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Food Selection of the Abalone, *Haliotis discus hannai* on Various Diets

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ABSTRACT

In this study, the food selection of abalone, *Haliotis discus hannai*, on four various diets, *Ulva pertusa, Laminaria japonica, Navicula* spp., and artificial diet, was investigated. The abalones in *Ulva pertusa* and *Navicula* spp groups had the higher migration rate than the others. The artificial group had the lowest migration rate. As to the growth, *Ulva pertusa* group had the highest daily increment and the growth rate, which is 120.7 μm and 2.41%. The value of *Navicula* spp. group is 102.0 μm and 2.04% and that of *Laminaria japonica* group is 88.7 μm and 1.77%. The lowest one is 81.7 μm and 1.63%, which appeared at the artificial diet group.

We suggest that, when breeding *Haliotis discus hannai* and the diets which is easy to be ingested and digested, as well as contains much nutrient content, should be used. If the artificial diet is used, it should contain low concentration of flesh-eating content.

Keywords: *Haliotis discus hannai*, Migration rate, Growth, Food selection

INTRODUCTION

Haliotis discus hannai, which subjects to Mollusca, Gastropoda, Prosobranchia, Archaeogastropoda, Haliotidae, distributes widely all over the world, such as Korea, China, Japan, America, New Zealand, Austrilia, *etc.* This species has a well-developed pedal portion. It is very nutrient and delicious. Analyzed on the dried flesh, the content of protein, glycogen and lipid can reach 40%, 33.7% and 0.9%. It also has a certain medical value. Furthermore, its shell can be made into adornment, and the abalone can be bred to produce the pearl. The culture of abalone is playing a more and more important role in aquaculture. Hence it is commercially important and valuable nowadays.

Haliotis discus hannai is a pop subject in scientific study for a long time. Kawamura *et al.* (1995) used nine species of benthic diatom to investigate their dietary value for the growth of post-larval abalone. A series of comparative studies on the nutrition of this species, as well as another abalone, *Haliotis tuberculata* were performed with: effects of dietary vitamin C on survival, growth and tissue concentration of ascorbic acid (Mai, 1998), optimum dietary protein level for growth (Mai *et al.,* 1995), response of abalone to various levels of lipid (Mai et al., 1995) and the role of polyunsaturated fatty acid of macroalgae in abalone nutrition (Mai *et al.,* 1996). Takami *et al.* (1997) investigated the survival and growth rates of post-larval abalone *Haliotis discus hannai* fed conspecific trail mucus and/or benthic diatom *Cocconeis scutellum* var. *parva.* As is known that the diets are very important in the development and growth of animals. Some researchers suggested that the food limitation could stimulate meteporphosis of competent larvae and alters postmetamorphic growth rate in some species (Pechenik *et al.,* 1997). The diet choice in some invertebrate, for example, and omnivorous salt-marsh crab, was also studied (Buck *et al.,* 2003). As to this abalone, it is reported that,

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under artificial conditions in aquaculture, the various artificial and natural diets, which are nutrient and easy to be devoured or digested, should be fed to the abalone according to different developmental stages, including some benthic diatoms and unicellular microalgae, such as *Navicula, Cocconeis, Nitzschia, Phaeodactylum, Chaetoceros, Tetraselmis, Chrysophyta, etc* (Wang, 1993). In this study, we designed an experiment to do some investigation on the selection of abalone to different artificial and natural diets.

MATERIALS AND METHODS

1. Rearing samples

The abalones, *Haliotis discus hannai,* were collected from the inshore area of Yosu City, Korea. The average shell length of the abalones was about 5.0 cm. After collection, they were bred in four breeding troughs, which is 1 meter long, containing filtered seawater immediately. Here every 100 individuals were bred in one trough, and all the abalones in four troughs were reared at the same environmental conditions: temperature 22℃, salinity 33%, except for the feeding diets.

2. The diets

The abalones were put at one end of the trough, and four different diets, including *Ulva pertusa, Laminaria japonica, Navicula* spp., and artificial diet, were fed from the other end to each of the trough, respectively. The artificial diet was prepared as the following stuff (Table 1), and these four kinds of diets were different in the content nutritionally (Table 2).

