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Feeding Habits and Growth of the Sea Urchin, *Strongylocentrotus pulcherrimus* (A. Agassiz) Reared in the Laboratory*

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實驗室에서 飼育한 말똥성게 *Strongylocentrotus pulcherrimus* (A. Agassiz)의 食性과 成長*

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ABSTRACT

Strongylocentrotus pulcherrimus is one of the very important fishery stock in this country since its high demand for raw gonad. Although the demand has been continuously increasing, the natural stock of this species seems to be decreasing. Since fresh macroalgae are not always available, the substitution of terrestrial vegetables for algae as a principal food was examined for the intensive indoor culture of the sea urchin.

The results from the studies on selective and non-selective feeding habits and nutritional efficiencies using 13 food stuffs (6 macroalgae, 5 vegetables and 2 animal products) indicate that algae can be substituted with vegetables in sea urchin culture. Although the growth of body weight was the highest when sea urchins were fed *Undaria pinnatifida*, the gonad index of the sea urchins fed on spinach, radish leaf and lettuce was higher than that of this brown alga. Considering the different food efficiencies of body and gonad growth, spinach and radish leaf will be adequate during gonad growth season, while lettuce and Chinese cabbage will be suitable for test growth season. In particular, radish leaf, which is usually not eaten by humans, could be highly beneficial and very economical in the sea urchin culture.

要 約

高價의 食品으로 이용되는 말똥성게의 生殖巢의 소비가 증가됨에 따라 연안의 말똥성게 자원은 계속 감소하고 있어 이 종류에 대한 양식 기술개발은 중요한 연구 과제이다. 따라서 본 연구는 말똥성게를 室內에서 양식할 경우 먹이로서 신선한 海藻類를 대치할 수 있는 육상식물을 조사하였다.

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海藻類 6종류 (미역, 구멍갈파래, 지충이, 개지누아리, 모자반, 곰피), 육상식물 5종류 (시금치, 상치, 무우잎, 배추, 케일), 동물성 먹이 2종류 (바지락, 쇠고기)를 대상으로 말똥성게의 선택적 및 비선택적 食性과 영양 효과를 비교한 결과, 말똥성게의 먹이로서 육상 식물의 이용이 가능하였다. 미역을 공급한 경우 말똥성게의 체중의 성장은 가장 높았으나 生殖巢指數는 시금치, 무우잎 또는 상치를 공급할 경우가 미역의 경우보다 더 높았다. 시금치와 무우잎의 공급은 生殖巢가 성장하는 계절에 적합하고, 殼이 성장하는 시기에는 상치 또는 배추가 효과적일 것으로 판단된다. 특히 무우잎은 食用으로 이용하지 않고 버려지므로 무우잎을 이용한 말똥성게의 양식은 매우 경제적일 것이다.

INTRODUCTION

Sea urchins constitute one of the most important fishery stocks in Korea. Fishing efforts on these species have rapidly been increased since the 1970s, and the total catch amounted to 5,565 M/T in 1982(Chung, 1985). Ten species of sea urchins have been reported in the Korean coastal waters (Kim, 1979), but two principal species *(Strongylocentrotus pulcherrimus* and *Anthocidaris crassispina)* are exploited commercially.

Salted gonads collected during the spawning season are highly appreciated, and the current price of this product is generally over US$ 20 per kg in Korean markets. In spite of its commercial importance, the limited natural stocks seem to be decreasing because of overfishing and coastal water pollution. Accordingly, the importance of intensive culture has recently been recognized.

