Attraction Activities of Terrestrial Vegetable Extracts for Aquatic Animals

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Attraction activities of terrestrial vegetables for black abalone *Haliotis discus*, oriental weatherfish *Misgurnus anguillicaudatus*, and yellowtail *Seriola quinqueradiata* were estimated by behavioral experiments in a laboratory test tank as well as an attraction index *a* for both abalone and oriental weatherfish, and another attraction index *gr* for yellowtail. The indexes *a* and *gr* were estimated by a method described in previous papers. Most of the vegetables tested (39 breeds from 36 kinds of vegetables) showed, to some extent, attraction activities for these three animals tested. The highest activity was observed in soybean *Glycine max* for black abalone, cabbage *Brassica oleracea* var. *capitata* (Nakawase 2) for weatherfish, and onion *Allium cepa* for yellowtail. The attraction activities of these vegetables clearly depended on the concentrations used.

Key words: attraction, vegetables, aquatic animals, behavior, abalone, oriental weatherfish, yellowtail

We examined the attraction activities of terrestrial food substances such as spices, herbal drugs, and fruits, which are foreign to aquatic environments, toward black abalone *Haliotis discus*, oriental weatherfish *Misgurnus anguillicaudatus*, and yellowtail *Seriola quinqueradiata* by behavioral experiments.¹⁻⁶⁾ The effectiveness of several spices, herbal drugs, and fruits has been proved to induce exploratory and feeding behaviors by tank experiments for the three aquatic animals described above.¹⁻⁶⁾

To find attractants from easily available vegetables, similar experiments using the same target species were conducted, and the results are described in the present paper.

Materials and Methods

Test Animals

Young black abalone of 1.5 cm average shell length were supplied by the Yamaguchi Prefecture Gaikai Fisheries Experimental Station. Fifty individuals were used for each test. Adult oriental weatherfish 8.2 cm average body length were obtained from a private aquaculture farm in Shiga Prefecture and 60 individuals were used in each test. Juvenile yellowtails 4.9 cm average fork length were obtained from an aquaculture farm of Senzaki Cooperative in Yamaguchi Prefecture. One hundred and fifty three fish were accommodated in a test tank and the experiments were performed with the same fish. During the experimental period, 113 individuals were successively removed as they grew too big for testing in the test tank. Maintenance of the test animals and the procedures for the experiments were the same as described in previous papers.⁷⁻⁹⁾

Test Samples

Thirty-nine breeds from 36 kinds of vegetables tested

are listed in Table 1. Each test sample was prepared as follows. Edible portions of the vegetable were thoroughly chopped into small pieces and homogenized with a food processor and an Ultra-Turrax homogenizer (Janke & Kunkel GmbH & Co., KG, Germany) in an equal volume of deionized water. The homogenate was then centrifuged for 15 min at $8,000 \times g$ below 5°C and the supernatant was filtered through a filter paper (Advantec Toyo No. 2). The filtrate was, if necessary, adjusted to pH 6.5 by a dilute sodium hydroxide or hydrochloric acid solution and stored at -40°C before use.

Estimation of Attraction Indexes

Attraction indexes, the A.I. *a* for both abalone and oriental weatherfish, and the A.I. *gr* for yellowtail were estimated by the methods described in the previous papers.⁷⁻⁹⁾ Briefly, the estimation of A.I. *a* and A.I. *gr* was based on applying the remained and the entered or left time-courses obtained from a behavioral experiment to a logistic curve $y = g / \{1 + \exp[-r(x-a)]\}$. In respective tests, three test samples were chosen arbitrarily from the 39, and set in the test compartment of three channels arranged arbitrarily out of the four in the test tank (one channel being left as a dummy). Statistical significance was evaluated using the chi-square test. A.I. *a* and A.I. *gr* correspond to the average remained time (min) and the number of locomotive fish at the coefficient *a*, respectively. A crumpled gauze (a sheet of 25 cm × 25 cm) in which 7.5 ml of test sample was absorbed was set in each of the four compartments in the test tank to observe the behavior of the animals. Attraction activities of three arbitrary test samples and a dummy were measured at a time.

