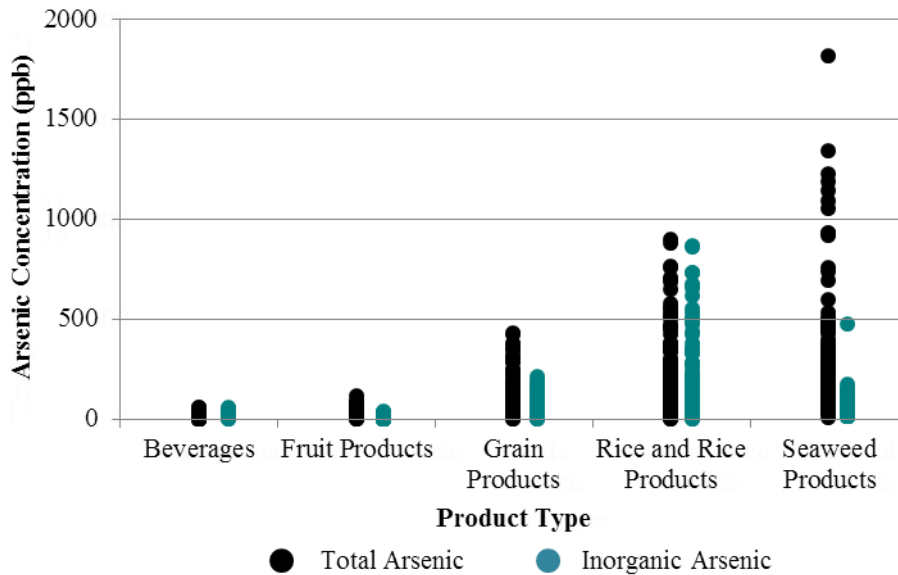


Figure 3 – Concentrations of total and inorganic arsenic in samples by product type

Note – Only samples with a detectable level of one or more arsenic species are included. For the purpose of this survey “total arsenic” refers to the sum of the six arsenic species (four in the case of seaweed products) and inorganic arsenic refers to the sum of the two inorganic arsenic species examined using the analytical method outlined in section 2.4

Overall, beverages had the lowest maximum and average concentrations of total arsenic detected, while seaweed products had the highest maximum and average total arsenic concentrations. It should be noted that the average concentrations were calculated using only those samples for which one or more species of arsenic was detected (i.e. average of the positive results only). When considering only the inorganic arsenic species, rice and rice products had the highest average inorganic arsenic concentrations, while beverages had the lowest average concentrations of inorganic arsenic.

Table 3 – Average total arsenic and inorganic arsenic levels detected in food samples (in order of increasing average inorganic arsenic concentration)

Commodity type	Number of Samples	Samples with Detectable Arsenic	Samples with No Detectable Arsenic	Average Total Arsenic* (ppb)	Average Inorganic Arsenic* (ppb)
Beverages	575	392	183	3.97	3.84
Fruit Products	232	167	65	10.68	6.53
Seaweed Products	145	145	0	271.53**	37.19
Grain Products	454	434	20	69.44	48.37
Rice and Rice products	609	609	0	116.17	94.19

*Average of the positive results only

** Includes only two of the four possible organic arsenic species (DMA and MMA) due to analytical method limitations

The data in Table 3 illustrates that the majority of the arsenic species measured in this study in seaweed are organic in nature. The remaining product types contained between 79% and 93% inorganic species.

3.2 Survey Results by Product Type

Detailed analyses of the results for each individual product type are presented in the sections below. Total arsenic concentrations are calculated as the sum of the six arsenic species investigated with the analytical method discussed in section 2.4, with the exception of seaweed, for which the total arsenic concentration reported herein represents the sum of four arsenic species. It should also be noted that average arsenic concentrations were calculated using only the positive results.

3.2.1 Beverages

A total of 575 beverages were sampled and analyzed for arsenic content in the current targeted survey. Beverage types included bottled water, flavoured beverages, juice/nectars (including apple, orange, pineapple, blends of fruits, grape, cranberry, blackcurrant, blueberry, carrot, cherry, coconut, grapefruit, guava, lemon/lime juice, lemonade, mango, peach, pear, pomegranate, prune, quince, and raspberry) and apple cider. Thirty-two percent of beverage samples analyzed did not contain a detectable level of any arsenic species. Of the remaining 392 samples with a detectable level of one or more arsenic species, non-mineral/spring waters had the lowest levels of both total arsenic and inorganic arsenic. Cranberry juice (which may have included cranberry cocktails) had the highest maximum concentrations of both total arsenic and inorganic arsenic species observed, whereas grape juices had the highest average concentrations of both total and inorganic arsenic.

