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Original Article

Distribution of Accumulated Arsenic in the Plant Body of Akamoku, *Sargassum horneri*

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Summary

Arsenic accumulation in Akamoku, *Sargassum horneri*, a member of the *Phaeophyta* Family, was determined throughout the whole plant by thermal neutron activation analysis. We collected Akamoku plants at a sea coast along Ise Bay, where Hijiki plants have also been harvested. The arsenic distribution in the plant body was not uniform along the stem as found in Hijiki plants ; however, the arsenic concentration was higher than the level in the Hijiki plants harvested at the same coast. The arsenic concentrations were discussed comparing the characteristic distributions in the two species.

Keywords : *Sargassum horneri* ; Akamoku ; arsenic distribution ; thermal neutron activation analysis ; various tissues.

Introduction

Traditionally, Japanese people take large amounts of seaweeds of the *Phaeophyta* family, some of which have been reported to contain rather high amounts of arsenic[1−3]. Hijiki[4], *Sargassum fusiforme*, of this family has been found to contain some levels of arsenic irrespective of their harvesting areas of the ocean[5,6], although the pre-cooking process of Hijiki reduced the arsenic level considerably[7,8]. Akamoku, *Sargassum horneri*, a member of the same family, is also known to contain rather high levels of arsenic[9,10]. Akamoku, although taken as foodstuffs only in restricted areas, is of interest as livestock feed as well as more general foodstuffs.

Thus, we intended to determine the arsenic level in the fresh whole plant of Akamoku and to compare its accumulating process with that in Hijiki.

Materials and Methods

1. Akamoku plants

Whole plants of Akamoku were harvested at sea coast, Mugisaki district, Katada, along Ise Bay, Japan. Akamoku plants grow underneath the ocean sea surface even at the lowest tide, in contrast to Hijiki, which is exposed to sunshine on rocks for a few hours during the lowest tide.

For the comparison, Hijiki plants were also collected near the Akamoku-growing site, 10 to 20 m toward the coast line.

2. Preparation of samples of Akamoku plants

Harvested Akamoku or Hijiki plants were transported in a cool-box with ice from the sea shore to the laboratory. The plant samples were washed with enough amounts of artificial sea water, Daigo SP grade successively three times. Then, they were washed twice with distilled water and once with ultra pure water, MiliQ. Excessive water on the samples was removed by blotting on filter paper.

The male and female plants were separately treated by confirming their genital organs.

The respective branches were cut into 10 cm pieces from the bottom, designated as, a', b', c', etc and separated into stalks and twigs. The twigs were designated as Twig-1, Twig-2, Twig-3, etc from the bottom (Fig. 1). Each sample was sealed in a polyethylene bag and the wet weight was measured. They were stored in a freezer under −30℃ until they were lyophilized. After the measurement of their dry weights, some portions of the dried samples were divided into small polyethylene bags and put in Neuma-Capsules. Forty small sample-bags and 10 standard amounts of pure arsenate were packaged in a Neuma-capsule.

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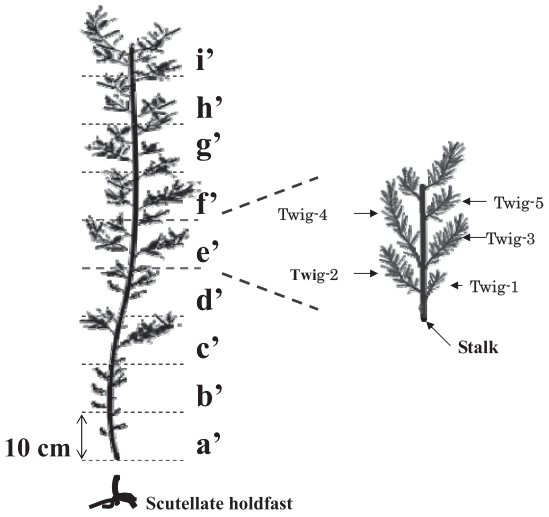

Fig. 1 Sectioning and fractionation of a plant sample of Akamoku.
The respective sections, designated as explained in the text, were treated for the further analysis.