Table 1. Terrestrial vegetables tested

Common name	Japanese name	Botanical name
Aralia family	Ukogika	Araliaceae
Udo	Udo	<i>Aralia cordata</i>
Arum family	Satoimoka	Araceae
Taro	Satoimo	<i>Colocasia esculenta</i>
Bean family	Mameka	Leguminosae
Broad bean	Soramame	<i>Vicia faba</i>
Pea	Akaendoumame	<i>Pisum sativum</i>
Soybean	Edamame	<i>Glycine max</i>
Ginger family	Shougaka	Zingiberaceae
Ginger	Shouga	<i>Zingiber officinale</i>
Mioga	Myouga	<i>Zingiber mioga</i>
Gourd family	Urika	Cucurbitaceae
Cucumber	Kyuuri	<i>Cucumis sativus</i>
Grass family	Ineka	Gramineae
Bamboo shoot	Takenoko	<i>Phyllostachys bambusoides</i>
Lily family	Yurika	Liliaceae
Chinese chive	Nira	<i>Allium tuberosum</i>
Onion	Tamanegi	<i>Allium cepa</i>
Rakkyo	Rakkyo	<i>Allium chinense</i>
Mallow family	Aoika	Malvaceae
Gumbo	Okura	<i>Abelmoschus esculentus</i>
Mint family	Sisoka	Labiatae
Perilla (I)	Siso	<i>Perilla ocymoides</i>
Perilla (II)	Aosisomejiso	<i>Perilla ocymoides</i>
Mustard family	Aburanaka	Cruciferae
Broccoli	Burokkori	<i>Brassica oleracea</i> var. <i>italica</i>
Cabbage (I)	Kyabetu	<i>Brassica oleracea</i> var. <i>capitata</i> (Nakawase 2)
Cabbage (II)	Kyabetu	<i>Brassica oleracea</i> var. <i>capitata</i> (Kinsyun)
Cauliflower	Karifurawa	<i>Brassica oleracea</i> var. <i>botrytis</i>
Japanese radish	Daikon	<i>Raphanus sativus</i> var. <i>longipinnatus</i>
Pakchoi	Chingensai	<i>Brassica campestris</i> var. <i>chinensis</i>
Turnip	Kabu	<i>Brassica campestris</i>
Wasabi	Wasabi	<i>Eutrema wasabi</i>
Osmund family	Zenmaika	Osmundaceae
Zen mai	Zenmai	<i>Osmunda japonica</i>
Parsley family	Serika	Umbelliferae
Carrot	Ninjin	<i>Daucus carota</i>
Celery	Serori	<i>Apium graveolens</i> var. <i>dulce</i>
Japanese hornwort	Mituba	<i>Cryptotaenia japonica</i>
Parsley	Paseri	<i>Petroselinum crispum</i>
Water dropwort	Seri	<i>Oenanthe japonica</i>
Potato family	Nasuka	Solanaceae
Eggplant	Nasu	<i>Solanum melongena</i>
Irish potato (I)* ¹	Jagaimo	<i>Solanum tuberosum</i>
Irish potato (II)* ³	Jagaimo	<i>Solanum tuberosum</i>
Sunflower family	Kikuka	Compositae
Edible burdock (I)* ¹	Gobou	<i>Arctium lappa</i>
Edible burdock (II)* ²	Gobou	<i>Arctium lappa</i>
Garland chrysanthemum	Shungiku	<i>Chrysanthemum coronarium</i>
Head lettuce	Retasu	<i>Lactuca sativa</i>
Japanese butterbur	Fuki	<i>Petasites japonicus</i>
Leaf lettuce	Saniretasu	<i>Lactuca sativa</i>
Mugwort	Yomogi	<i>Artemisia princeps</i>

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Determination of Free Amino Acids

Free amino acid contents in the vegetable extracts were determined by high-performance liquid chromatography (HPLC). The HPLC was performed with a Hitachi L-6000 series by the OPA method described in the Hitachi HPLC Instruction Manual.