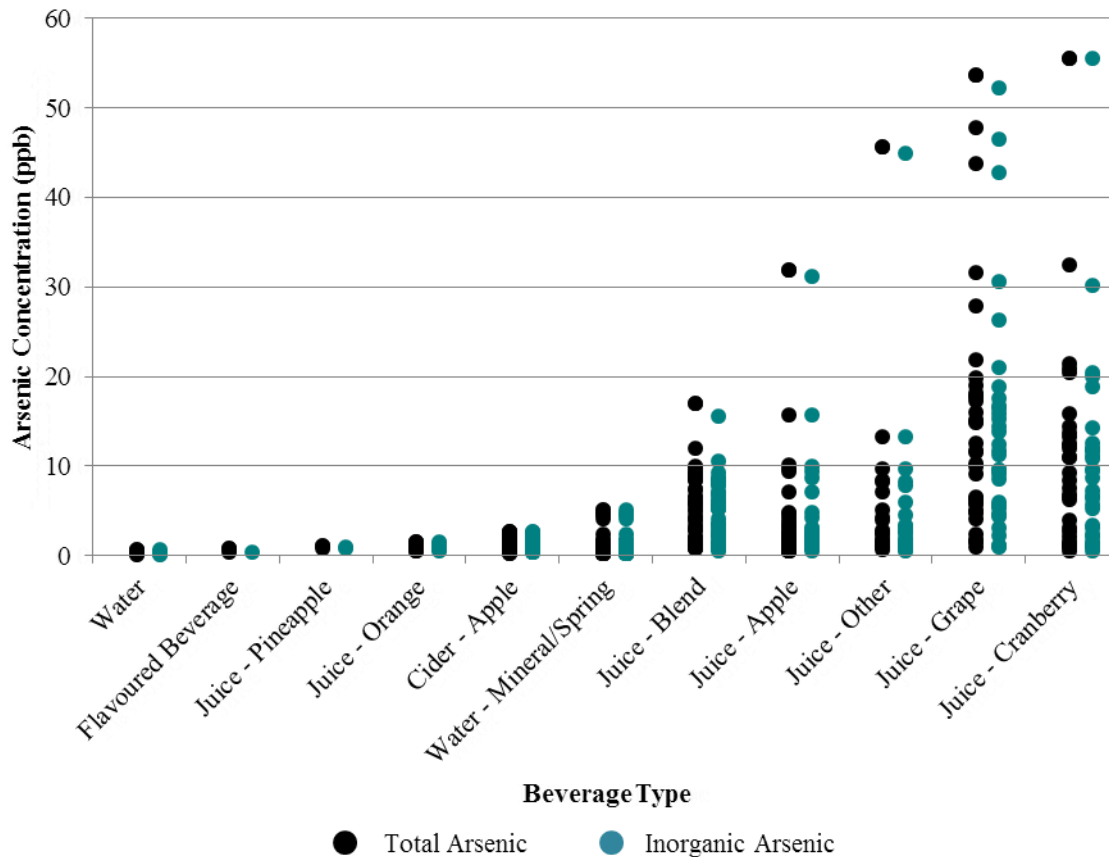


Figure 4 - Concentrations of total arsenic and inorganic arsenic in samples by beverage type

Figure 4 shows the ranges of total arsenic and inorganic arsenic concentrations for the different beverage types. For each individual beverage type, there is little difference between the ranges of total arsenic and inorganic arsenic. This indicates that the majority of arsenic detected in beverages was inorganic. However, the levels of total arsenic observed in beverages were the lowest of all product types tested. Health Canada's BCS is of the opinion that the arsenic concentrations in these samples would not be expected to pose a health concern. Two of the 39 apple juice samples tested in the current survey had total arsenic levels in excess of the proposed new 10 ppb tolerance for apple juice and none of the water samples tested contained total arsenic concentrations in excess of the proposed 10 ppb tolerance for bottled water.

A variety of beverages have been examined in a previous FSAP targeted survey. In 2009-2010, thirty-four samples of pear juice and nectar were analyzed for the same six arsenic species examined in the current survey. Twenty-three samples (68%) had a detectable level of one or more arsenic species. The concentrations of inorganic arsenic species ranged from 4.15 ppb to 9.01 ppb. In 2010-2011, 229 samples of juice, nectar drinks and tea were analyzed for the same six arsenic species examined in the current survey. It should be noted that the 2010-2011 survey specifically targeted pear-based beverage

products. Of the beverage samples analyzed, 168 of the beverage samples (73%) contained a detectable level of one or more of the arsenic species examined.

Concentrations of inorganic arsenic in beverages from the various surveys undertaken by the CFIA were consistent throughout the years. See Figure 5 for a depiction of the ranges of inorganic arsenic detected in beverages over the survey years.

