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Attraction Activities of Fruit Flesh Water Extracts for Yellowtail *Seriola quinqueradiata* *1

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The attraction activities of flesh water extracts of fruits and in some cases fruit rind (outer cover) were statistically estimated on the basis of an exploratory behavior of carnivorous yellowtail *Seriola quinqueradiata*. The fruit fleshes of certain apple, European plum, Japanese medlar, nectarine, grape, kiwi fruit, netted melon, and persimmon strongly attracted the yellowtail. The most active fruits were the Japanese medlar and the apple, and the attraction activity of the Japanese medlar increased appreciably as the concentration increased. The fruit rinds of some oranges also faintly attracted the yellowtail.

1 Introduction

The majority of studies on feeding attractants for aquatic animals have dealt with the attractive effect of natural food of fishes and shellfishes, its constituents and compounds.[1] Among the various substances, amino acids and related compounds, and nucleic acid related compounds have received attention.

In contrast, several studies deal with the attractive effect of constituents and compounds in "plant" food substances which are foreign to aquatic environments.[2-6]

Michelson[2] determined the reaction of test snail to various baits such as Romaine lettuce *Lactuca sativa* var. *longifolia*, untreated watercress *Nasturtium officinale*, ground watercress, wheat germ and so on by observing the behavior of a series of snail *Australorbis glabratus* in a "Y"-shaped maze. The wheat germ was attractive, but the ground watercress was repellent. However the Romaine lettuce and the untreated watercress were non-reactive. Takei[3] reported that anise oil obtained from certain spice is favoured by rainbow trout *Salmo gairdneri*, but not favoured by carp *Cyprinus carpio* or yellowtail *Seriola quinqueradiata*. In such a manner, the attraction of the "plant" materials and their substances has been reported sporadically. Meanwhile, Harada[4-6] has tested systematically the attraction activities of various spices and herbal drugs for three aquatic animals, such as black abalone *Haliotis discus*, oriental weatherfish *Misgurnus anguillicaudatus*, and yellowtail *Seriola quinqueradiata*. Many species of spices and herbal drugs are found to be attractive to three test specimens described above. Apart from the attractive effect of foreign "plant" food of fishes and shellfishes, foreign "animal" food are also found to be effective to fishes such as common catfish *Amiurus nebulosus*,[7] sockeye *Oncorhynchus nerka*,[8] salmon *Salmo gairdneri*,[3] carp *Cypri-*

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nus carpio,[3] sea bream *Chrysophrys major*,[9] and oriental weatherfish *Misgurnus anguillicaudatus*.[10] On the basis of these results, some foreign materials as well as natural ones to aquatic animals are estimated in order to show their attractivity.

In this connection, the present paper deals mainly with the attraction activities of various fruit flesh water extracts for the yellowtail.

2 Materials and Methods

2.1 Animals and test tank

Juvenile yellowtail *Seriola quinqueradiata* (6.5cm in average fork length at the initial of experiment) were kindly supplied from Senzaki Station of Aquaculture in Yamaguchi prefecture. The individuals used for the experiments were 178 (at the initial of experiment) to 42 (at the end) yellowtail. The maintenance of yellowtail was the same as described in the previous paper.[11] Briefly they were transported to the test tank, as shown in Fig.1 and fed to satiation only once at 16:00 daily with formulated eel feed (Nihon Haigoushiryou Co. Ltd.). Seawater was introduced continuously into the test tank through each inlet of delivery tube I at the rate of 1 liter per minute. Terms h_1 and h_2 are elliptical holes (a=5cm, b=10cm) provided on septa.

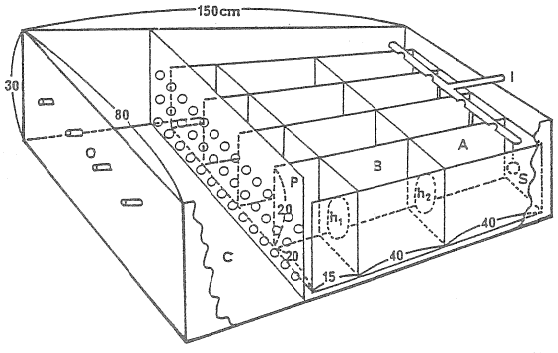

Fig. 1. Test tank used for attraction study of yellowtail S: position of gauze containing test sample or dummy (control); tank dimensions in cm.