Results and Discussion

The calculated values of the attraction indexes of vegetable samples for the three test animals are listed in Table 2. The values in this table can be compared only among those in the same series No. Test samples with a higher value of attraction index than that of the dummy were regarded to

Table 2. Attraction activities of vegetables

No. Vegetables	Attraction activities*			
	Abalone (A.I. <i>a</i>)	Oriental weatherfish (A.I. <i>a</i>)	Yellowtail (A.I. <i>gr</i>)	
1 {	Dummy	5.1	2.8	167.8 [?]
	Garland chrysanthemum	5.0	6.4	158.1
	Japanese hornwort	5.5	8.7	134.0
	Water dropwort	7.4	2.9	128.4
2 {	Dummy	5.7	1.9	181.4
	Chinese chive	4.6	3.5	173.5
	Mugwort	7.9	3.9	118.5
	Parsley	6.0	12.2	166.1
3 {	Dummy	6.3	2.0	32.6
	Cabbage (I)	11.8	3.6	53.7
	Leaf lettuce	10.0	2.3	44.2
	Head lettuce	4.0	2.9	31.1
4 {	Dummy	4.6 [?]	2.5 [?]	68.7
	Cabbage (II)	6.0	3.1	122.2
	Perilla (I)	5.3	2.3	142.5
	Perilla (II)	5.2	2.2	79.9
5 {	Dummy	5.7	1.7	73.8
	Japanese butterbur	5.5	1.8	75.7
	Udo	6.9	3.1	37.9
	Zen mai	5.0	2.1	38.3
6 {	Dummy	5.3	2.9	166.9
	Bamboo shoot	6.3	3.2	88.2
	Onion	6.4	3.7	191.6
	Rakkyo	4.4	4.5	181.2
7 {	Dummy	4.4	0.6	65.1
	Edible burdock (I)	4.1	3.7	51.5
	Turnip	6.2	2.8	121.0
	Wasabi	9.6	1.3	12.5
8 {	Dummy	5.4 [?]	1.2	8.6
	Carrot	5.2 [?]	2.1	17.3
	Irish potato (I)	6.7	2.5	15.2
	Japanese radish	4.0 [?]	2.9	26.2
9 {	Dummy	3.8	2.6	94.9
	Edible burdock (II)	3.1	3.8	51.4
	Ginger	5.8	3.3	29.1
	Irish potato (II)	4.8	2.0	70.8
10 {	Dummy	6.2	1.8	71.3 [?]
	Broad bean	8.0	2.9	79.8
	Pea	9.1	2.1	65.7
	Soybean	10.3	2.2	105.1
11 {	Dummy	9.8 [?]	3.3	35.3
	Cucumber	6.5	2.3	80.0
	Eggplant	9.9	3.2	46.7
	Gumbo	6.3	1.9	35.2
12 {	Dummy	5.0	5.6	93.5
	Celery	8.4 [?]	3.5 [?]	105.2
	Mioga	4.5	6.6	106.7
	Taro	4.9	3.6 [?]	75.2
13 {	Dummy	10.9	3.2	168.1
	Broccoli	9.6 [?]	4.0 [?]	123.1
	Cauliflower	8.0	4.2	138.0
	Pakchoi	5.2	4.7	143.1

* A.I. *a* and *gr* are derived from the coefficients of a logistic curve $y = g / \{1 + \exp[-r(x - a)]\}$ being applied to remained, and entered or left time-courses for black abalone and oriental weatherfish, and yellowtail, respectively. The indexes, which were estimated from the series of data showing good fitness, $Pr(\chi^2 > \chi^2_{0.100})$ were listed, otherwise attached with a mark "?".

be effective in attraction. For abalone, the following vegetables were effective in attraction: Japanese hornwort, water dropwort, mugwort, parsley, cabbage (I), leaf lettuce, cabbage (II), perilla (I), perilla (II), udo, bamboo shoot, onion, turnip, wasabi, Irish potato (I), ginger, Irish potato (II), broad bean, pea, soybean, and celery. Among them, leaf lettuce, cabbage (I), wasabi, soybean, and celery were most attractive.