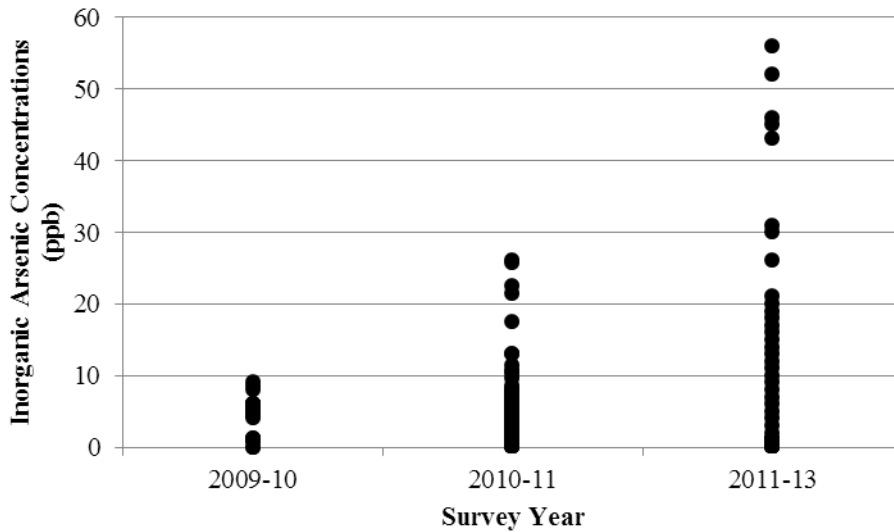


Figure 5 – Distribution of inorganic arsenic concentrations in beverages by survey year

3.2.2 Fruit Products

Two hundred and thirty-two fruit products were sampled for the current survey. Samples were categorized as fruit purées (such as apple sauce, cranberry sauce, fruit sauce, etc.), dried fruit (e.g. apples, apricots, cranberries, dates, mangoes, pineapple, plantain, prune, raisins and strawberries), fruit snacks (such as fruit leathers, fruit chews and other fruit based treats) or canned fruit products (which consisted of fruit in a cup or a can packaged with water or syrup). Of the 232 fruit products analyzed, 65 (28%) did not contain a detectable level of any of the arsenic species analyzed. Of the remaining 167 samples with one or more arsenic species present, canned fruit products contained the lowest levels of both total and inorganic arsenic, while fruit snacks contained the highest levels of both total and inorganic arsenic.

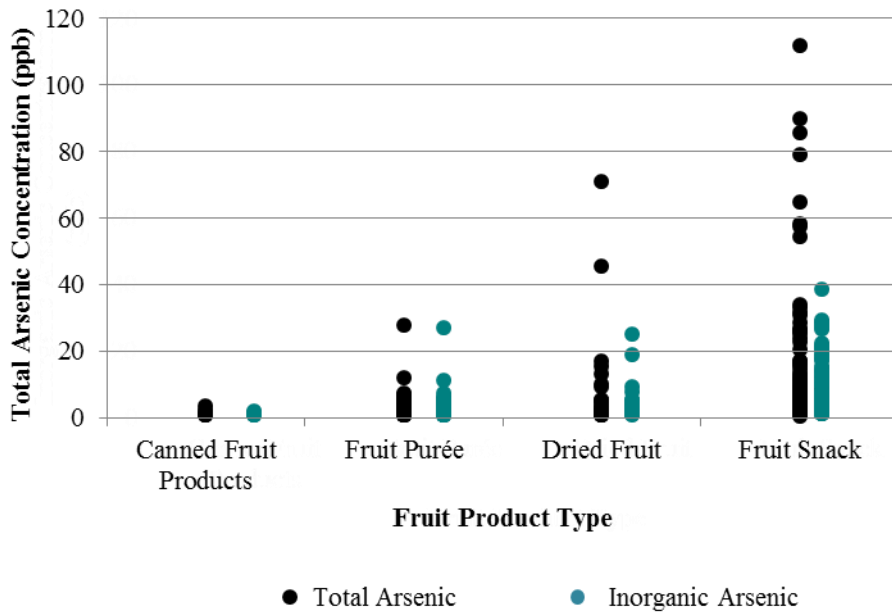


Figure 6 - Concentrations of total arsenic and inorganic arsenic in samples by fruit product type

Figure 6 illustrates the ranges of total and inorganic arsenic observed in the different fruit product types tested. Dried fruit and fruit snacks had the lowest average proportions of inorganic arsenic (70% and 78% respectively) to total arsenic content. Canned fruit products and fruit purées had higher proportions of inorganic arsenic levels, but the levels of inorganic arsenic observed in these commodities were very low and would not be expected to pose a health concern.

In the 2009-2010 arsenic speciation targeted survey, pear based baby foods (purées) and pear-based fruit snacks were examined. Similar to the results of the current survey, fruit snacks contained higher concentrations of inorganic arsenic than purées. See Figure 7 for the range of inorganic arsenic concentrations detected in fruit purées and fruit snacks between survey years.