3. Arsenic determination by thermal neutron activation analysis[11)]

The samples in the Neuma-capsules were irradiated in a flux of 10^{13} neutrons·cm^{-2}·sec^{-1} for 20 min in the center position of the nuclear reactor of the Research Reactor Institute, Kyoto University. After the cooling time of 72 h, the arsenic contents in the samples were determined by gamma radiation from ^{76}As using a pure Ge gamma-detector at 559.1 keV. The energy levels of ^{60}Co and ^{137}Cs were used for the calibration.

Results

1. Growth conditions

At the harvesting time, the lengths of Akamoku plants were 1 m or longer and they float under seawater even at the lowest tide, just outside the area where Hijiki plants grow. The plants are fixed to the rocks by their scutellate holdfast.

The numbers of the twigs in the respective sections were several to 10, and their lengths were shorter at the section a' than at the other sections (Table 1).

2. Arsenic concentrations expressed on the wet weight basis (Table 2)

The twigs of the lower position as sections such as a' , c', d' of Akamoku male plants had arsenic concentrations from several to 20 μg As/g wet weight, mostly 10μg As/g wet weight of tissues, indicating mostly the values less than the average. Those of female plants had 10 to less than 20μg As/g wet weight, indicating mostly less than the average value. The arsenic concentrations were shown to be higher than 10μg As/g wet weight, up to 25 μg As/g wet weight or more in the upper sections (Table 2). The arsenic contents in the stalks were lower than those in the twigs, i.e., several to 15μg As/g wet weight. The average value was 10.2 ± 1.7μg As/g wet weight.

3. Arsenic concentrations expressed on the dry weight basis

The arsenic levels in the Akamoku twigs were 114.3 ± 27.0 μg As/g dry weight in average in female plants and 144.8 ± 61.6 μg As/g dry weight in average in male plants, although the stalks contained 51.4 ± 6.6 μg As/g dry weight and 59.2 ± 13.6 μg As/g wet weight in average in both male and female plants, respectively (Table 3).

These values are remarkably higher than those of Hijiki[5, 6, 11)] (Table 4).

4. Distribution of arsenic concentrations along the stalks

As shown in Table 2 and 3, arsenic concentrations in Akamoku plants are not so uniform along the stalks as found in Hijiki[5, 6, 11)]. It was observed that the upper sections tended to contain greater arsenic concentrations than the lower sections and in the twigs the arsenic concentrations were higher than those in stalks (Table 2 and 3).

5. Comparison of the arsenic concentration with those of Hijiki

The arsenic concentrations in the respective tissues of Akamoku were shown in Table 2 and Table 3 and those of Hijiki[12)], in Table 4. In spite of the non-uniformity along the stalk, the average values of the respective tissues in Hijiki[12)] were not so diferent each other, except the genital organs.

However, the average values of arsenic concentrations of Akamoku showed higher concentratins in Twigs.

Discussion

The twigs of Akamoku plants at the lowest sections (section a') were shorter than those at the upper sections. The arsenic concentrations were low in the twigs of the section a'. The arsenic levels in the twigs of the respective sections were not uniform, and the lengths of the twigs do not seem to be correlated to the arsenic concentrations on the dry weight basis.

Interestingly, rather higher levels of arsenic accumulation were observed in the upper portions of Akamoku. In Hijiki also, highest levels of arsenic were sometimes recog-

Table 1 Growing state of Akamoku plants harvested at Mugisaki, Ise Bay.