For oriental weatherfish, the following vegetables were effective in attraction: garland chrysanthemum, Japanese hornwort, Chinese chive, mugwort, parsley, cabbage (I), leaf lettuce, head lettuce, cabbage (II), udo, zen mai, bamboo shoot, onion, rakkyo, edible burdock (I), turnip, wasabi, carrot, Irish potato (I), Japanese radish, edible burdock (II), ginger, broad bean, pea, soybean, mioga, broccoli, cauliflower, and pakchoi. Among them, garland chrysanthemum, Japanese hornwort, mugwort, parsley, cabbage (I), edible burdock (I), turnip, wasabi, Irish potato (I), and Japanese radish were most attractive.

For yellowtail, the following vegetables were effective in

Fig. 1. Effects of concentrations on attraction activities, (A) soybean for black abalone, (B) cabbage (I) for oriental weatherfish, (C) onion for yellowtail.

Attraction activity was examined for three relative concentrations diluted from the original vegetable extract.

Table 3. Attraction activities of active vegetables for abalone

No. Vegetables	Attraction activities* (A.I. <i>a</i>)	No. Vegetables	Attraction activities* (A.I. <i>a</i>)		
14	{ Dummy	5.5 [?]	15	{ Dummy	—
	{ Cabbage (I)	16.0		{ Irish potato (I)	5.1
	{ Mugwort	9.0		{ Onion	3.7 [?]
	{ Water dropwort	6.4		{ Wasabi	6.3
16	{ Dummy	2.5 [?]	17	{ Dummy	—
	{ Celery	5.8		{ Cabbage (I)	5.3
	{ Ginger	2.4 [?]		{ Soybean	8.6
	{ Soybean	7.4 [?]		{ Wasabi	7.4 [?]

* legends in Table 2. Nos. 14–16: intermediate selection. No. 17: final selection.

Table 4. Attraction activities of active vegetables for oriental weatherfish

No. Vegetables	Attraction activities* (A.I. <i>a</i>)	No. Vegetables	Attraction activities* (A.I. <i>a</i>)		
18 {	Dummy	3.0	19 {	Dummy	1.9
	Cabbage (I)	7.7		Edible burdock (I)	3.7
	Japanese hornwort	3.9		Rakkyo	3.0 [?]
	Parsley	5.9		Udo	2.6 [?]
20 {	Dummy	2.7	21 {	Dummy	1.0
	Japanese radish	4.3		Cabbage (I)	4.5
	Mioga	2.9		Edible burdock (I)	3.1
	Pakchoi	3.9		Japanese radish	4.3

* legends in Table 2. Nos. 18–20: intermediate selection. No. 21: final selection.

Table 5. Attraction activities of active vegetables for yellowtail

No. Vegetables	Attraction activities* (A.I. gr)	No. Vegetables	Attraction activities* (A.I. gr)		
22 {	Dummy	61.5	23 {	Dummy	122.7
	Cabbage (I)	69.4		Japanese radish	178.1
	Onion	84.0		Soybean	163.6 [?]
	Perilla (I)	63.0		Turnip	138.9
24 {	Dummy	104.8	25 {	Dummy	76.5
	Carrot	113.9		Cucumber	86.7
	Cucumber	242.4		Japanese radish	101.6
	Mioga	118.1		Onion	121.1

* legends in Table 2. Nos. 22–24: intermediate selection. No. 25: final selection.

attraction: cabbage (I), leaf lettuce, cabbage (II), perilla (I), perilla (II), onion, rakkyo, turnip, carrot, Irish potato (I), Japanese radish, broad bean, soybean, cucumber, eggplant, celery, and mioga. Among them, perilla (I), onion, carrot, Japanese radish, and cucumber were most attractive.

