Feeding attractants and stimulants for aquatic animals

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SUMMARY: Feeding attractants and stimulants were compared by behavioral observation for the black abalone *Haliotis discus*, the oriental weatherfish *Misgurnus anguillicaudatus*, and the yellowtail *Seriola quinqueradiata*. Attraction activities were estimated by applying a logistic curve ($y = g / \{1 + \exp[-r(x - a)]\}$) to the cumulated number polygons of the individuals entered into or retained in the baited sector, while stimulation activities were estimated by comparing average feed intake of the test diet with that of the control. Feeding attraction and stimulation activities of sugars and nucleic acid related compounds were varied depending on target animals. All attractants and stimulants were not necessarily coincided with each other. Feeding attractants, which orientate the animals toward the feed by distant perception, and feeding stimulants, which enhance feed intake by contact perception, should be distinguished.

KEY WORDS : abalone; attraction; fish; nucleic acid related compound; stimulation; sugar

INTRODUCTION

Chemical compounds involved in feeding behaviors of aquatic animals have been investigated by many researchers, varying their experimental methods. Most of studies on these compounds have been performed based on ethological¹⁻¹¹⁾ or electrophysiological response¹²⁻¹⁵⁾ and it has been reported that several chemical compounds e.g. amino acids, nucleic acid-related compounds, betains etc. contained in soluble extract of feeds evoke the response depending on the species of aquatic animals.

Lindstedt¹⁶⁾ has proposed a classification of chemical effectors of feeding behavior into several categories, although no clear definitions of these compounds have been established. So, we define in this paper these effects on positive feeding behaviors evoked by distant perception as "feeding attraction activity" ("feeding attractants" as compound) and those evoked by contact perception as "feeding stimulation activity" ("feeding stimulants" as compounds). Namely, feeding attractants are the chemical compounds that orientate the animals toward the feed and attract them around it, whether they stimulate feed intake or not is not regarded. Feeding stimulants are the chemicals that increase feed intake.

There are many systematical researches on several chemical compounds, e.g. amino acids, nucleic acid related compounds, as feeding stimulants by electrophysiological methods. In contrast to it, only a few were reported on the activities for a series of these compounds by behavioral observations. So we have been investigated feeding attraction and stimulation activities of sugars¹⁻³⁾ and nucleic acid related compounds⁹⁾ for three aquatic animals, mollusk abalone *Haliotis discus*, freshwater fish oriental weatherfish *Misgurnus anguillicaudatus* and saltwater fish yellowtail *Seriola quinqueradiata* by two different behavioral methods. Comparison of feeding attraction and stimulation activities of these compounds for these animals were dealt in this paper.

MATERIALS AND METHODS

Estimation of feeding attraction activity

Estimation of feeding attraction activity was as follows: a test tank with one residence and four test sectors was used

(Fig. 1).¹⁷⁻²⁰⁾ Three test sample solutions and distilled water as a dummy soaked in gauze balls were set in the end of test sector and saltwater or freshwater was continuously flew from the test sector to the residence sector. The number of animals entered and left was counted for each test sector for 10 (oriental weatherfish and yellowtail) or 20 (abalone) minutes. Experiments were conducted four times for each combination of the sample changing the arrangement of sample and dummy balls on the Latin square method. The cumulated number of individuals entered into, left from or retained in the sector with the test gauze ball increasing in accordance with the passing of the observation time following a logistic curve $y = g / \{1 + \exp[-r(x - a)]\}$ was obtained. In our laboratory, the activity of bait as feeding attractant have been evaluated by using these parameters a and gr .¹⁷⁻²⁰⁾

Estimation of feeding stimulation activity

Stimulation activity was judged from the average feed intake for each test diet comparing with that of the control. Test tanks and test diets for the abalone and the oriental weatherfish were designed considering the feeding behavior for each test animal (Fig. 1). For the abalone, agar diet plate contained sample solution was fed to the animal over a night and the feed intake was measured. For the oriental weatherfish, prescribed moist pellets made of casein basal diet put in glass tubes were fed for 40 min and feed intake was measured. For yellowtail, prescribed moist pellets made of casein basal diet were fed to satiation twice a day for three days, although test and control diets were fed to the same tank fish by turns.²¹⁾

RESULTS AND DISCUSSION

Sugars

As shown in Table 1, about a half or more sugars and artificial sweeteners tested by our research showed attraction activity for the abalone and the yellowtail and stimulation activity for the oriental weatherfish and the yellowtail, especially attraction for the yellowtail (11/15 tested). Except maltose for the oriental weatherfish, no sugars and artificial sweeteners tested showed negative effect includ-

Fig. 1 Test tanks for evaluating feeding attraction and stimulation activities.