Male

Sections	Tissues	Length (cm)	Wet Weight (g)	Dry Weight (g)	Ratio (Wet weight/Dry weight)
i'		6.0	0.280	0.050	5.56
h'		10.0	0.611	0.107	5.71
g'		10.0	0.691	0.117	5.88
f'		10.0	0.689	0.130	5.30
e'	Stalk	10.0	0.691	0.131	5.30
d'		10.0	0.755	0.143	5.28
c'		10.0	0.721	0.145	4.98
b'		10.0	0.673	0.176	3.82
a'		10.0	0.557	0.137	4.06
Scutellate holdfast			0.826	0.222	3.71
	Twig-8	20.5	6.309	0.739	8.54
	Twig-7	22.5	7.974	1.010	7.90
	Twig-6	0.5	0.020	0.002	8.47
i' (Apex)	Twig-5	5.5	0.935	0.111	8.40
	Twig-4	8.0	1.090	0.125	8.70
	Twig-3	16.0	4.828	0.524	9.21
	Twig-2	25.0	9.658	1.147	8.42
	Twig-1	0.5	0.027	0.004	7.24
	Twig-11	22.0	7.190	0.806	8.92
	Twig-10	11.5	2.331	0.262	8.91
	Twig-9	3.5	0.772	0.081	9.54
	Twig-8	3.0	0.321	0.036	8.80
	Twig-7	12.0	3.070	0.323	9.52
h'	Twig-6	5.0	1.178	0.139	8.46
	Twig-5	12.5	2.882	0.333	8.66
	Twig-4	17.0	3.431	0.391	8.77
	Twig-3	0.5	0.011	0.002	5.88
	Twig-2	12.5	5.065	0.587	8.63
	Twig-1	11.5	2.953	0.339	8.70
	Twig-7	7.0	1.793	0.201	8.92
	Twig-6	10.0	2.094	0.237	8.82
	Twig-5	12.0	2.977	0.347	8.58
g'	Twig-4	7.0	1.408	0.155	9.08
	Twig-3	10.5	5.015	0.575	8.72
	Twig-2	11.5	2.622	0.299	8.78
	Twig-1	10.5	1.726	0.199	8.69
	Twig-7	16.5	3.289	0.354	9.28
	Twig-6	13.0	1.482	0.164	9.04
	Twig-5	13.5	2.178	0.252	8.63
f'	Twig-4	17.5	3.162	0.331	9.54
	Twig-3	20.0	5.341	0.607	8.80
	Twig-2	13.0	2.363	0.263	8.97
	Twig-1	12.0	1.995	0.228	8.75
	Twig-4	1.0	0.011	0.002	5.91
e'	Twig-3	1.5	0.018	0.003	6.18
	Twig-2	10.5	1.954	0.216	9.03
	Twig-1	9.0	1.243	0.141	8.85
	Twig-10	7.0	0.988	0.107	9.24
	Twig-9	3.0	0.262	0.028	9.23
	Twig-8	1.0	0.027	0.004	7.55
	Twig-7	3.5	0.274	0.031	8.98
d'	Twig-6	6.0	0.598	0.063	9.47
	Twig-5	12.0	2.669	0.280	9.52
	Twig-4	4.0	0.267	0.027	9.79
	Twig-3	1.0	0.033	0.005	7.33
	Twig-2	7.0	0.696	0.081	8.61
	Twig-1	5.0	0.382	0.039	9.76
	Twig-8	8.0	0.959	0.103	9.27
	Twig-7	3.0	0.174	0.018	9.47
	Twig-6	8.0	1.435	0.146	9.84
c'	Twig-5	1.0	0.017	0.002	10.60
	Twig-4	5.0	0.376	0.040	9.33
	Twig-3	1.0	0.019	0.002	7.92
	Twig-2	0.5	0.008	0.001	5.65
	Twig-1	1.0	0.008	0.001	6.78
	Twig-6	0.5	0.013	0.002	8.25
	Twig-5	9.5	1.495	0.172	8.71
	Twig-4-6	1.5	0.505	0.055	9.11
	Twig-4-5	10.0	6.724	0.746	9.01
	Twig-4-4	10.0	8.675	0.978	8.87
b'	Twig-4-3	10.0	8.953	1.051	8.52
	Twig-4-2	10.0	4.855	0.565	8.59
	Twig-4-1	10.0	1.460	0.191	7.65
	Twig-3	18.5	7.926	0.930	8.52
	Twig-2	13.0	2.551	0.276	9.25
	Twig-1	8.0	1.117	0.128	8.76
	Twig-10	15.0	3.203	0.360	8.89
	Twig-9	3.5	0.242	0.028	8.52
	Twig-8	3.5	0.408	0.048	8.46
	Twig-7	0.5	0.006	0.001	4.70
a'	Twig-6	2.0	0.099	0.016	6.30
	Twig-5	1.0	0.023	0.002	10.01
	Twig-4	2.0	0.400	0.048	8.42
	Twig-3	0.5	0.113	0.013	8.80
	Twig-2	0.5	0.041	0.006	7.19
	Twig-1	2.5	0.278	0.033	8.41