Although active research for seedling production of this animal were begun by Japanese scientists (Tsunoda et al., 1970 ; Kakuda and Nakamura, 1974 a, b ; Kakuda 1978 a, b ; Watanabe and Ogata, 1980), the project now seems to be of international interest (Régis, 1980 ; Kim, 1981 ; Keats et al., 1984). Since sea urchins feed on macroalgae in natural habitat, the growth and density of sea urchins in relation to macroalgae have been examined by many authors (Fuji and Kawamura, 1970 ; Wharton and Mann, 1981 ; Sivertsen, 1981 ; Hagen, 1983). Lang and Mann (1976) have found that gonad indices of sea urchins from kelp beds ranged from 1.2 to 4.0 times the gonad indices of sea urchins from overgrazed area. Variations of gonad contents with habitats and food have been reported by Lawrence (1975). Keats et al.(1984) indicated that sea urchins, which had low gonad contents, could be collected from food limited habitats, and held in boxes with adequate food supply on a short term, thereby enhancing the gonad content to a level suitable for marketing. On the other hand, Régis (1980) reported that farming projects involving control of the whole life cycle from egg to marketable size was unrealistic because of low growth rate. This author suggested also that sea urchins farming of an extensive type in an almost natural habitat might be possible.

Considering the findings of the above mentioned authors, the nature of the food supply is a prime factor for intensive echinoid culture. Although research regarding feeding and nutritional ecology of *Strongylocentrotus* have been conducted (Lasker and Giese, 1954 ; Paine and Vadas, 1969 ; Vadas, 1977 ; Larson et al., 1980), these were generally limited to marine macroalgae. However, the available algae for sea urchins culture can not be always collected easily throughout the year. So therefore, the possibility of substitution of vegetables for marine macroalgae as feed for *Strongylocentrotus pulcherrimus* was investigated. This species, which is commercially important, was reared in laboratory during the gonad growth season. Feeding habits and gonad growth of the sea urchins fed on various algae and terrestrial vegetables were examined as well as the light and temperature effect on its gonad growth.

MATERIALS AND METHODS

Individuals of *Strongylocentrotus pulcherrimus* used in the study were collected at the intertidal zone near the Institute of Marine Sciences, National Fisheries University of Pusan. Six species of macroalgae *(Grateloupia prolongata, Chondrus* sp., *Sargassum thunbergii, S. sagamianum, Ulva pertusa, Undaria pinnatifida),* which were abundant in this area, have been selected as test foods. In addition, 5 kinds of vegetables (spinach, radish leaf, kale, lettuce, Chinese cabbage) and 2 kinds of amiml foods—beef and short necked clam *(Tapes japonica)*—were also tested in this experiment.

Selective feeding preference for the 12 kinds of foods mentioned above (but excluding *Undaria pinnatifida)* were examined during October 20—29. Twenty specimens of small sea urchins from 4 to 8 g in body weight (20—27mm in test diameter) and the same number of large sea urchins (14—22 g, 33—38 mm) were starved for 48 h and held separately in 45 ℓ culture vessels with continuous aeration. Food supply which was about 50% of the total body weight of the sea urchins consisted of 12 kinds of food stuff in equal amount. Foods were rinsed with sea water before being supplied. Vegetables were submerged by inserting them into wire loops because of their high buoyancy. The residues after 24 h were examined to detect the preferred or rejected food items. Dry weight of the supplied foods and residues in wet condition were recalculated by drying at 150℃ for 1 h. The selective feeding experiment was repeated 3 times.

The experiment for non-selective feeding habit was carried out in 13 rectangular plastic baskets(36 ×51×30cm) covered with nets, each containing 20 specimens (5—7g in body weight each). After starving the sea urchins for 48 h, each basket was supplied with one of the before mentioned food samples, and the sea urchins were reared during four days (October 24—28) in a concrete raceway(375 ×46×58 cm).