Table 1. Preparation stuff of artificial diet.

Stuff	Mixture percent (%)
White fishmeal	15.0
Soybean meal	15.0
Sea mustard powder	32.0
Wheat flour	10.0
Sodium alginate	20.0
Squid liver	2.0
Mineral mixture	4.0
Vitamin mixture	2.0

Table 2. Proximate composition (%) of the diets used for experiment.

Kind of feed	Crude protein	Crude lipid	Water
Artificial diet	24.2	3.3	13.6
Ulva pertusa	2.1	0.2	94.6
Laminaria japonica	1.9	0.2	88.7
Navicula spp.	2.1	0.3	95.4

3. Examining the migration rate and growth

At 6 h, 12 h, 18 h, 24 h, 30 h after the breeding and feeding, the migration of abalones to the dietend in four troughs was examined respectively.

30 days later, the shell length of abalones in four troughs was measured. The daily increment in growth and the specific growth rate were calculated as the following formulas: Daily Increment (μm) = (Final shell length (mm) Initial shell length (mm))/Rearing days (d) × 1000; Growth Rate (%) = Daily Increment (μm)/(Initial shell length (mm) × 1000) × 100.

RESULTS

1. Migration rate

At 6 h, the migration of abalones in four troughs had no significant difference. The abalones were all within the range of 0-40 cm. The migration rate of 0-20 cm range at four diets, *Ulva pertusa, Navicula* spp, *Laminaria japonica,* and artificial diet, was 59%, 55%, 57%, and 67%, respectively. The rate of 20-40 cm range was 41%, 45%, 43%, and 33%. At 12 h, though the individuals were all within the range of 0-80 cm, the migration rates showed the difference. The rate of 60-80 cm range at *Ulva pertusa* and *Navicula* spp groups had reached 67% and 65%, while the artificial diet group was only 10%. At 18 h, 79% and 82% numbers of abalones at *Ulva pertusa* and *Navicula* spp. groups had moved to 80-100 cm range, and only 9% and 8% individuals were still at 0-20 cm range. At the same time, at artificial diet group, there were just 11% abalones within the 80-100 cm range, and most of the individuals (67%) was at 40-80 cm range. At *Laminaria japonica* group, the migration rate of 80-100 cm range was 57%. At 24 h, most of abalones at *Ulva pertusa* and *Navicula* spp. groups had

Table 3. Migration rate (%) of *Haliotis discus hannai* after 30 hours in experimental tank with *Ulva pertusa*.

Range (cm)	Elapsed time (hour)				
	6	12	18	24	30
0-20	59	13	9	-	-
20-40	41	6	-	4	2
40-60	-	9	-	-	-
60-80	-	67	12	4	3
80-100	-	-	79	92	95

Table 4. Migration rate (%) of *Haliotis discus hannai* after 30 hours in experimental tank with *Navicula* spp.

Range (cm)	Elapsed time (hour)				
	6	12	18	24	30
0-20	55	15	8	-	-
20-40	45	5	-	5	3
40-60	-	10	-	-	-
60-80	-	65	10	7	6
80-100	-	-	82	88	91

Table 5. Migration rate (%) of *Haliotis discus hannai* after 30 hours in experimental tank with *Laimnaria japonica*.

Range (cm)	Elapsed time (hour)				
	6	12	18	24	30
0-20	57	10	9	5	-
20-40	43	17	-	-	-
40-60	-	21	23	9	6
60-80	-	52	11	10	7
80-100	-	-	57	76	87

migrated to the range of 80-100 cm (92% and 88%), the numbers of which at artificial diet group was just 46%. At 30 h, most of individuals at *Ulva pertusa, Navicula* spp., *Laminaria japonica* groups had congregated at the range of 80-100 cm, the rates of which were 95%, 91% and 87%. At artificial diet group, the migration rate of 80-100 cm range was

Table 6. Migration rate (%) of *Haliotis discus hannai* after 30 hours in experimental tank with artificial diet.

Range (cm)	Elapsed time (hour)				
	6	12	18	24	30
0-20	67	47	5	-	-
20-40	33	31	17	3	3
40-60	-	12	31	25	15
60-80	-	10	36	26	12
80-100	-	-	11	46	70

70%, as well as the rates of 40-60 cm and 60-80 cm were 15% and 12% (Table 3, 4, 5 and 6).