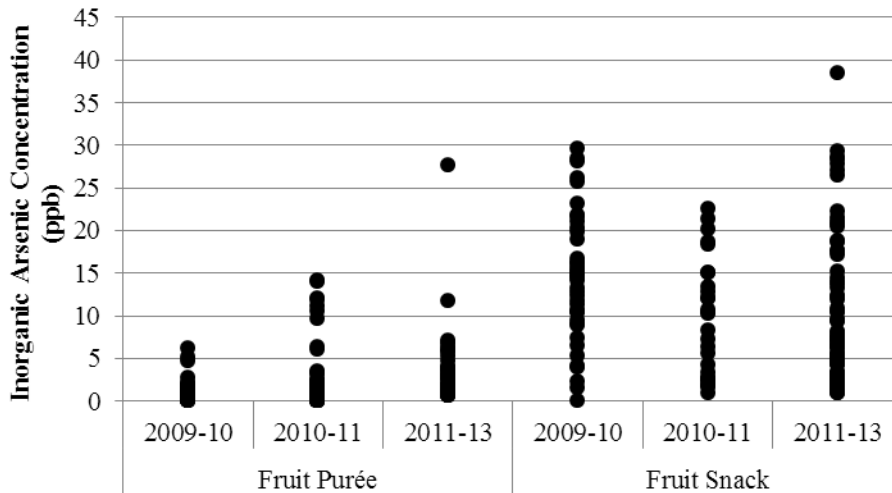


Figure 7 - Concentrations of inorganic arsenic in samples by fruit product type and survey year

The average levels of inorganic arsenic in fruit purées were 1.73 ppb in the 2009-2010 survey. These samples were solely pear based baby foods. The average inorganic arsenic concentrations were 3.21 ppb and 3.337 ppb in the 2010-2011 and 2011-2013 surveys, respectively. Samples from these survey years encompassed a larger number and wider range of fruit based purées, which may account for the differences in average concentration.

Canned pear products were sampled in the 2010-2011 survey year, and showed that there was a low prevalence of inorganic arsenic; only one of 19 samples analyzed contained a detectable level of inorganic arsenic (1.49 ppb). In the current survey year, six canned/fruit-in-a-cup type products were analyzed and exhibited a higher prevalence of inorganic arsenic, but showed a similarly low average level of inorganic arsenic detected (1.04 ppb).

3.2.3 Grain Products

Four hundred and fifty-four grain products were analyzed in the current targeted survey. Grain product samples consisted of breakfast cereals targeted at adults, children and infants, as well as wheat bran. Only 20 samples (4%) did not have detectable levels of one or more arsenic species. Wheat bran had the lowest levels of total and inorganic arsenic detected. Average levels of total arsenic and inorganic arsenic were very similar between product form and showed similar trends in arsenic concentrations in relation to primary grain ingredient. Rice-based and multigrain cereals generally exhibited the highest concentrations of arsenic. Health Canada determined that the inorganic arsenic concentrations in grain products are not expected to pose a safety concern.

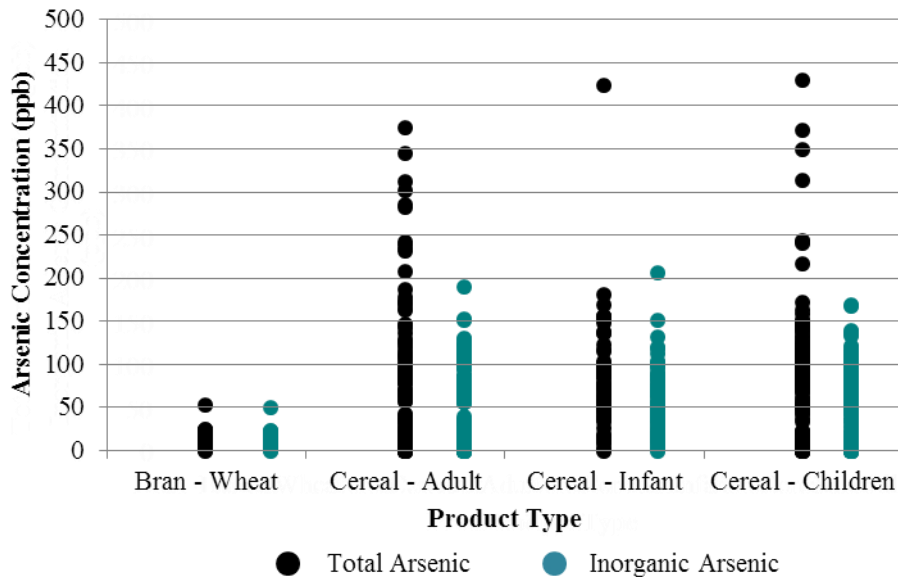
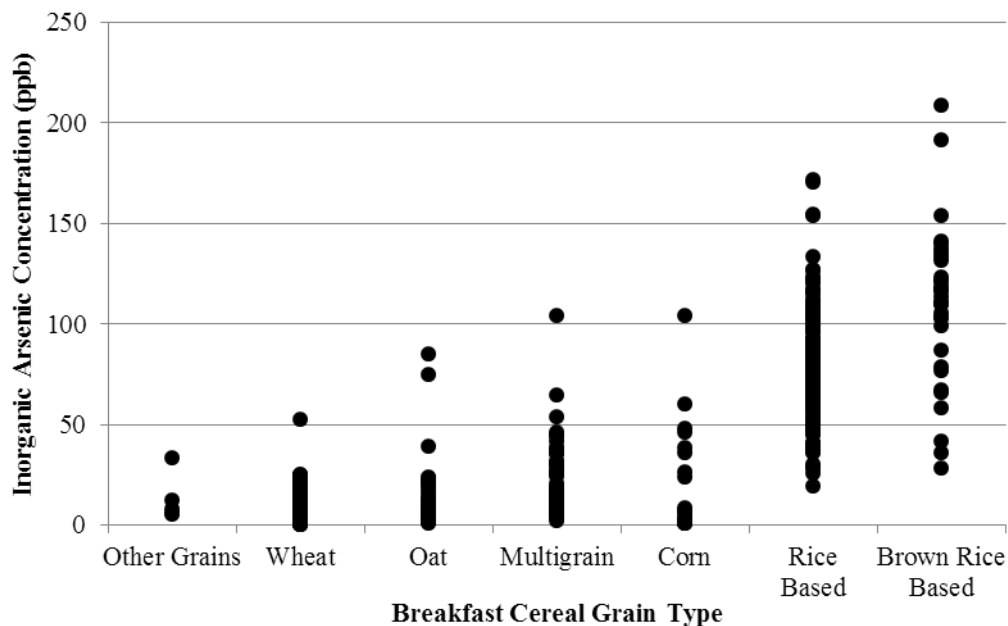