Continuous air was supplied to the raceway, and the water quality was protected by a continuous flow system(turnover rate, 1/h). The amount of food supplied per day for a basket was 5% of the total body weight of 20 sea urchins. The amounts of animal foods and kale were reduced to 2.5% of the total body weight because of the observed low feeding intake of these foods. The residues were collected after 4 days, and the feeding amount was calculated in dry weight. Taking the results of previous experiments into consideration, 5 species of algae *(Grateloupia prolongata, Sargassum thunbergii, S. sagamianum, Chondrus* sp., *Undaria pinnatifida)* and 4 kinds of vegetables (spinach, radish leaf, lettuce, Chinese cabbage) were selected for a test of the values of each food in long term culture. The rectangular plastic vessel used previously was filled with 10 kg of sand and 35 ℓ of sea water. Sand filtration with an air lift system was adopted for this experiment. Twenty specimens of 6—9 g in body weight were reared in a vessel supplied with one of the food samples. Vegetables were supplied by using the wire loop, and daily food supplies were about 2—6% of the total body weight depending on consumption rate. The experiment was carried out in an open flow system with a turnover rate of 1/h. The experiment for the test group of *Undaria pinnatifida* and *Sargassum thunbergii* was begun on December 9, because of their previous unavailability. The other groups were however begun on November 20. The rearing of these 9 food groups was continued up to March 14. Consequently, environmental conditions except food were the same during the rearing period. After 95 or 114 days from the stocking, the surviving sea urchins were examined for body and gonad weight as well as gonad index (gonad weight/body weight×100) to evaluate the importance of different food groups.

Effects of environmental factors such as temperature and light on gonad growth of the sea urchins were also examined. Concerning the test of temperature effects, the same vessel which was used previously was utilized with a sand filtration sysytem. Water temperatures of 5 vessels were controlled to 10± 1℃, 15± 1℃, 20± 1℃, 25± 1℃ and 30± 1℃. Thirty sea urchins of 6−7g in body weight were held in a vessel, and reared during 74 days (December 30 − March 14). With reference to light condition, the same vessel and filtration technique used for the temperature experiments were adopted. The water temperature was controlled to the level of natural sea water (6.2−12.2℃). The natural light was interrupted by black polyvinyl for two vessels, and one fluorescent lamp(20w) was installed in one of them. Accordingly, one was continuously light with 20w, and the other dark. One vessel was held at natural light condition. Thirty sea urchins of 6−7 g in body weight were held in a vessel, and reared during 95 days from December 9 to March 14. Sea urchins were continuously fed on *Undaria pinnatifida* for the experiment of temperature and light effect on gonad growth. At the end of the experiment, gonad and body weight of surviving individuals were measured.

RESULTS

Table 1 shows the results of selective feeding for small sea urchins. *Grateloupia prolongata* was found to be the most selected food for the small sea urchins. Its mean consumption per g of body weight per day was 9.51 mg. Conversely, *Ulva pertusa* was the lowest (1.69 mg). Consumption of spinach was also very high (8.01 mg), and was the highest among vegetables. *Sargassum thunbergii* and radish leaf were of intermediate value. Short necked clam was more available than beef for sea urchins, but the consumption of these animal products was relatively low. Among vegetables, the feeding of Chinese cabbage was the lowest.

For large sea urchins, the mean consumption per g of body weight per day was 20.66 mg, which was about 40% of that of the small ones, 51.24 mg (Table 1). With respect to selectivity, large sea urchins showed the same tendency as that of the small ones. The highest selectivity was found for *Grateloupia prolongata*(3.65 mg) and spinach, *Sargassum thunbergii*, radish leaf and lettuce followed. *Ulva pertusa* was the least selected for the large sea urchins (0.57mg/day/g of body weight). Small and large sea urchins seem to have the same tendencies as to the priority of food option. The amount consumed of vegetables for small sea urchins occupied 44% of the total. This was a little higher than that for the large individuals (40%). Nevertheless, the feeding amount on algae in both groups of the sea urchins was approximately at the same level, and animal foods consumed by large and small sea urchins were 14% and 11% respectively.