2.2 Preparation of fruit test samples

The fruits examined were 36 forms of 25 species, as shown in Table 1. Fruit test samples were prepared as follows. The fresh fruit flesh or rind (outer cover) was thoroughly chopped up with a knife. The chopped fruit was homogenized using an Ultra-Turrax apparatus after adding a volume of water equal to the weight of the starting material of flesh, or after adding a volume of water double equal to the weight of the starting material of rind. The homogenate was then centrifuged for 15 min at 8000 × g below 5°C, and the supernatant was filtered through filter paper (Toyo Roshi No.2). The filtrate obtained was, if necessary, adjusted to pH 6.5 by addition of diluted sodium hydroxide or hydrochloric acid. The filtrate adjusted was used as the test sample unless otherwise stated.

2.3 Estimation of the attractive index

The estimate of attraction activity in terms of the attraction index gr (A.I.gr in abbreviation) was described in a previous paper.[11] To summarize, in this series of experiments a test sample (7.5 m*l*) as described below was applied to a crumpled gauze sheet (25×25 cm) and placed at the S position in the compartment of the test tank, as shown in Fig.1. Gauze without a test sample was used as a dummy (control). The experiments were carried out with a group 178 to 42 individuals twice a day. Namely the experiments were conducted at 10:00 and 15:00 hours, following a design similar to the Latin square method. Three test sample with a dummy (control) were placed at each S position, and the septum (P) was immediately lifted. Each batch of yellowtail that entered each compartment (A or B) from the residence (C), left the compartment, or remained in the compartment was counted for 10-min intervals. Four series of numbers counted every 1 min in each test sample were summed. The numbers summed were integrated succes-

Table 1. Fruits tested

Common and botanical names	Japanese names (forms)
Rosaceae	
Apple *Malus pumila* var. *domestica*	(a) Ringo (Fuji[a])
	(b) Ringo (Golden delicious[b])
	(c) Ringo (Ohrin[c])
Apricot *Prunus armeniaca*	(a) Anzu (Heiwa[d])
	(b) Anzu (Sanzou[e])
	(c) Anzu(Shindai[f])
Cherry *Prunus avium*	(a) Outou (Napoleon[g])
	(b) Outou (Satounishiki[h])
Prunus cerasus	(c) Outou (Sanka)
Common pear *Pyrus communis*	Nashi (Seiyounashi)
European plum *Prunus domestica*	(a) Sumomo (Soldum[i])
Prunus salicina	(b) Sumomo (Soldar)
Japanese apricot *Prunus mume*	(a) Ume (Kichijyou[j])
	(b) Ume (Nankou[k])
Japanese medlar *Eriobotrya japonica*	Biwa (Mogi)
Japanese pear *Pyrus serotina*	(a) Nashi (Kousui[l])
	(b) Nashi (Nijjiseiki[m])
Nectarine *Prunus persia* var. *nucipersica*	Nactarine (Shuuhou)
Peach *Prunus persica*	(a) Momo (Hakuhou[n])
	(b) Momo (Hakutou[o])
	(c) Momo (Yamane[p])
Strawberry *Fragaria chiloensis* var. *ananassa*	Ichigo (Toyonoka)
Rutaceae	
Bitter orange *Citrus natsudaidai*	Amanatsu
Chinese orange *Fortunella japonica*	Kinkan
Citrus orange *Citrus hassaku*	Hassaku
Grape fruit *Citrus paradisi*	Grape fruit (Marshseadress)
Iyo orange *Citrus iyo*	Iyokan
Unshiu orange *Citrus unshiu*	Mikan (Unshuumikan)
Vitaceae	
Grape *Vitis* spp.	(a) Budou (Delaware[q])
	(b) Budou (Kyohou[r])
	(c) Budou (Mascat[s])
Actinidiaceae	
Kiwi fruit *Actinidia chinensis*	Kiwi (Heiward)
Cucurbitaceae	
Netted melon *Cucumis melo*	Melon (Muskmelon)
Ebenaceae	
Persimmon *Diospyros kaki*	Kaki (Fuyuu)
Moraceae	
Fig *Ficus carica*	Ichijiku (Dophin)
Myricaceae	
Myrica *Myrica rubra*	Yamamomo (Zuikou)