Female

Sections	Tissues	Length (cm)	Wet Weight (g)	Dry Weight (g)	Ratio (Wet weight/Dry weight)
g'		10.0	0.414	0.068	6.07
f'		10.0	0.492	0.084	5.83
e'		10.0	0.534	0.092	5.81
d'	Stalk	10.0	0.566	0.092	6.12
c'		10.0	0.559	0.105	5.32
b'		10.0	0.522	0.114	4.57
a'		10.0	0.519	0.112	4.63
Scutellate holdfast			0.774	0.135	5.72
	Twig-8	4.0	0.503	0.063	7.99
	Twig-7	6.5	0.862	0.114	7.57
	Twig-6	5.5	0.796	0.100	7.93
g' (Apex)	Twig-5	4.0	0.559	0.066	8.53
	Twig-4	4.0	0.545	0.071	7.64
	Twig-3	5.5	1.217	0.141	8.64
	Twig-2	5.0	1.073	0.118	9.12
	Twig-1	5.0	0.776	0.099	7.84
	Twig-8	6.0	1.501	0.168	8.95
	Twig-7	4.0	0.788	0.076	10.34
	Twig-6	3.0	0.540	0.058	9.34
f'	Twig-5	3.0	0.742	0.077	9.67
	Twig-4	3.5	1.405	0.159	8.86
	Twig-3	3.5	0.737	0.069	10.73
	Twig-2	4.5	1.070	0.102	10.52
	Twig-1	6.0	1.405	0.135	10.40
	Twig-5	4.0	0.762	0.070	10.91
	Twig-4	4.0	0.763	0.068	11.18
e'	Twig-3	5.5	1.076	0.097	11.10
	Twig-2	4.5	1.707	0.142	11.99
	Twig-1	6.5	1.516	0.141	10.76
	Twig-5	3.5	0.686	0.065	10.50
	Twig-4	1.0	0.118	0.012	9.98
d'	Twig-3	5.0	0.962	0.094	10.19
	Twig-2	5.5	1.046	0.099	10.60
	Twig-1	4.0	0.709	0.074	9.61
	Twig-4	7.0	1.147	0.121	9.51
c'	Twig-3	4.0	0.782	0.083	9.47
	Twig-2	5.5	1.135	0.104	10.86
	Twig-1	5.5	1.042	0.116	8.96
	Twig-4	4.5	0.737	0.075	9.89
b'	Twig-3	5.5	1.421	0.135	10.50
	Twig-2	3.5	0.872	0.096	9.12
	Twig-1	4.0	1.008	0.109	9.23
	Twig-12	1.5	0.240	0.029	8.39
	Twig-11	4.0	0.738	0.085	8.70
	Twig-10	3.5	0.544	0.060	9.12
	Twig-9	7.0	1.355	0.150	9.00
	Twig-8	1.5	0.191	0.021	9.16
a'	Twig-7	2.0	0.213	0.024	9.04
	Twig-6	2.0	0.366	0.043	8.51
	Twig-5	1.0	0.108	0.014	7.55
	Twig-4	1.0	0.083	0.010	8.70
	Twig-3	1.0	0.127	0.013	9.66
	Twig-2	1.0	0.085	0.014	6.22
	Twig-1	1.5	0.164	0.020	8.32

* The Twig-4 of the section b' had 6 twigs. They were designated as Twig-1-1, Twig-1-2 etc from the bottom to the upperside.

nized in the genital organs (Table 4).

Brown algae, the *Phaeophyta* family, have been traditionally used as foodstuffs by Japanese and their usefulness could not be disregarded nutritionally. It has been our intention to find out some technical methods to reduce the arsenic levels in brown algae used as foodstuffs, and one of conditions to reduce arsenic levels in Hijiki products was described in separate papers[7, 8]. Those for Akamoku are

Table 2 Arsenic concentration in Akamoku plants, harvested at Mugisaki, Ise Bay, on the wet weight basis.