The vegetables that were effective in attraction did not in-

duce any unusual behavior pattern during the experiment, and the test individuals swam into and away from the test compartment as in the test of attractants previously reported.¹⁻⁶⁾

Furthermore, to determine the most effective vegetables for each test animal, 9 vegetables, which showed strong effects in Table 2, were sorted from the 39, and tests were

Table 6. Attraction magnitude and organoleptic taste and/or flavor of vegetables tested

Common name	Attraction magnitude* ¹			Taste or taste with flavor
	A* ²	O* ²	Y* ²	
Aralia family				
Udo	+	+		Astringent
Arum family				
Taro				Slightly sweet
Bean family				
Broad bean	+	+	+	Very slightly sweet
Pea	+	+		Slightly sweet
Soybean	++	+	+	Slightly sweet
Ginger family				
Ginger	+	+		Bitter
Mioga		+	+	Astringent
Gourd family				
Cucumber			++	Slightly sweet
Grass family				
Bamboo shoot	+	+		Slightly sweet
Lily family				
Chinese chive		+		Strongly bitter
Onion	+	+	++	Strongly sweet
Rakkyo		+	+	Strongly sweet
Mallow family				
Gumbo				No taste, strong grassy flavor
Mint family				
Perilla (I)	+		++	Astringent
Perilla (II)	+		+	Astringent
Mustard family				
Broccoli		+		Bitter, sweet flavor
Cabbage (I)	++	++	+	Slightly sweet
Cabbage (II)	+	+	+	Slightly sweet
Cauliflower		+		Bitter, sweet flavor
Japanese radish		++	++	Slightly sweet
Pakchoi		+		Bitter, grassy flavor
Turnip	+	++	+	Slightly sweet
Wasabi	++	++		Hot, pungent
Osmund family				
Zen mai		+		Bitter
Parsley family				
Carrot		+	++	Slightly sweet
Celery	++		+	Astringent
Japanese hornwort	+	++		Bitter
Parsley	+	++		Bitter
Water dropwort	+			Bitter
Potato family				
Eggplant			+	Slightly sweet
Irish potato (I)	+	++	+	Slightly sweet
Irish potato (II)	+			Slightly sweet
Sunflower family				
Edible burdock (I)		++		Slightly sweet
Edible burdock (II)		+		Slightly sweet
Garland chrysanthemum		++		Strongly bitter
Head lettuce		+		Slightly sweet
Japanese butterbur				Bitter, sweet flavor
Leaf lettuce	++	+	+	Slightly sweet, grassy flavor
Mugwort	+	++		Astringent

*¹ +; weak, ++; strong.

*² A; black abalone, O; oriental weatherfish, Y; yellowtail.

repeated using the same method as the previous one, i.e., for combinations of 3 out of the 9 (Tables 3, 4, and 5). As the results of the final combination test (Nos. 17, 21, and 25 in Tables 3, 4, and 5, respectively), it was found that soybean, cabbage (I), and onion were the most active for abalone, oriental weatherfish, and yellowtail, respectively. The effect of concentration of the three vegetable extracts on attraction activity was tested for corresponding animals (Fig. 1). Attraction activities of the three concentrations of each vegetable extract with the dummy were measured. At-

traction activities for all the three extracts increased with increasing concentration over the concentration range investigated. The results of the experiments are summarized together with the organoleptic taste of the vegetable extracts in Table 6, which indicate that attractant vegetables for all the test animals were broad bean, soybean, onion, cabbage (I), cabbage (II), turnip, Irish potato (I), and leaf lettuce.