Figure 8 - Concentrations of total arsenic and inorganic arsenic in samples by grain product type

Figure 8 illustrates the ranges of total and inorganic arsenic observed in the different grain product types tested. Breakfast cereal samples had lower proportions of inorganic arsenic than wheat bran. This can be seen in the reduction of the ranges observed in these commodities in Figure 8. Overall the range of inorganic arsenic concentrations was consistent between the different categories of breakfast cereals.

In order to examine the influence of the grain type on inorganic arsenic levels in breakfast cereals, samples were categorized by their main grain type (i.e. the first grain based component in the products list of ingredients). Rice based cereals had the highest levels of inorganic arsenic observed, whereas the breakfast cereals with millet, spelt, kamut and quinoa (called “other grains” in Figure 9) had the lowest levels of inorganic arsenic observed.



* Other grains included millet, spelt, kamut and quinoa based cereals.

Figure 9 - Concentrations of inorganic arsenic in samples by breakfast cereal grain type

Breakfast cereals were examined in the 2010-2011 inorganic arsenic targeted survey. Figure 10 illustrates that the ranges of inorganic arsenic concentrations are very consistent between the survey years. Rice based cereals contained the highest levels of inorganic arsenic in both the 2010-2011 data and the current survey.

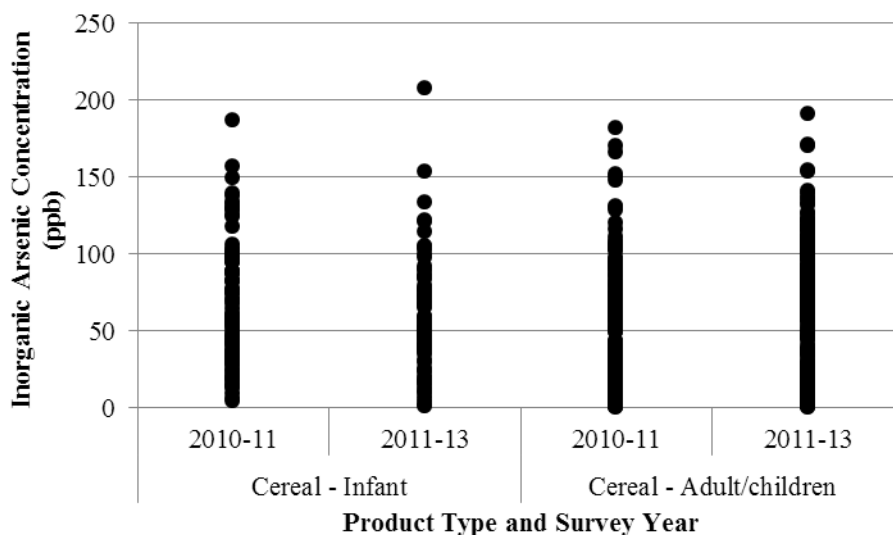


Figure 10 – Concentrations of inorganic arsenic in breakfast cereal samples by survey year

3.2.4 Rice and Rice Products

Six hundred and nine samples of rice and rice products were collected for the current targeted survey. Sample types included rice based beverages, rice flour, rice grains, rice bran and processed rice products (i.e. noodles/pasta, paper/wrappers, crackers/cakes/ crisps, vinegar, pudding and crumbs). All of the samples analyzed contained detectable levels of at least one arsenic species. Rice beverage samples contained the lowest concentrations of both total and inorganic arsenic, while rice bran contained the highest levels of both total and inorganic arsenic (see Figure 11). There appears to be little difference between the ranges of total and inorganic arsenic concentrations for each product type, indicating that the majority of the arsenic in rice and rice products is inorganic in nature.

