



Inorganic arsenic in seaweed and certain fish

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Executive summary

Arsenic is a naturally occurring element which can be introduced into food from natural sources and as a result of human activities. Food is a significant source of arsenic intake, with 77.5% of exposure to arsenic in children originating from food and water. Arsenic can be present in food in many different forms of varying toxicity, with inorganic arsenic forms, arsenite (As³⁺) and arsenate (As⁵⁺), being the most toxic. Inorganic arsenic typically accounts for one to three per cent of the total arsenic found in food.

Arsenic can bioaccumulate in species of fish. The NSW Food Authority has previously conducted a testing program of metals in fish. In this program elevated total arsenic levels were found in some fish, mainly angel fish, angel shark, flake, or fish cocktail. The Australian New Zealand Food Standards Code (the Code) includes a regulatory limit for inorganic arsenic (not total arsenic) and further testing was undertaken to assess compliance with the Code.

Less information is available on the type and level of arsenic present in seaweed. International food regulatory agencies issued warnings about the inorganic arsenic content of hijiki seaweed. Food Standards Australia New Zealand issued similar warnings in 2004 and border inspection regimes were tightened to target all shipments of hijiki seaweed. The warnings, however, do not apply to other edible seaweeds such as arame, nori, kombu and wakame.

From January to May 2010, 48 seaweed and ten fish samples were collected from retail outlets. All samples were sent to National Measurement Institute and tested for total and inorganic arsenic. The results were then compared to regulatory limits as specified in *Standard 1.4.1 – Contaminants and Natural Toxicants* of the Australian New Zealand Food Standards Code. The limits for inorganic arsenic in seaweed and fish are 1 mg/kg and 2 mg/kg respectively.

The survey found that 98.3% of samples tested contained inorganic arsenic below the regulatory limit. One dried seaweed product contained inorganic arsenic at the level of 38 mg/kg. This is equivalent to 5.7 mg/kg when the seaweed is hydrated to 85% water content, as specified in the Standard. The product has been withdrawn and no longer imported to Australia.

1. Introduction

Arsenic is a naturally occurring element which can be introduced into food from natural sources such as rocks and sediments and as a result of human activities such as industrial effluent, atmospheric deposition (through the burning of fossil fuels and waste incineration), and drainage from old gold mines. Levels of arsenic are higher in the aquatic environment than on land (FSA, 2004a; NHMRC, 2003).

Food is a significant source of arsenic intake. Other sources of exposure include air and soil, but in Australia, levels of arsenic in air and soil are generally very low. The average Australian dietary intake of arsenic is approximately 0.04 mg per day (NHMRC, 2003). In urban areas, air levels of inorganic arsenic range from 0.001 to 0.1 µg/m³, and soil generally contain less than 20 ppm arsenic (Queensland Health, nd). Small children aged between three and five years old are the group most exposed to inorganic arsenic, thus APVMA conducted a study to determine the exposure level of arsenic from food, water and environment for this age category. The study found that dietary intake of arsenic in children contributed to 77.5% of the total daily intake of arsenic (APVMA, 2005).

Arsenic can be present in food in many different forms which vary in toxicity, with inorganic arsenic forms, arsenite (As³⁺) and arsenate (As⁵⁺), being the most toxic. Most of the arsenic in the diet is present in the organic form. Inorganic arsenic typically accounts for one to three per cent of the total arsenic found in food (FSA, 2004a).

The main adverse effects reported to be associated with long term ingestion of inorganic arsenic in humans are skin lesions, cancer, developmental toxicity, neurotoxicity, cardiovascular diseases, abnormal glucose metabolism, and diabetes. Neurotoxicity is mainly reported with acute exposure from deliberate poisoning, or at high concentrations in drinking water. There is emerging evidence of negative impacts on foetus and infant development, particularly reduced birth weight (EFSA, 2009).

Arsenic is bioaccumulated by many species of fish and shellfish and is present in poultry and livestock. Studies have demonstrated most arsenic found in finfish and shellfish occurs as methylated arsenic compounds, with only small amounts of inorganic arsenic present. The complex arsenic compounds are much less acutely toxic than soluble inorganic compounds, with arsenobetaine (the predominant form found in finfish) being virtually non-toxic (Schoof *et al.*, 1999).