Table 1 Summary of feeding stimulation and attraction activities of sugars and artificial sweeteners for fishes and abalone

	Abalone ^{*1}		Oriental weatherfish ^{*2}		Yellowtail ^{*3}		Rainbow trout ^{*4}	Eel ^{*5}
Methods	Attraction ¹⁾	Stimulation ^{*6}	Attraction ²⁾	Stimulation ^{*6}	Attraction ³⁾	Stimulation ^{*6}	Behavior	Feed intake
Concentration (mmol/L or kg)	60	60	200	60	600	69	1000	8
Monosaccharides								
Glucose(p)	+				+	+	+100mM	•
Fructose(p)			+	+	+	+	+	•
Galactose(p)	+			+	+	+	•	•
Xylose(p)					+	•	•	•
Rhamnose(L)					+	•	•	•
Glucosamine(p)						•	•	•
Disaccharides								
Sucrose			+			+	+	•
Maltose	+			-	+	+	•	+
Lactose		+	+		+	•	•	•
Trehalose	•		•	+	•	+	•	•
Trisaccharides								
Raffinose	•		•	+	•		•	•
Sugar alcohols								
Sorbitol(p)	+			+	+	+	•	•
Mannitol	+			+	+	•	•	•
Dulcitol	+			+			•	•
Xylitol				+			•	•
Artificial sweeteners								
Saccharin 2Na	+10mM		+33mM	+	+100mM	•	•	•
Aspartame	10mM		+33mM		+100mM	•	•	•

^{*1}: *Haliotis discus*, ^{*2}: *Misgurnus anguillicaudatus*, ^{*3}: *Seriola quinqueradiata*, ^{*4}: *Oncorhynchus mykiss* (Jones, 1990⁴⁾), ^{*5}: *Anguilla japonica* (Takii, 1989⁵), ^{*6}: oral presentation. +: effective, -: negative effect, blank column: not effective, •: not tested.

ing for the rainbow trout *Oncorhynchus mykiss*⁴⁾ and the eel *Anguilla japonica*,⁵⁾ although only a few were reported on the activities of various sugars for one valuable aquatic species. These findings suggested that most of sugars and artificial sweeteners, which show 'sweet taste' for the human, were good attractant and stimulant.

Comparing the attraction and stimulation activities for the three aquatic animals, compounds showed both activity were fructose for the oriental weatherfish and the yellowtail, glucose, galactose, maltose and sorbitol for the yellowtail, and saccharin for the oriental weatherfish. In

other compounds, both activities were inconsistent with each other.

Nucleic acid related compounds

Feeding attraction and stimulation activities of nucleic acid related compounds for several aquatic animals reported are summarized in Table 2. Several compounds, mainly ribonucleotides and nucleosides, have ever been tested for several fishes by ethological or electrophysiological method. We have tested 26 kinds of these compounds

Table 2 Summary of feeding stimulation, attraction and gustatory response of several nucleic acid-related compounds for fishes and abalone