2. Growth, daily increment and growth rate

After rearing for 30 days, initiating with the same shell length (5.0 cm), the final shell length of abalones at *Ulva pertusa, Navicula* spp, *Laminaria japonica,* and artificial diet groups was 8.6 cm, 8.1 cm, 7.7 cm, and 7.5 cm, respectively. The highest daily increment was at *Ulva pertusa* group, which was 120.7 μm. The smallest one appeared at artificial diet group, 81.7%. As to the growth rate, the value of *Ulva pertusa* group is 2.41%, and the second was *Navicula* spp group, 2.04%. The third one appeared at *Laminaria japonica* group, 1.77%. The artificial diet group had the lowest growth rate, which was 1.63% (Table 7).

DISCUSSION

Haliotis discus hannai is dioecious. Usually, it is liable to inhabit the marine area with ample algae, clean water quality and smooth current. Under natural conditions, if the sea area has a certain inflow of freshwater, it won't survive. The juvenile abalones mainly eat the benthic diatom, while the adult individuals are polyphagous. Its diet mainly includes

Table 7. Growth of *Haliotis discus hannai* reared at various diets for 30 days.

Food	Shell length ± SD (mm)		Daily increment (μm)	Specific growth rate (%)
	Initial	Final		
Navicula spp.	5.0 ± 1.0	8.1 ± 1.1	102.0	2.04
Ulva pertusa	5.0 ± 1.0	8.6 ± 1.4	120.7	2.41
Laminaria japonica	5.0 ± 1.0	7.7 ± 0.8	88.7	1.77
Artificial diet	5.0 ± 1.0	7.5 ± 1.2	81.7	1.63

Data presented as mean ± SD

Table 8. Amino acid content, ratio of essential amino acid (EAA) to total amino acid (TAA) of various diets used in experiment.

Amono acids	mg/100 g edible portion (%)			
	Artificial diet	*Ulva pertusa*	*Laminaria japonica*	*Navicula* spp.
Alanine	1371.3 (6.6)	123.0 (10.6)	96.2 (4.9)	10.3 (8.1)
Ammonia	230.0 (1.1)	19.2 (1.6)	12.4 (0.6)	2.8 (2.2)
Arginine	1199.9 (5.8)	79.8 (6.8)	35.4 (1.8)	4.9 (3.9)
Aspartic acid	2205.9 (10.6)	144.9 (12.4)	608.2 (31.1)	0.9 (13.2)
Cysteine	166.2 (0.8)	24.2 (2.1)	13.8 (0.7)	1.7 (1.4)
Glutamic acid	3817.6 (18.4)	149.7 (12.8)	571.0 (29.2)	16.3 (12.8)
Glycine	1222.9 (5.9)	75.6 (6.5)	53.5 (2.7)	8.6 (6.7)
Histidine	337.4 (1.6)	12.8 (1.1)	15.1 (0.8)	2.0 (1.6)
Isoleucine	777.2 (3.7)	40.2 (3.4)	31.0 (1.6)	4.8 (3.8)
Leucine	1665.2 (8.0)	72.6 (6.2)	62.8 (3.2)	9.1 (7.1)
Lysine	1007.5 (4.8)	38.1 (3.3)	45.8 (2.3)	4.4 (3.4)
Phenylalanine	928.2 (4.5)	57.2 (4.9)	41.9 (2.1)	7.1 (5.6)
Proline	1339.1 (6.4)	49.8 (4.3)	19.4 (4.7)	6.9 (5.4)
Serine	1011.3 (4.9)	72.4 (6.2)	58.5 (3.0)	7.4 (5.8)
Taurine	36.1 (1.7)	9.4 (0.8)	33.1 (1.7)	0.9 (0.7)
Threonine	982.3 (4.7)	73.2 (6.3)	87.0 (4.4)	8.1 (6.4)
Tyrosine	662.7 (3.2)	34.1 (2.9)	29.0 (1.5)	4.0 (3.2)
Valine	915.6 (4.4)	68.4 (5.9)	49.9 (2.5)	7.7 (6.1)
Total	20803.2 (100)	1165.7 (100)	1958.6 (100)	127.0 (99.9)
EAA/TAA (%)	33.1	31.8	17.4	34.9

the Phaeophyta, Chlorophyta, Bacillariophyta, as well as *Rhodophyta,* spermatophyte, lower plant, and a little other small animals, such as Globigerina, Gastropod, Copepod, Foraminiferida, and Hydrozoans (Wang, 1993). The abalone has a strong selectivity to the various algae. They often firstly eat their preferred algal species. Under the conditions of starvation and passive feeding, they are very sensitive to the diet, and usually perform the feeding day and night.