Male

Sections	Tissues	μg As/g Wet weight	Percentage ratio (%)*
i'		10.46	76.9
h'		10.68	78.5
g'		8.20	60.2
f'		8.50	62.5
e'	Stalks	9.31	68.4
d'		11.21	82.4
c'		8.76	64.4
b'		13.61	100.0
a'		11.23	82.5
Average		10.22	
SD		1.72	
Scutellate holdfast		15.03	
i' (Apex)	Twig-8	20.76	74.9
	Twig-7	20.80	75.0
	Twig-6	21.23	76.6
	Twig-5	20.97	75.6
	Twig-4	21.10	76.1
	Twig-3	18.56	66.9
	Twig-2	26.63	96.0
	Twig-1	27.73	100.0
h'	Twig-11	21.59	78.5
	Twig-10	24.55	89.3
	Twig-9	17.49	63.6
	Twig-8	15.18	55.2
	Twig-7	22.07	80.2
	Twig-6	22.29	81.0
	Twig-5	27.05	98.3
	Twig-4	26.06	94.7
	Twig-3	14.94	54.3
	Twig-2	27.51	100.0
	Twig-1	25.88	94.1
g'	Twig-7	20.99	76.2
	Twig-6	22.97	83.4
	Twig-5	21.20	77.0
	Twig-4	21.24	77.2
	Twig-3	18.22	66.2
	Twig-2	23.58	85.7
	Twig-1	27.53	100.0
f'	Twig-7	19.80	67.9
	Twig-6	22.66	77.8
	Twig-5	17.17	58.9
	Twig-4	25.38	87.1
	Twig-3	19.61	67.3
	Twig-2	19.80	68.0
	Twig-1	29.14	100.0
e'	Twig-4	10.83	42.9
	Twig-3	14.16	56.1
	Twig-2	25.23	100.0
	Twig-1	21.92	86.9
d'	Twig-10	17.32	105.0
	Twig-9	15.49	93.9
	Twig-8	11.82	71.6
	Twig-7	13.26	80.3
	Twig-6	12.07	73.2
	Twig-5	16.41	99.4
	Twig-4	7.57	45.9
	Twig-3	6.42	38.9
	Twig-2	16.50	100.0
	Twig-1	13.09	79.3
c'	Twig-8	12.96	100.0
	Twig-7	7.01	54.1
	Twig-6	12.08	93.2
	Twig-5	3.06	23.6
	Twig-4	8.14	62.8
	Twig-3	6.16	47.5
	Twig-2	4.70	36.3
	Twig-1	4.64	35.8
b'	Twig-6	5.02	20.6
	Twig-5	15.95	65.3
	Twig-4-6	11.21	45.9
	Twig-4-5	18.76	76.8
	Twig-4-4	24.42	100.0
	Twig-4-3	21.10	86.4
	Twig-4-2	14.17	58.0
	Twig-4-1	9.79	40.1
	Twig-3	13.93	57.1
	Twig-2	17.70	72.5
	Twig-1	10.70	43.8
a'	Twig-10	14.19	68.6
	Twig-9	13.01	62.9
	Twig-8	13.32	64.4
	Twig-7	4.71	22.8
	Twig-6	8.90	43.0
	Twig-5	3.28	15.9
	Twig-4	16.26	78.6
	Twig-3	8.98	43.4
	Twig-2	20.69	100.0
	Twig-1	16.21	78.3
Average		16.77	
SD		6.79	
b' (Average value)**	Twig-4-1 ～ Twig-4-6	16.57	56.9

** The Twig-4 of the section b' had 6 twigs. They were designated as Twig-1-1, Twig-1-2 etc from the bottom to the upperside.