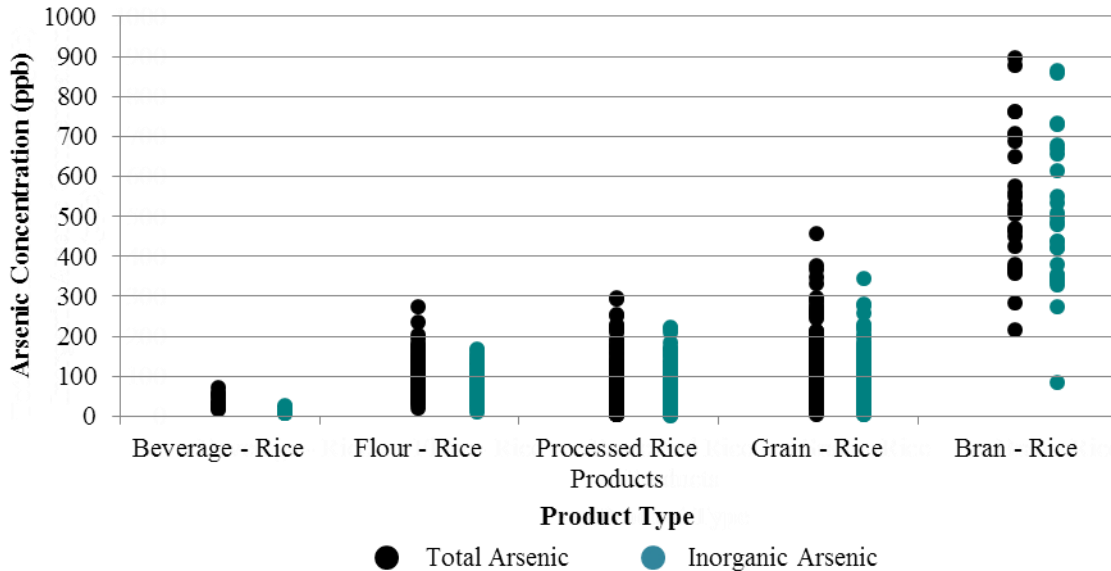


Figure 11 - Concentrations of total arsenic inorganic arsenic in samples by rice product type

Rice bran has been shown to accumulate higher levels of arsenic than the other portions of the rice grain, and as brown rice is unmilled (i.e. still contains the germ and bran) it would follow that brown rice would have higher levels of arsenic as well. Comparison of inorganic arsenic levels in rice grains labelled as brown rice versus other rice varieties (e.g. white rice, jasmine rice, calrose rice, basmati rice, etc.) illustrates this point well (see Figure 12). The average total and inorganic arsenic concentrations in samples labelled as brown rice were approximately 1.7 times higher than concentrations in rice grains of other varieties, however inorganic arsenic concentrations detected in rice or rice products would not be expected to pose a safety concern.

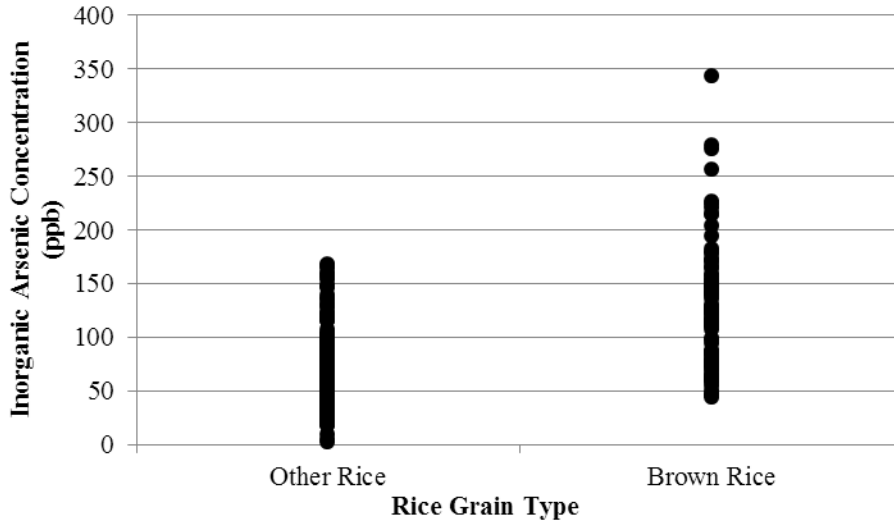


Figure 12 - Concentrations of inorganic arsenic in rice grains

A variety of rice grains and rice products have been sampled in previous survey years. See Figure 13 for a comparison of the ranges of inorganic arsenic concentrations detected in the different types of rice products tested. Overall the ranges of concentrations are very consistent between survey years.