	Abalone* ¹		Oriental weatherfish* ²		Yellow-tail* ³	Feeding stimulation						Gustatory response		
	Att.* ⁴	Sti.* ⁵	Att.* ⁴	Sti.* ⁵	Att.* ⁴	Yellow-tail* ⁶	Jack-mackerel* ⁷	Sea bream* ⁸	Turbot* ⁹	Rock-fish* ¹⁰	Eel* ¹¹	Yellow-tail* ¹²	Puffer* ¹³	Chub mackerel* ¹⁴
Concentration (mmol/L or kg)	1.0	1.0	1.0	1.0	1.0	obscure	2.0-10.0	obscure	0.95	10.0	1.7	1.0-10.0	1.0	0.001-0.1
Bases														
Adenine			+		+	.	.	.	.	.	.	.	.	.
Guanine					+	.	.	.	.	.	.	.	.	.
Cytosine	+				+	.	.	.	.	.	.	.	.	.
Uracil						.	.	.	.	.	.	.	.	.
Thymine						.	.	.	.	.	.	.	.	.
Xanthine	+					.	.	.	.	.	.	.	.	.
Hypoxanthine						.		.	.	.	.	.	.	.
Nucleosides														
Adenosine						.		.		.	.	+		.
Guanosine			+			.		.	+	.	.	.	.	.
Cytidine						.	.	.		.	.	.	.	.
2'-Deoxyadenosine						.	.	.		.	.	.	.	.
2'-Deoxyguanosine						.	.	.		.	.	.	.	.
2'-Deoxycytidine						.	.	.	.	.	.	.	.	.
Thymidine		+		+		.	.	.		.	.	.	.	.
Inosine						.		.	+	+	.	+	.	.
Ribonucleotide														
Adenosine-5'-monophosphate	+	+			+	.		.		+	-	+	+	+
Adenosine-5'-diphosphate		+		+		.		+	.	+	.	+	+	+
Adenosine-5'-triphosphate		+				.		.	+	.	.	+	+	+
Guanosine-5'-monophosphate		+	+			.	+	.	+	.	.	.		.
Uridine-5'-monophosphate					+	.	+	.		.	+	+	+	+
Cytidine-5'-monophosphate						.	.	.		.	.	.		.
Inosine-5'-monophosphate		+		+		+	+	+	+	+	.	+	+	.
Deoxyribonucleotides														
2'-Deoxyadenosine-5'-monophosphate						.	.	.		.	.	.		.
2'-Deoxyguanosine-5'-monophosphate					+	.	.	.		.	.	.		.
2'-Deoxycytidine-5'-monophosphate		+				.	.	.	.	.	.	.		.
Thymidine-5'-monophosphate				+		.	.	.		.	.	.		.

*¹: *Haliotis discus*, *²: *Misgurnus anguillicaudatus*; *³: *Seriola quinqueradiata*, *⁴: attraction activity⁶⁾, *⁵: stimulation activity (oral presentation), *⁶: *Seriola quinqueradiata* (Hosokawa *et al.*, 1976, oral presentation), *⁷: *Trachurus japonicus* (Ikeda *et al.*, 1988⁷⁾, 1991⁸⁾); *⁸: *Chrysophrys major* (Hosokawa *et al.*, 1978, oral presentation), *⁹: *Scophthalmus maximus* (Mackie and Adron, 1978⁹⁾), *¹⁰: *Sebasticus marmoratus* (Takaoka *et al.*, 1990¹⁰⁾), *¹¹: *Anguilla japonica* (Takeda *et al.*, 1984¹¹⁾), *¹²: *Seriola quinqueradiata* (Hidaka *et al.*, 1985¹²⁾), *¹³: *Fugu pardalis* (Kiyohara *et al.*, 1975¹³⁾), Hidaka *et al.*, 1977¹⁴⁾), *¹⁴: *Scomber japonicus* (Ishida and Hidaka, 1987¹⁵⁾). +: effective, blank column: not effective, - : repellent, . : not tested.

for the abalone, the oriental weatherfish and the yellowtail as feeding attractants or stimulants. As shown in Table 2, most of active compounds reported were ribonucleotides. Inconsistency of attraction and stimulation activities were shown in nucleic acid related compounds as well as in sugars so far as testing for the abalone and the oriental weatherfish on 26 compounds with the exception of adenosine-5'-monophosphate (AMP). AMP was not only a good attractant but also a good stimulant for the abalone, although it was inactive or repellent for the eel.¹¹⁾ Stimulation activity of inosine-5'-monophosphate (IMP) has been tested by many researchers including gustatory response.¹²⁻¹⁴⁾ All of those reports supported the positive stimulation activity of IMP for various animals. Contrary to it, IMP showed no attraction activity for the three aquatic animals. IMP was considered to be a good stimulant but not an attractant for these aquatic animals.

Conclusion

Feeding attraction and stimulation activities of sugars and nucleic acid related compounds were varied depending on target animals. All attractants and stimulants were not necessarily coincided with each other so far as sugars and nucleic acid related compounds for the abalone, the oriental weatherfish and yellowtail. Feeding attractants, which orientate the animals toward the feed by distant perception, and feeding stimulants, which enhance feed intake by contact perception, should be distinguished, although the enhancement of feed intake is introduced by the feeding attraction to the feed.

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