[a] Hybridization of Rall's Janet and Jonathan forms in USA.
[b] Golden delicious form in USA.
[c] Adventitious seedling of Golden delicious form.
[d] Form found in Japan.
[e] Adventitious seedling in Japan.
[f] Adventitious seedling in Japan.
[g] Napoleon bigrreau form in Europe.
[h] Hybridization of Napoleon bigrreau and "Kidama" (Japanese) forms.
[i] Introduced from USA.
[j] Form of Wakayama prefecture in Japan.
[k] Adventitious seedling in Japan.
[l] Hybridization of "Kikusui" (Japanese) and "Wasekouzou" (Japanese) forms.
[m] Adventitious seedling found at Chiba prefecture in Japan.
[n] Adventitious seedling found at Okayama prefecture in Japan.
[o] Hybridization (tetraploid) of [n] and "Tachibanawase" (Japanese) forms.
[p] Adventitious seedling found at Aichi prefecture in Japan.
[q] Delaware (adventitious seedling found in USA).
[r] Hybridization of Centunial and "Ishiwarawase" (Japanese) forms.
[s] Hybridization of Bailey and Alexandria forms.

sively with time. The numbers integrated were used as the time-course data to estimate A.I.gr. The attraction index can be presented as the product of coefficients g and r of a logistic curve $y = g/\{1 + \exp[-r(x-a)]\}$. Where the logistic curve $Y_x = \Sigma y_x$ the calculation method is as follows. The y_x shows the number of yellowtail which entered or left in the test compartment x-1 to x (one min interval) after the start of the experiment. The r was estimated from the coefficient of the regression of reciprocal Y_x on reciprocal of Y_{x-1}, while a and g were estimated from the coefficient and constant of the regression line of reciprocal of Y_x on $[-rx]$ $(x = 1$ to $10)$ (observed x or weighted by x). The degree of significance was established with 0.100 by the chi-squared test. The coefficients g, r and a indicate maximal locomotion (entering and leaving) number in unlimited time, inclination and average locomotion time, respectively. Furthermore the product value of gr, namely A.I.gr, shows locomotion numbers at coefficient a (min), as gr is obtained from $Y'_{x=a} = gr/4$.

3 Results

The attraction activities of flesh water extracts in 36 fruit forms were shown in Table 2. Among 22 forms of Rosaceae (Nos.1-3, 6, strawberry in

Table 2. Attraction activities of fruit fleshes for yellowtail

Nos.	Fruit fleshes	Attraction activities[a] (A.I.gr)	Nos.	Fruit fleshes	Attraction activities[a] (A.I.gr)
1	Dummy (control)	42.2*	2	Dummy (control)	15.1*
	Apple (a)	43.6*		Apricot (a)	21.8*
	Apple (b)	37.2*		Apricot (b)	11.3*
	Apple (c)	64.5*		Apricot (c)	10.9*
3	Dummy (control)	67.0**	4	Dummy (control)	52.8*
	Cherry (a)	30.7*		Chinese orange	30.7*
	Cherry (b)	13.0*		Fig	40.3*
	Cherry (c)	39.0**		Myrica	50.1*
5	Dummy (control)	31.6*	6	Dummy (control)	55.8*
	Citrus orange	33.6*		European plum (a)	79.8*
	Iyo orange	18.4*		European plum (b)	79.4*
	Unshiu orange	44.7*		Nectarine	88.6*
7	Dummy (control)	90.2*	8	Dummy (control)	34.3*
	Grape (a)	79.2*		Japanese apricot (a)	—
	Grape (b)	71.6*		Japanese apricot (b)	24.2*
	Grape (c)	109.8*		Bitter orange	35.3*
9	Dummy (control)	63.9*	10	Dummy (control)	59.4*
	Japanese pear (a)	51.7*		Japanese medlar	122.1**
	Japanese pear (b)	64.0*		Grape fruit	72.6**
	Common pear	73.1**		Parsimmon	103.3**
11	Dummy (control)	59.4**	12	Dummy (control)	56.9*
	Kiwi fruit	114.6*		Peach (a)	60.1*
	Netted melon	97.0*		Peach (b)	62.8*
	Surawberry	61.0*		Peach (c)	—

[a] The gr of attraction index (A.I.gr in abbreviation) are derived from the coefficients of a logistic curve $y=g/\{1+\exp[-r(x-a)]\}$ being applied to entered or left time-course for yellowtail. *$Pr(x^2 > x^2_{0.100}) > 0.100$; ** Pr=slightly less than 0.100.