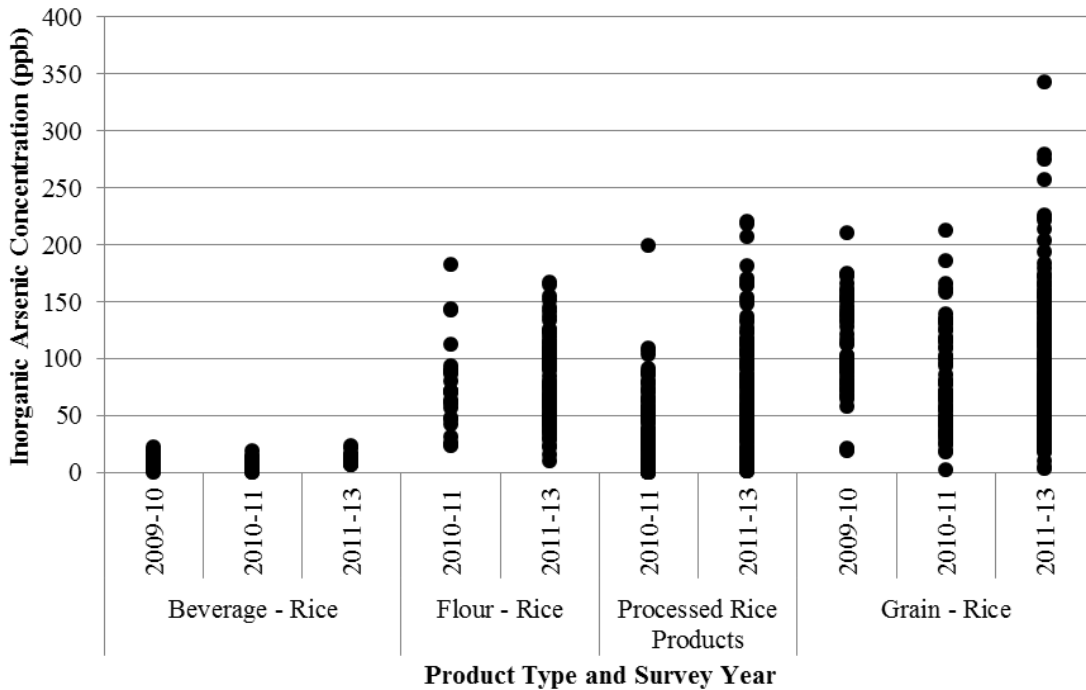


Figure 13 – Concentrations of inorganic arsenic in rice and rice products arranged by survey year

The average inorganic arsenic concentration for rice and rice products is also presented in Table 4. Despite slight variations in the ranges of inorganic arsenic concentrations detected, the average levels of inorganic arsenic are fairly consistent, with the exception of processed rice products. This disparity could be due in part to the variation in types and proportions of different processed rice products sampled between survey years.

Table 4 – Summary of minimum, maximum and average inorganic arsenic concentrations in rice and rice products by survey year

Commodity	Survey Year	Number of samples	Minimum (ppb)	Maximum (ppb)	Average Inorganic Arsenic Concentration (ppb)
Rice Grains	2009-2010	55	18.83	209.67	108.88
	2010-2011	72	2.33	212.1	79.85
	2011-2013	324	2.59	342.8	83.59
Rice Flour	2010-2011	25	23.1	182.9	75.00
	2011-2013	84	9.69	166.46	80.74
Processed Rice Products	2010-2011	90	1.47	199.3	38.75
	2011-2013	154	0.73	220.1	62.25
Rice Beverages	2009-2010	40	1.16	22.16	9.65
	2010-2011	72	1.22	19.25	6.22
	2011-2013	19	6.14	23.7	11.98

3.2.5 Seaweed Products

One hundred and forty-five seaweed products were analyzed in the current targeted survey. Seaweed samples consisted of dried nori sheets (commonly used for making sushi), dulse, laver, wakame, kombu and other varieties of dried seaweed. As mentioned previously, it should be noted that for seaweed products, due to method limitations, it was only possible to quantify four of the six arsenic species outlined in Table 1. All of the samples analyzed contained a detectable level of one or more arsenic species. Seaweed products contained the highest average and maximum levels of total arsenic observed in this survey (296 ppb and 1815 ppb respectively). Figure 14 shows the ranges of total arsenic and inorganic arsenic concentrations in seaweed products.