Female

Sections	Tissues	μg As/g Wet weight	Percentage ratio (%)*
g'		11.48	85.3
f'		9.98	74.1
e'		13.47	100.0
d'	Stalks	7.31	54.3
c'		13.12	97.4
b'		12.22	90.8
a'		8.97	66.6
Average		10.94	
SD		2.28	
Scutellate holdfast		3.57	
g' (Apex)	Twig-8	13.20	60.0
	Twig-7	18.94	86.2
	Twig-6	14.25	64.8
	Twig-5	18.39	83.7
	Twig-4	19.69	89.6
	Twig-3	14.22	64.7
	Twig-2	12.83	58.4
	Twig-1	19.77	90.0
f'	Twig-8	18.55	84.4
	Twig-7	14.37	65.4
	Twig-6	14.03	63.9
	Twig-5	15.12	68.8
	Twig-4	14.10	64.2
	Twig-3	14.08	64.1
	Twig-2	12.13	55.2
	Twig-1	12.89	58.6
e'	Twig-5	11.87	54.0
	Twig-4	10.43	47.5
	Twig-3	11.88	54.1
	Twig-2	10.90	49.6
	Twig-1	11.47	52.2
d'	Twig-5	8.92	40.6
	Twig-4	21.98	100.0
	Twig-3	5.98	27.2
	Twig-2	8.58	39.0
	Twig-1	8.95	40.7
c'	Twig-4	11.69	53.2
	Twig-3	10.26	46.7
	Twig-2	9.88	44.9
	Twig-1	11.29	51.4
b'	Twig-4	7.99	36.3
	Twig-3	13.62	62.0
	Twig-2	11.87	54.0
	Twig-1	12.84	58.4
a'	Twig-12	11.51	52.4
	Twig-11	9.90	45.0
	Twig-10	12.42	56.5
	Twig-9	9.47	43.1
	Twig-8	12.00	54.6
	Twig-7	13.05	59.4
	Twig-6	14.52	66.0
	Twig-5	9.85	44.8
	Twig-4	9.16	41.7
	Twig-3	9.49	43.2
	Twig-2	14.91	67.8
	Twig-1	15.01	68.3
Average		12.79	
SD		3.39	

The designation of the sections was as described in the text.
* The highest value of the stalks or the twigs was taken as 100 %.
Of the twigs of male, the highest values in the resfective sections were taken as 100 %.

Table 3 Arsenic concentration in Akamoku plants, harvested at Mugisaki, Ise Bay, on the dry weight basis.

Male

Sections	Tissues	μg As/g Dry weight	Percentage ratio (%)*
i'		58.17	95.3
h'		61.03	100.0
g'		48.20	79.0
f'		45.10	73.9
e'	Stalks	49.33	80.8
d'		59.25	97.1
c'		43.65	71.5
b'		51.93	85.1
a'		45.55	74.6
Average		51.36	
SD		6.60	
Scutellate holdfast		55.84	
i' (Apex)	Twig-8	177.23	69.5
	Twig-7	164.21	64.4
	Twig-6	179.76	70.5
	Twig-5	176.16	69.1
	Twig-4	183.53	72.0
	Twig-3	170.91	67.0
	Twig-2	224.22	87.9
	Twig-1	200.84	78.8
h'	Twig-11	192.67	75.6
	Twig-10	218.66	85.7
	Twig-9	166.86	65.4
	Twig-8	133.60	52.4
	Twig-7	210.07	82.4
	Twig-6	188.69	74.0
	Twig-5	234.36	91.9
	Twig-4	228.61	89.6
	Twig-3	87.87	34.5
	Twig-2	237.28	93.0
	Twig-1	225.26	88.3
g'	Twig-7	187.27	73.4
	Twig-6	202.60	79.4
	Twig-5	181.90	71.3
	Twig-4	192.82	75.6
	Twig-3	158.83	62.3
	Twig-2	207.02	81.2
	Twig-1	239.31	93.8
f'	Twig-7	183.70	72.0
	Twig-6	204.79	80.3
	Twig-5	148.18	58.1
	Twig-4	242.21	95.0
	Twig-3	172.62	67.7
	Twig-2	177.60	69.6
	Twig-1	255.01	100.0
e'	Twig-4	64.05	25.1
	Twig-3	87.47	34.3
	Twig-2	227.92	89.4
	Twig-1	193.99	76.1
d'	Twig-10	160.03	62.8
	Twig-9	142.96	56.1
	Twig-8	89.21	35.0
	Twig-7	119.06	46.7
	Twig-6	114.39	44.9
	Twig-5	156.19	61.2
	Twig-4	74.09	29.1
	Twig-3	47.06	18.5
	Twig-2	142.11	55.7
	Twig-1	127.80	50.1
c'	Twig-8	120.08	47.1
	Twig-7	66.32	26.0
	Twig-6	118.92	46.6
	Twig-5	32.41	12.7
	Twig-4	75.89	29.8
	Twig-3	48.73	19.1
	Twig-2	26.54	10.4
	Twig-1	31.43	12.3
b'	Twig-6	41.39	16.2
	Twig-5	138.86	54.5
	Twig-4-6	102.15	40.1
	Twig-4-5	169.14	66.3
	Twig-4-4	216.63	84.9
	Twig-4-3	179.71	70.5
	Twig-4-2	121.70	47.7
	Twig-4-1	74.93	29.4
	Twig-3	118.69	46.5
	Twig-2	163.67	64.2
	Twig-1	93.71	36.7
a'	Twig-10	126.05	49.4
	Twig-9	110.93	43.5
	Twig-8	112.77	44.2
	Twig-7	22.16	8.7
	Twig-6	56.14	22.0
	Twig-5	32.89	12.9
	Twig-4	136.96	53.7
	Twig-3	78.95	31.0
	Twig-2	148.64	58.3
	Twig-1	136.34	53.5
Average		144.79	
SD		61.59	
b' (Average value)**	Twig-4-1 ～ Twig-4-6	144.04	