No.11, and No.12), nine forms were measurably effective in attraction. Apple (c), European plums (a and b), nectarine, and Japanese medlar were the most potent. Among 6 forms of Rutaceae (Chinese orange in No.4, No.5, bitter orange in No.8, and grape fruit in No.10), unshiu orange and grape fruit were weakly effective in attraction. Among Vitaceae (No.7), only grape (c) was the most potent. Among other five families (fig and myrica in No.4, persimmon in No.10, and kiwi fruit and netted melon in No.11), persimmon of Ebenaceae, kiwi fruit of Actinidiceae, and netted melon of Cucurbitaceae were effective in attraction and were strong attractants.

Furthermore the attraction activities of the fruit rinds of six orange forms in Rutaceae were shown in Table 3. Only iyo orange (No.13) and unshiu orange (No.14) were weak attractants, as opposed to the flesh of iyo orange (cf.No.5).

To determine the strongest attractants among the attractive forms indicated, we selected nine forms with high attraction activity and compared their attraction activity (Table 4). First three series (Nos.15-17) of arbitrarily chosen combinations of three of the nine forms were examined. Apple (c) (No.15), Japanese medlar (No.16), and kiwi fruit (No.17) were most effective. In the next experiment (No.18), the attraction activity of these three fruits were compared. The attraction activity of Japanese medlar was highest.

The relationship between attraction activity and concentration was shown in Fig.2 for potent

Table 3. Attraction activities of fruit rinds for yellowtail

Nos.	Fruit fleshes	Attraction activities[a] (A.I.gr)	Nos.	Fruit fleshes	Attraction activities[a] (A.I.gr)
13	Dummy (control)	42.1*	14	Dummy (control)	32.5*
	Bitter orange	20.5*		Chinese orange	30.2*
	Citrus orange	35.0*		Grape fruit	18.7*
	Iyo orange	50.1*		Unshiu orange	41.2*

Signs; as legends in Table 2.

Table 4. Comparison test of attractive fruit fleshes for yellowtail

Nos.	Fruit fleshes	Attraction activities[a] (A.I.gr)	Nos.	Fruit fleshes	Attraction activities[a] (A.I.gr)
15	Dummy (control)	62.3*	16	Dummy (control)	53.9*
	Apple (c)	82.3*		Japanese medlar	81.5*
	European plum (a)	75.7*		Nectarine	70.4*
	Netted melon	75.8*		Persimmon	73.8*
17	Dummy (control)	48.2*	18	Dummy (control)	68.3*
	Common pear	50.3*		Apple (c)	93.5*
	Grape (c)	59.0*		Japanese medlar	110.2*
	Kiwi fruit	59.7*		Kiwi fruit	82.1*

Signs; as legends in Table 2.

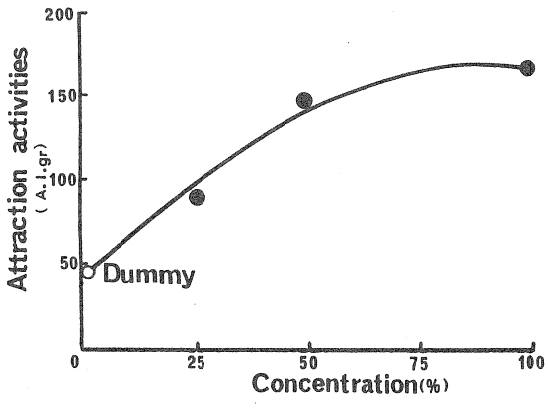

Fig. 2. Effect of concentration of the test fruit Japanese medlar on attraction activities.

Japanese medlar. The attraction activity was examined for the three concentrations (25, 50 and 100%) diluted from the original fruit extract (100%). The attraction activity increased appreciably as the concentration increased.

4 Discussion

The test fruits are from terrestrial plants, which do not occur in the sea. Marine animals have no opportunity to feed on them. However, a terrestrial plant or its product obviously attracts and/or stimulates mollusks of the snail[2] and the black abalone,[5,6] and fishes of rainbow trout,[3] oriental weatherfish[4,5,10] and yellowtail.[5,6] From these studies it appears that the organisms accept either non-seawater or non-freshwater plant products.

An attractant elicits a response such as orientation towards or increase in receptivity to the apparent source; a stimulus promotes ingestion and continuation of feeding.[12] In some fishes and shellfishes, an attractant is also a stimulant.[1] In this connection, the attraction activities of various fruits were tested in yellowtail as part of a study on the feeding attractants of fishes and shellfishes.