There have been several studies on the attractive effect of constituents in food "plants" that are foreign to aquat-

Table 7. Contents of free amino acids in vegetable extracts tested (mg/100 ml test solution)

Common name	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Leu	Tyr	Phe	Lys	His	Arg	Total
Aralia family																		
Udo	15.4	112.4	1.6	83.4	—	0.6	2.6	—	2.8	—	3.4	5.0	—	—	—	6.6	—	233.8
Arum family																		
Taro	15.2	11.2	11.8	18.0	—	1.4	7.4	—	6.0	7.2	3.6	16.2	—	7.8	3.2	2.2	—	111.2
Bean family																		
Broad bean	37.0	52.4	18.0	49.0	—	9.4	70.4	—	19.6	—	48.6	15.4	26.6	26.2	33.8	28.0	229.6	664.0
Pea	10.6	65.4	34.4	168.2	—	31.4	46.8	—	38.8	7.2	65.2	33.4	28.0	31.8	50.4	28.8	272.2	912.6
Soybean	51.6	36.2	39.4	10.8	25.6	24.4	81.4	—	21.6	—	27.4	22.6	—	104.6	27.8	50.2	93.0	616.6
Ginger family																		
Ginger	21.0	23.0	16.8	11.0	—	2.0	9.6	—	5.6	13.2	38.4	39.6	—	5.0	6.8	2.0	1.8	195.8
Mioga	11.8	11.2	9.2	7.6	—	4.0	2.0	—	1.4	—	1.0	1.2	—	2.4	0.8	1.4	—	54.0
Gourd family																		
Cucumber	3.0	29.6	8.0	13.6	11.4	6.4	3.8	—	3.6	—	5.2	5.6	—	4.4	3.6	2.0	—	100.2
Grass family																		
Bamboo shoot	17.6	28.4	27.0	29.4	—	3.8	11.0	—	17.2	—	15.0	20.8	81.4	17.6	21.8	15.6	15.6	322.2
Lily family																		
Chinese chive	19.0	27.6	4.8	78.8	—	5.8	24.8	—	11.0	—	16.0	14.2	—	10.2	28.4	4.4	9.0	254.0
Onion	9.4	26.2	7.0	33.6	—	1.0	4.8	—	7.0	—	7.8	15.4	15.2	9.2	23.6	10.6	41.2	212.0
Rakkyo	12.0	37.2	13.6	118.6	13.4	2.4	17.4	—	2.6	11.0	4.0	3.4	—	14.4	30.6	14.2	141.2	436.0
Mallow family																		
Gumbo	48.6	69.8	12.8	19.4	2.4	2.8	17.6	—	5.4	—	5.4	2.6	—	8.6	2.4	5.2	—	203.0
Mint family																		
Perilla (I)	5.8	3.2	2.6	20.6	—	2.8	6.4	—	—	—	2.6	1.8	—	5.2	—	—	—	51.0
Perilla (II)	9.6	2.4	1.8	12.2	—	1.2	6.6	—	—	—	1.0	1.2	—	3.2	—	—	—	39.2
Mustard family																		
Broccoli	73.6	187.8	91.8	110.0	15.6	7.8	45.4	—	76.6	—	34.2	22.0	13.0	83.6	44.8	47.0	153.4	1006.6