The NSW Food Authority has tested fish for a range of trace metals and mercury over the years. Elevated levels of total arsenic were confined to certain species and warranted further testing to confirm that inorganic arsenic standards have not been exceeded. High total arsenic levels are mainly limited to samples identified as angel fish or angel shark. Samples identified as 'flake' and another identified as 'fish cocktails' were also high. As many of the samples precede the widespread adoption of the Fish Names Standard it is likely that the angel fish samples were actually angel shark.

Less information is available on the type of arsenic present in seaweed. Since 2004, international food regulatory agencies issued warnings about the inorganic arsenic content of hijiki seaweed (CFIA, 2001; FSA, 2004c; FSA, 2010). Food Standards Australia New Zealand issued similar warnings in 2004 and border inspection regimes were tightened to target all shipments of hijiki seaweed. The warnings, however, do not apply to other edible seaweeds such as arame, nori, kombu and wakame (FSANZ, 2004).

From 2003 to 2009 the European Rapid Alert System lists 27 incidents of elevated arsenic levels in seaweed products: 26 edible seaweeds and 1 dietetic supplements. The species of seaweed was not specified (RASFF).

A wide range of seaweed products can be found in the Australian market place. Many of the products are imported in the original packaging and over-labelled with an English language sticker for sale in Australia. The species of seaweed in the product can be difficult to determine. Thus, this survey was conducted to analyse retail seaweed products in the NSW market place for levels of inorganic arsenic. Any products with high levels of inorganic arsenic will be investigated to determine whether it is hijiki or a different species of concern. In addition, a number of shark samples will also be collected and tested for inorganic arsenic.

2. Method of analysis

From January to May 2010, 48 seaweed and ten fish samples were collected from retail outlets. Packaged seaweed was purchased and stored according to the manufacturer's instruction until a suitable number of samples for an analytical batch were accumulated. Fish samples were purchased, frozen and then delivered to the laboratory.

All samples were sent to National Measurement Institute and tested for total and inorganic arsenic. The results were then compared to regulatory limits as specified in *Standard 1.4.1 – Contaminants and Natural Toxicants* of the Australian New Zealand Food Standards Code. The limits for inorganic arsenic in seaweed and fish are 1 mg/kg and 2 mg/kg respectively.

3. Results and discussion

Fifty eight packaged seaweed and fish samples (angel shark, saw shark, flake and fish ray) were tested for total arsenic and inorganic arsenic. The results are in Table 1 and Table 2.

Table 1. Total arsenic results (mg/kg as received)

Product	Mean	Median	Range
Seaweed (n=48)	39.0	39.5	8.1 – 140
Fish (n=10)	15.8	12.0	2.5 – 41

Table 2. Inorganic arsenic results (mg/kg as received)

Product	Acceptable		Unacceptable
	Not detected (LOR = 0.05mg/kg)	Below regulatory limit	Above regulatory limit
Seaweed (n=48)	5 (10.4%)	42 (87.5%)	1 (2.1%)
Fish (n=10)	10 (100%)	-	-

The levels of total arsenic in seaweed found in this survey are similar to those found in a survey conducted by the UK Food Standards Agency (FSA) in 2004. In the FSA survey, 22 seaweed samples were tested and the total arsenic level was averaged at 35.6 mg/kg, ranged from 18.2 to 75.2 mg/kg (FSA, 2004b).

In this survey, only one dried seaweed sample was found to contain inorganic arsenic above the regulatory limit, that being a sample of dried shredded seaweed at a level of 38 mg/kg (5.7 mg/kg at 85% seaweed hydration). The product was withdrawn from the market and is no longer imported to Australia. The rest of the samples were below the regulatory limit, and levels ranged from not detected to 0.75 mg/kg.

The levels of total arsenic found in fish tested in this survey are higher than those found in the FSA survey (FSA, 2004a; FSA, 2005) or reported by Schoof *et al.* (1999). However, none of the samples contained a detectable level of inorganic arsenic.