In our experiment, the abalones fed with *Ulva pertusa* and *Navicula* spp. had a relatively strong locomotivity. 18 h later after the feeding, most of individuals (79% and 82%) at these two groups had migrated to the range of 80-100 cm. At 24 h, almost all the abalones (92% and 88%) had reached the diet end of the trough. At *Laminaria japonica* group, the rate of 80-100 cm range at 18h and 24h was 57% and 76%. As to the artificial diet group, the trend was weak. At 18 h, only 11% individuals moved to the range of 80-100 cm, and at 24 h, this rate was 46%, much lower than the former three groups. Concerning the final result at 30h, 95%, 91% and 87% abalones at *Ulva pertusa, Navicula* spp. and *Laminaria japonica* groups had migrated to the diet end. Only a few (2, 3, 6 individuals) were still at the range of 0-60 cm. While at artificial diet group, the migration rate of 80-100 cm range was 70%, and there were still 18 individuals at the range of 0-60 cm. From these data, we can infer that, the abalones prefer *Ulva pertusa* and *Navicula* spp. to *Laminaria japonica,* and the artificial diet has the weakest attraction to the abalones. Analyzed on the basis of component content and total amino acid (TAA), as well as essential amino acid (EAA) (Table 8), we can deduce that, though the artificial diet has a high content of protein and lipid, due to the high content of flesh-eating component, it is not preferred by the abalones. On the contrary, the natural diets, *Ulva pertusa* and *Navicula* spp., are more useful.

In the daily increment, the *Ulva pertusa* group had the highest value, 120.7 μm. The lowest value appeared at the artificial diet group, only 81.7 μm. Concerning that the abalone grow slowly *per se* (it may take 3.5-4 years to grow from 1.5 cm to 6.5 cm for the abalones), this difference is relatively significant. At *Navicula* spp. and *Laminaria japonica* groups, the increment is 120.7 μm and 88.7 μm, both of which are lower than that of *Ulva pertusa* group. The specific growth rate has the same contrast; *Ulva pertusa* group (2.41%) > *Navicula* spp. group (2.04%) > *Laminaria japonica* group (1.77%) > artificial diet group (1.63%). Concerning the amino acid (AA) content and the size of these diets, it is suggested that, though *Laminaria japonica* has a higher AA content, the abalone may take more energy in chew and digest this macroalga, so it has a weaker effect than the microalgae, *Ulva pertusa* and *Navicula* spp., on the growth of abalones. As to *Ulva pertusa* and *Navicula* spp. obviously, the high AA content, which is 1165.7 mg/g and 127.0 mg/g in *Ulva pertusa* and *Navicula* spp. respectively, leads to the well individual growth.

Analyzed on the amino acid composition, we can observe that, the diatoms had a high content of aspartic acid and glutamic acid. These two amino acids may play an important role in the larval growth of *Haliotis discus hannai.* Aspartic acid and glutamic acid are two kinds of neurotransmitters, which have the effect on promoting K^+ to transfer to the cerebral portion. As to the effect mechanism of these two amino acids, we suggest that, they can stimulate the larval sense organ, such as the pedal portion and the third antenna, to promote the individual growth.

Some researchers performed the similar experiment to study the effect of different diets to the growth of juvenile abalones, and the result showed that, the diatom had a better effect than laver. It is corresponding with our study. On the basis of the above result, we suggest that, when breeding *Haliotis discus hannai,* the diet, which is easy to be ingested and digested, as well as contains much nutrient content, should be used. If the artificial diet is used, it should contain low concentration of flesh-eating content. The green algae and diatom have a good effect to the growth of abalones.

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