Cabbage (I)	20.2	93.8	17.4	13.0	—	3.8	25.0	—	11.8	—	16.8	10.4	—	6.0	19.0	12.2	21.0	270.4
Cabbage (II)	19.8	45.8	12.6	6.8	—	2.2	15.8	—	—	—	13.8	8.0	—	4.6	4.6	9.0	16.0	159.0
Cauliflower	35.8	27.2	15.4	40.6	9.2	5.2	30.0	—	15.8	—	13.2	16.2	7.0	8.8	15.8	3.6	—	243.8
Japanese radish	15.0	48.8	6.8	4.6	—	2.4	7.2	—	5.8	—	5.0	2.2	—	2.2	3.4	3.0	12.6	119.0
Pakchoi	19.2	14.6	7.0	7.4	—	1.8	9.0	—	9.0	—	4.8	6.8	—	6.8	—	3.0	—	89.4
Turnip	12.6	14.8	7.0	14.6	—	4.2	6.8	—	4.2	40.4	11.6	5.0	—	14.4	3.6	2.4	7.4	149.0
Wasabi	20.0	45.0	12.4	31.4	—	1.4	13.2	—	6.6	—	6.6	3.0	—	4.8	5.8	3.0	6.0	159.2
Osmund family																		
Zen mai	5.2	27.6	1.8	46.8	—	0.4	6.2	—	—	—	188.6	—	14.8	46.8	—	—	—	338.2
Parsley family																		
Carrot	25.0	54.6	6.8	1.2	—	1.6	21.0	—	6.0	13.6	5.2	3.0	—	4.8	4.0	—	4.8	151.6
Celery	7.8	57.4	6.6	1.8	—	1.0	5.6	—	13.6	—	10.6	8.0	—	9.2	5.4	5.2	—	132.2
Japanese hornwort	4.0	1.6	2.6	2.0	—	1.0	4.4	—	—	—	2.4	2.2	—	7.0	—	—	—	27.2
Parsley	19.4	10.2	4.6	25.4	—	3.4	15.4	—	14.0	—	12.6	24.0	—	15.8	16.8	2.4	10.0	174.0
Water dropwort	10.4	17.4	0.4	7.6	—	0.8	5.6	—	3.8	—	47.6	11.0	—	58.8	—	—	88.2	251.6
Potato family																		
Eggplant	15.8	26.2	3.6	3.2	—	1.6	3.2	—	4.8	14.8	4.6	2.8	109.4	9.8	3.8	3.6	—	207.2
Irish potato (I)	15.6	73.6	7.4	7.0	—	2.8	8.2	—	25.2	7.8	9.6	6.2	—	23.2	9.8	5.0	40.0	241.4
Irish potato (II)	37.4	94.4	13.2	24.4	—	4.6	13.2	—	40.6	13.2	20.0	11.4	—	43.6	23.0	10.6	61.4	411.0
Sunflower family																		
Edible burdock (I)	6.8	1.8	1.6	5.4	—	0.6	1.8	—	—	—	2.6	1.2	—	8.2	—	—	6.2	36.2
Edible burdock (II)	35.2	17.8	1.4	165.6	—	2.0	8.6	—	5.8	—	9.0	4.8	—	16.6	2.2	5.8	130.2	405.0
Garland chrysanthemum	4.1	1.6	1.2	3.4	—	0.6	1.2	—	—	9.2	2.8	1.2	—	—	—	—	—	25.3
Head lettuce	5.0	23.4	5.0	4.8	—	1.2	2.6	—	2.4	—	3.8	2.6	2.6	5.8	1.6	0.8	—	61.6
Japanese butterbur	1.8	2.2	1.8	4.8	—	0.4	11.4	—	1.0	—	1.2	0.6	—	2.6	—	—	—	27.8
Leaf lettuce	6.2	3.6	2.2	9.4	—	0.6	3.2	—	—	—	3.2	2.4	—	—	—	—	—	30.8
Mugwort	5.8	3.2	2.2	10.6	—	0.6	5.0	—	2.0	—	2.6	4.0	—	8.6	—	0.8	—	45.4