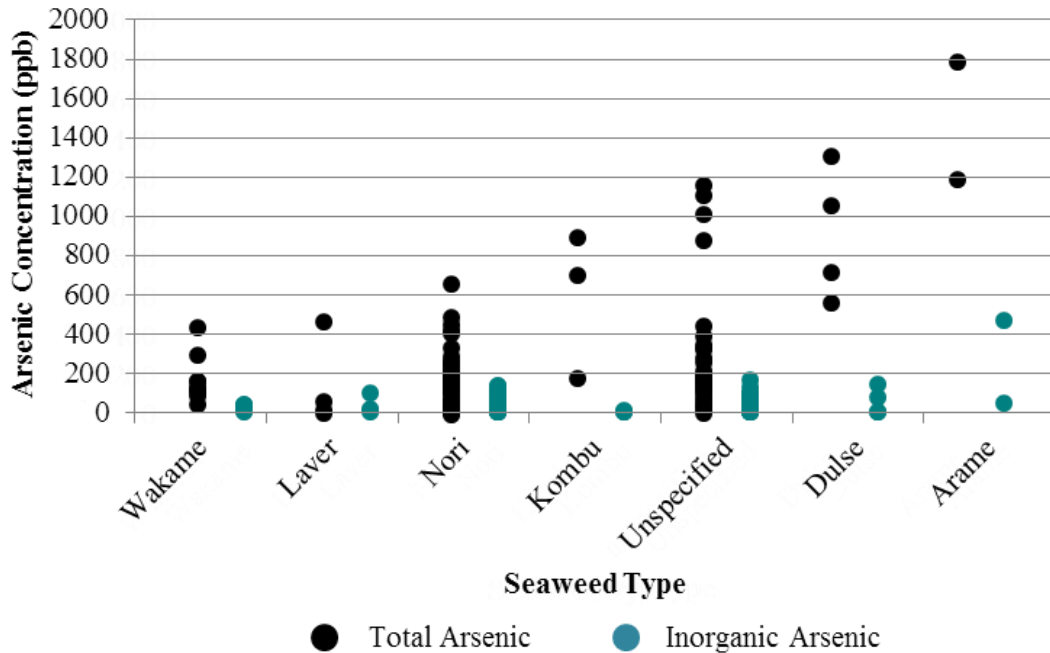


Figure 14 - Concentrations of total arsenic inorganic arsenic in samples by seaweed product type

Of note is the disparity between the ranges of concentrations of total and inorganic arsenic in Figure 14. As only four arsenic species were considered in the calculation of total arsenic, it would be expected that this disparity would be even more pronounced if all organic species were quantified. These differences reinforces that the majority of arsenic species in seaweed are organic in nature¹⁰.

Seaweed products were also targeted in the 2010-2011 inorganic arsenic survey. With the exception of a single elevated sample of dried seaweed detected in the current survey year, the range of inorganic arsenic concentrations detected in seaweed products from the two years agree well with each other (see Figure 15).

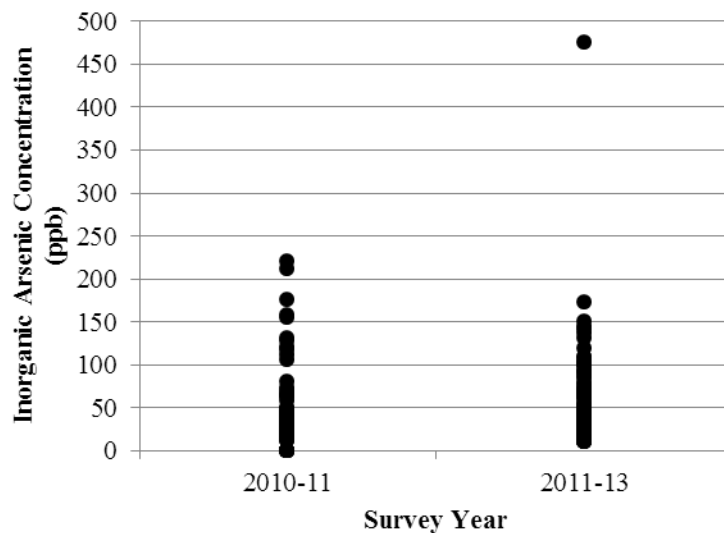


Figure 15 – Concentrations of inorganic arsenic in seaweed samples by survey year

4. Conclusions

The present survey generated baseline surveillance data on the levels of the various forms of arsenic in domestic and imported products available on the Canadian retail market.

In total, 87% of samples tested contained detectable levels of one or more arsenic species. Total average arsenic concentrations were lowest in beverage samples and highest in seaweed products. When considering the levels of only the inorganic species (noted to be of greater toxicological significance to human health than other forms of arsenic), beverages had the lowest average levels, whereas rice and rice products contained the highest average concentrations of inorganic arsenic. The proportions of inorganic arsenic were varied across the commodity types tested in this survey, with seaweed products containing the lowest proportions of inorganic arsenic, and rice/rice products containing the highest proportion of inorganic arsenic.

The results of the current survey were compared with the results from previous arsenic speciation surveys conducted in 2009-2010 and 2010-2011 and there was consistent agreement between the survey years for concentrations of inorganic arsenic in similar product types.

There is an arsenic tolerance for fruit juice, nectar, beverages when ready-to-serve and water in sealed containers (other than spring or mineral water) specified in Division 15 of the *FDR*. This tolerance is considered outdated and is in the process of being reviewed by Health Canada. Health Canada has proposed lower tolerances for apple juice and bottled water; two apple juice samples tested in the current survey had total arsenic levels greater than the proposed new tolerance for apple juice and none of the water samples contained total arsenic concentrations higher than the proposed lower tolerance for bottled water.

There are no other Canadian regulations for arsenic in any of the other foods tested in this survey; therefore compliance with a numerical standard could not be assessed for these products. All data generated were shared with Health Canada for use in human health risk assessments. The levels found were not considered to pose a concern to human health. No product recalls were warranted given the lack of health concern.

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