Table 5 indicated the extent of attraction

Table 5. Attraction effect and characteristics of fruit fleshes

Common names	Attraction effect	Characteristics[a]	
		Organoleptic	Main components
Rosaceae			
Apple (a)		Sweet, Sour	Fructose, Glucose,
Apple (b)			Malic acid
Apple (c)	**		
Apricot (a)	*	Sweet, Strong	Sucrose, Citric
Apricot (b)		sour	acid, Malic acid
Apricot (c)			
Cherry (a)		Sweet, Sour	Acetic acid,
Cherry (b)			Butyric acid,
Cherry (c)			Caproic acid
Common pear	*	Weak sweet, Weak sour	Potassium
European plum (a)	**	Peach flavour,	Reducing sugar
European plum (b)	**	Sour	
Japanese apricot (a)		Plum flavour,	Citric acid,
Japanese apricot (b)		Strong sour	Malic acid
Japanese medlar	**	Weak flavour, Weak sour	Vitamin, Mineral
Japanese pear (a)		Sweet, Sour	Potassium
Japanese pear (b)			
Nectarine	**	Sweet, Sour	Acetic acid
Peach (a)	*	Strong sweet	Acetic acid,
Peach (b)	*		Valeric acid,
Peach (c)			Caprylic acid
Strawberry		Strong sweet, Sour	Glucose, Fructose, Citric acid, Malic acid

Table 5. – (Cont'd)

Common names	Attraction effect	Characteristics[a]	
		Organoleptic	Main components
Rutaceae			
Bitter orange		Sweet, Weak sour	Fructose, Sucrose, Citric acid
Chinese orange		Sweet	Vitamin, Mineral
Citrus orange		Weak sour	Fructose, Glucose, Citric acid
Grape fruit	*	Weak sweet, Sour, Bitter	Citric acid, Naringin
Iyo orange		Weak sweet, Weak sour	Sucrose, Fructose, Citric acid
Unshiu orange	*	Sweet, Weak sour	Sucrose, Fructose, Citric acid
Vitaceae			
Grape (a)		Sweet	Glucose, Fructose, Tartaric acid
Grape (b)			
Grape (c)	**		
Actinidiaceae			
Kiwi fruit	**	Weak sweet, Weak sour	Vitamin C
Cucurbitaceae			
Netted melon	**	Refreshing sweet	Glucose, Sebasic acid ester
Ebenaceae			
Persimmon	**	Weak sweet	Glucose, Fructose, Sucrose
Moraceae			
Fig		Sweet	Fructose, Glucose
Myricaceae			
Myrica		Strong sweet, Weak sour	Acetic acid

*, **; Weak and strong, respectively.
[a] Society of Japanese Fruit Juice: Cyclopedia of Fruit Juice and Drink, Asakura, Tokyo, 1978, pp.1-523.

activity obtained in our experiment and the general characteristics of fruits. The magnitude of the attraction is based on the comparison between the attraction indexes of fruit flesh and dummy (control); i.e., "strong" is much higher and "weak" is only slightly higher than the value from the dummy. Among 36 forms of fruit, 15 had some attraction activity; nine of Rosaceae, two of Rutaceae, one of Vitaceae, and one of each of Actinidiaceae, Cucurbitaceae and Ebenaceae. The most active fruits were nine forms including apple (c) and other four forms of Rosaceae, grape (c) of Vitaceae, kiwi fruit of Actinidiceae, netted melon of Cucurbitaceae, and persimmon of Ebenaceae. These nine fruits also attracted the yellowtail in the time-course observations. When the relationship between attraction and families or characteristics of the fruit is considered, two third part of attractive fruit belongs to the family Rosaceae. Of the characteristics, the majority of fruit is, to some extent, sweet and sour as organoleptic to human, and contains monosaccharides and carboxylic acids as main components. Accordingly it might not be thought that the attractive fruits depended on those compounds. However the attractive fruits show most promising for the production of artificial feed. Furthermore it is also noteworthy that the rinds of some oranges attract yellowtail, and many fruits fleshes attract carnivorous one.

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ブリに対する果物の摂餌誘引活性

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ブリ稚魚に対する果物36品種の果肉，一部では外皮の水抽出液の摂餌誘引活性を行動学的に求めた。その結果，リンゴ（王林），スモモ（ソルダム，ソルダー），ビワ（茂木），ネクタリン（秀峰），ブドウ（マスカット），キーウィ（ヘイワード），メロン（マスクメロン）と柿（富有）に強い誘引活性が明らかとなった。これらの中で，ビワとリンゴが最も強い誘引活性を示した。ビワは濃度の増加と共に誘引活性が増大した。ミカン科に属する一部の品種の外皮が弱い誘引活性を示した。