The results of non-selective feeding are shown in Table 2. In this experiment, spinach was the must consumed food (15.45 mg/g of body weight/day), and short necked clam was the lowest (1.39mg). *Grateloupia prolongata* was the most successful food among algae (14.84mg). The consumption of *Undaria pinnatifida*, which was examined in December, was 8.42 mg. The priority of food selectivity in the experiment of non-selective feeding was in general similar to that of selective feeding experiment. Taking into consideration the results obtained in the previous experiments, 5 species of algae *(Grateloupia prolongata, Sargassum thunbergii, S. sagamianum, Chondrus* sp., *Undaria pinnatifida)* and

Table 1. Daily selective feeding amount in dry weight (mg) per gram body weight of the small and large sea urchins, *Strongylocentrotus pulcherrimus*

Food	Small group				Large group			
	Expt 1	Expt 2	Expt 3	Mean	Expt 1	Expt 2	Expt 3	Mean
Algae								
Grateloupia prolongata	9.14	9.52	9.89	9.51	3.31	3.35	4.30	3.65
Sargassum thunbergii	7.48	0.83	8.01	5.44	2.15	2.81	2.11	2.36
Chondrus sp.	1.74	3.93	6.12	3.93	1.40	1.74	2.08	1.74
Sargassum sagamianum	1.89	1.96	3.93	2.59	0.98	1.36	1.40	1.25
Ulva pertusa	2.42	0.23	2.42	1.69	0.41	0.38	0.92	0.57
Vegetables								
Spinach	9.28	7.10	7.63	8.01	1.79	2.72	3.63	2.71
Radish leaf	4.38	4.23	6.95	5.19	1.66	2.02	2.20	1.96
Kale	5.82	1.51	3.93	3.75	1.76	0.90	1.34	1.33
Lettuce	4.00	2.79	4.31	3.70	2.10	1.36	1.62	1.69
Chinese cabbage	1.89	1.13	2.42	1.81	0.44	0.60	0.73	0.59
Animals								
Short necked clam	3.93	3.70	3.25	3.63	1.61	1.53	1.37	1.50
Beef	2.72	0.08	3.17	1.99	1.29	1.47	1.16	1.31
Total feeding amounts(mg)	54.69	37.01	62.03	51.24	18.90	20.24	22.86	20.66
Supplied foods in wet(g)	77.2	77.8	77.5	77.5	76.1	77.5	75.5	76.4
Mean body weight(g)±S.D	6.62± 1.96	5.91± 1.10	6.44± 0.99	6.32± 1.35	19.31± 1.30	18.36± 7.24	16.38± 3.17	18.02± 3.90
No. of sea urchins	20	20	20	20	20	20	20	20

Table 2. Non−selective feeding amount in dry weight of various feed stuffs for the sea urchin, *Strongylocentrotus pulcherrimus*, during four days feeding experiment (October 24−28, 1984)

Food	Specimens		Total supply	Total feeding	Daily** feeding
	No.	Mean body weight±S.D(g)	(g)	(g)	(mg)
Algae					
Grateloupia prolongata	20	6.81±0.85	9.56	8.09	14.84
Sargassum thunbergii	20	6.56±0.37	8.88	7.67	14.62
Chondrus sp.	20	6.58±0.33	8.12	4.81	9.15
*Undaria pinnatifida**	20	7.05±0.60	5.33	4.75	8.42
Ulva pertusa	20	5.66±0.66	5.40	3.53	7.81
Sargassum sagamianum	20	7.29±0.55	4.48	3.48	5.97
Vegetables					
Spinach	20	6.29±0.21	7.90	7.77	15.45
Radish leaf	20	6.41±0.32	6.12	6.10	11.89
Lettuce	20	6.33±0.26	5.29	5.25	10.36
Kale	20	6.50±0.21	3.03	2.71	5.21
Chinese cabbage	20	6.40±0.29	3.40	2.48	4.83
Animals					
Beef	20	6.37±0.29	3.25	1.31	2.58
Short necked clam	20	6.45±0.28	2.20	0.72	1.39

* examined in December 9−13

** daily feeding amount per g body weight

4 kinds of vegetables (spinach, radish leaf, lettuce, Chinese cabbage) were finally selected to examine the food efficiency for long term culture. The result of this experiment carried out during 95 or 114 days is shown on Table 3.