ic environments.^{1-3,10-14)} In the previous papers, we have examined attraction activities of various spices, herbal drugs and fruits for black abalone, oriental weatherfish, and yellowtail.¹⁻⁶⁾ Most of the samples were found to be effective to some extent for the test animals. In the present study, all the vegetables tested except taro, Japanese butterbur, and gumbo also showed to some extent attraction activities for more than one test animal. All the Cruciferae vegetables tested (8 kinds) proved to be effective in attraction for oriental weatherfish and attraction activity was strong in half of these vegetables. This may suggest that the Cruciferae vegetables widely contain some specific attractive compound(s) for oriental weatherfish. However, no such strong effect was found for abalone nor yellowtail with vegetables of the family Cruciferae.

A kind of spice, anise *Pimpinella anisum*, attracted and stimulated rainbow trout *Salmo gairdneri*.¹¹⁾ Furthermore, a kind of vegetable, lettuce *Lactuca sativa* var. *longifolia*, stimulated herbivorous fish *Tilapia zillii*,^{12,13)} snail *Australorbis glabratus*¹⁰⁾ and pond snail *Lymnaea stagnalis*.¹⁴⁾ From these studies, it is possible that organisms which are not distributed in the inhabitant environment of aquatic animals might contain effective constituents as feeding attractants or stimulants for the animals.

The majority of attractive fruit extracts for abalone, oriental weatherfish, and yellowtail were, to some extent, sweet and sour tastes as organoleptic to human in our previous study.⁴⁻⁶⁾ Sugars and their related compounds, which are sweet for human, were also attractive for aquatic animals.¹⁵⁻¹⁷⁾ These findings suggested that sweet compounds contained in the extracts attract the aquatic animals. In the present study, most of the vegetables that showed high attraction activity were, to some extent, sweet tasting for human (Table 6). On the other hand, the following vegetables having a specific taste and flavor for human also attracted the test animals: wasabi and celery for black abalone, wasabi, Japanese hornwort, parsley, garland chrysanthemum, and mugwort for oriental weatherfish, and perilla (I) for yellowtail. These vegetable extracts provide no sweet taste for human (Table 6). It is probable that the components which caused the specific tastes and flavors participate in the attraction activity.

The test animals abalone, oriental weatherfish, and yellowtail were attracted by such compounds contained in their feed as sugars, lipids, nitrogenous bases, nucleic acid-related compounds, proteins, amino acids, and/or others.¹⁸⁻²²⁾ Amino acids that had high attraction activity were as follows: lysine, ornithine, and hydroxyproline for abalone; histidine, lysine, arginine, glycine, and alanine for oriental weatherfish; and histidine, glycine, threonine, and arginine for yellowtail.¹⁸⁻²⁰⁾ The free amino acid contents in the vegetable extracts tested were determined to examine the relationship between the attraction activity and the amino acid contents (Table 7). For abalone, effective vegetable extracts contained lysine (in soybean, cabbage (I), wasabi, celery, and leaf lettuce) at relatively low concentrations, although only lysine was determined among the attractants of amino acids described above. On the contrary, for oriental weatherfish and yellowtail, effective vegetable extracts contained alanine (in cabbage (I) and Japanese hornwort), lysine (in cabbage (I)), or arginine (in edible burdock (I), cabbage (I), Japanese radish, and Irish potato

(I)), and threonine (in Japanese radish, cucumber, and carrot) or arginine (in onion) at relatively high concentrations among the attractants of amino acids described above, respectively. These findings suggested that these amino acids were responsible for attraction activities of vegetable extracts for oriental weatherfish and yellowtail, but not for abalone. On the other hand, it is reported that the herbivorous fish *Tilapia zillii* was strongly attracted by the following amino acids fractionated from lettuce: glutamic acid, aspartic acid, lysine, alanine, and serine.¹²⁾ These attractive amino acids therefore probably participate at least in the attraction activity of the vegetable for herbivorous fish.

Among the terrestrial vegetables listed in Table 1, 2 specimens each of edible burdock and Irish potato were used from different places of production, while 2 specimens each of cabbage and perilla were also used from different breeds. The different attraction activities in these vegetables may be related to the different places of production or breed (Tables 2 and 6). Compositions in the vegetable extracts may delicately depend on the place of production, breed, maturity, or freshness. For examples, differences in the free amino acid compositions were observed in the present paper between the vegetables from different places of production or from different breeds. This difference in amino acid compositions and/or other components may affect the attraction activity.

In conclusion, most of the vegetables tested, which are foreign to aquatic animals, probably contain some attractants for black abalone, oriental weatherfish, and yellowtail.

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