** The Twig-4 of the section b' had 6 twigs. They were designated as Twig-1-1, Twig-1-2 etc from the bottom to the upperside.

Female

Sections	Tissues	μg As/g Dry weight	Percentage ratio (%)*
g'		69.67	89.0
f'		58.12	74.3
e'		78.27	100.0
d'	Stalks	44.75	57.2
c'		69.82	89.2
b'		55.84	71.3
a'		41.55	53.1
Average		59.72	
SD		13.64	
Scutellate holdfast		20.39	
g' (Apex)	Twig-8	105.37	63.4
	Twig-7	143.35	86.3
	Twig-6	113.07	68.1
	Twig-5	156.93	94.5
	Twig-4	150.48	90.6
	Twig-3	122.81	73.9
	Twig-2	117.06	70.5
	Twig-1	155.07	93.4
f'	Twig-8	166.08	100.0
	Twig-7	148.60	89.5
	Twig-6	131.14	79.0
	Twig-5	146.27	88.1
	Twig-4	124.91	75.2
	Twig-3	151.18	91.0
	Twig-2	127.61	76.8
	Twig-1	134.06	80.7
e'	Twig-5	129.45	77.9
	Twig-4	116.66	70.2
	Twig-3	131.91	79.4
	Twig-2	130.66	78.7
	Twig-1	123.43	74.3
d'	Twig-5	93.66	56.4
	Twig-4	39.70	23.9
	Twig-3	60.90	36.7
	Twig-2	90.92	54.7
	Twig-1	86.03	51.8
c'	Twig-4	111.20	67.0
	Twig-3	97.19	58.5
	Twig-2	107.31	64.6
	Twig-1	101.21	60.9
b'	Twig-4	78.95	47.5
	Twig-3	143.01	86.1
	Twig-2	108.33	65.2
	Twig-1	118.47	71.3
a'	Twig-12	96.54	58.1
	Twig-11	86.07	51.8
	Twig-10	113.24	68.2
	Twig-9	85.24	51.3
	Twig-8	109.83	66.1
	Twig-7	118.04	71.1
	Twig-6	123.50	74.4
	Twig-5	74.35	44.8
	Twig-4	79.72	48.0
	Twig-3	91.67	55.2
	Twig-2	92.80	55.9
	Twig-1	124.84	75.2
Average		114.32	
SD		26.95	

The designation of the sections was as described in the text.
* The highest value of the stalks or the twigs was taken as 100 %.

Table 4 Average values of the arsenic concentration of the respective tissues of Hijiki, harvested at Mugisaki district of Ise Bay[12)]

Hijiki

Tissues	μg As/g dry weight
Genital organs	72.94
Twig's leaves	51.77
Twig's stalks	54.12
Leaves	58.52
Stalks	47.06
Filamentous holdfast	58.82

currently under investigation.

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