In September 2009, the European Food Safety Authority's Expert Panel on Contaminants recommended that dietary exposure to inorganic arsenic should be reduced and as a consequence, EU-wide regulation of inorganic arsenic in foods is currently under discussion.

4. Conclusion

The survey found that 98.3% of samples complied with the regulatory limit for inorganic arsenic prescribed by the Code.

5. References

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6. Appendix: Results of testing

Sample number	Product	Type of seaweed	Arsenic (mg/kg as received)	Inorganic arsenic (mg/kg as received)
1102	Dried sea vegetable	Kombu	29	0.19
1103	Dried sea vegetable	Kombu	24	0.13
1104	Dried sea vegetable	Kombu	51	0.23
1114	Dried seaweed	Wakame	39	0.32
1125	Salted seaweed	Wakame	8.1	0.06
1126	DS dried seaweed		50	0.36
1128	Dried seaweed		26	0.2
1129	Dried seaweed		42	0.24
1131	Dried seaweed	Wakame	39	0.26
1134	Dried seaweed		40	0.29
1135	Seaweed		34	0.34
1136	Sea tangle		50	0.41
1137	Seaweed		33	0.21
5403	Dried seaweed (shredded)		50	0.31
5411	Dried seaweed (shredded)	Kombu	43	<0.05
5413	Dried kelp (shredded)		45	0.26
5414	Dried seaweed		53	0.13
7134	Dried seaweed		59	0.31
7135	Dried seaweed		54	<0.05
7136	Dried seaweed (shredded)		51	0.13
7137	Dried seaweed (shredded)		140	38*
7110	Dried seaweed (shredded)		49	0.56
7112	Dried seaweed (shredded)		47	0.75
7114	Dried seaweed (shredded)	Kombu	44	<0.05
7116	Dried seaweed (shredded)		42	0.19
7117	Kelp (shredded)		54	0.45
7118	Dried seaweed (shredded)		51	<0.05
7120	Dried seaweed (shredded)	Kombu	56	0.31
7121	Natural kelp (shredded)		49	0.05
7122	Seaweed		42	<0.05
7123	Kelp		48	0.21
7124	Dried seaweed		33	0.14
7131	Dried seaweeds (shredded)		10	0.29
5406	Nori sheets	Nori	20	0.35
5407	Roasted nori	Nori	19	0.31
5408	Roasted nori	Nori	20	0.39
5409	Dried seaweed	Kombu	59	0.52
5410	Dried seaweed (small shred)	Wakame	29	0.51
5411	Seaweed		11	0.27
5412	Dried sea vegetable (small shred)		28	0.45
5420	Wildness laver	Laver	31	0.53
5421	Dried seaweed		29	0.37
5422	Dried seaweed	Nori	19	0.38
5423	Dried seaweed (small shred)		33	0.58
5424	Wakame seaweed (small shreds)	Wakame	25	0.42
5425	Nori roasted seaweeds	Nori	16	0.08
5426	Roasted seaweed nori	Nori	19	0.29

Sample number	Product	Type of seaweed	Arsenic (mg/kg as received)	Inorganic arsenic (mg/kg as received)
5427	Roasted seaweed	Laver	27	0.35
5430	Angel shark		29	<0.05
5431	Saw shark		41	<0.05
5432	Angel shark		4.3	<0.05
5433	Angel shark (boneless fillets)		20	<0.05
5434	Flake		11	<0.05
5435	Baby flake		19	<0.05
5436	Fish ray		7.6	<0.05
5437	Angel shark		13	<0.05
5438	Flake (boneless fillets)		11	<0.05
5439	Flake (boneless and skinless)		2.5	<0.05

* Note: 38 mg/kg (as received) is equivalent to 5.7 mg/kg (at 85% seaweed hydration) as specified by the Food Standards Code.

NSW Food Authority
6 Avenue of the Americas
Newington NSW 2127
PO Box 6682 Silverwater NSW 1811
Phone 1300 552 406
Fax 02 9647 0026
www.foodauthority.nsw.gov.au