In order to estimate the gonad gain, fresh stocks were collected from natural population and 198 individuals were killed and examined for gonad weight. The rest (n=180) were placed on the same day with those which were already being used in long term culture. The linear regression between body and gonad weight of these specimens was y (gonad weight) = −0.177+0.114x (body weight), r=0.3512(t=5.251,***p<0.001).

At the end of the experiment, the survival rate was 100% except for the food groups of *Grateloupia prolongata, Sargassum thunbergii* and spinach. Mean gains of body weight of *Undaria pinnatifida* were the highest (38.2mg/day), and that of *Grateloupia prolongata* the lowest (6.1 mg/day). Lettuce was

Table 3. Nutritional efficiencies on body and gonad growth of the sea urchins, *Strongylocentrotus pulcherrimus*, for 114 days rearing period (Nov. 20, 1984 – Mar. 14, 1985)

Food	Stocking(20 inds)		Yield				Daily gain(mg)		Suppl-ied food** (g)	Gain/feed(%)	
	MBW± S.D (g)	MGW± S.D* (g)	Survival no	MBW± S.D (g)	MGW± S.D (g)	MGI± S.D (%)	Body	Gonad		Body	Gonad
Algae											
*Undaria pinnatifida****	7.05± 0.60	0.63± 0.07	20	10.68± 0.96	2.57± 0.30	24.10± 2.38	38.2	20.4	125.7	57.7	30.8
Chondrus sp.	6.92± 0.73	0.61± 0.08	20	8.88± 1.08	2.01± 0.69	22.56± 7.23	17.2	12.3	114.8	34.2	24.4
*Sargassum thunbergii****	7.75± 0.73	0.71± 0.08	18	9.40± 1.12	2.12± 0.59	22.08± 4.74	17.4	14.8	242.4	12.3	10.4
Sargassum sagamianum	7.42± 0.82	0.67± 0.09	20	9.07± 0.82	1.51± 0.43	16.86± 5.21	14.5	7.4	111.7	29.6	15.1
Grateloupia prolongata	7.18± 0.64	0.64± 0.07	19	7.88± 0.82	1.55± 0.50	19.66± 5.77	6.1	8.0	162.5	8.1	10.7
Vegetables											
Lettuce	7.12± 0.83	0.64± 0.10	20	10.94± 1.38	2.72± 0.67	24.86± 5.11	33.5	18.2	198.4	38.5	20.9
Spinach	6.99± 0.80	0.62± 0.09	18	10.03± 0.99	2.63± 0.55	26.10± 3.93	26.7	17.6	161.1	34.0	22.4
Radish leaf	7.35± 0.66	0.67± 0.08	20	10.37± 1.16	2.62± 0.57	25.20± 4.18	26.5	17.1	168.6	35.4	23.1
Chinese cabbage	7.42± 0.52	0.67± 0.06	20	10.52± 1.05	2.08± 0.51	19.88± 4.64	27.2	12.4	147.8	42.0	19.1

MBW : mean body weight ; MGW : mean gonad weight ; MGI : mean gonad index

* : estimated from the linear regression between body and gonad weight of 198 sea urchins, $y = -0.177 + 0.114x$

** : total supplied food in dry weight(g)

*** : reared during 95 days (Dec. 9, 1984 – Mar. 14, 1985) the highest among vegetables (33.5 mg/day), and vegetables were outstandingly successful foods comparing with algae. Concerning the gains of gonad, *Undaria pinnatifida* showed the highest increment (20.4 mg/day), and the lowest one appeared in *Sargassum sagamianum* (7.4mg/day). Lettuce produced the highest rate of gonad growth among four kinds of vegetables (18.2mg/day), but gains of gonad with Chinese cabbage were only 12.4mg/day, the lowest among vegetables.

With reference to food efficiency (total gains of body weight/supplied food ×100) on the gains of body weignt, *Undaria pinnatifida* showed the highest value (57.7%), and *Grateloupia prolongata* the lowest one (8.1%). It was also remarkable that Chinese cabbage was the best among vegetables (42.0%). On the other hand, food efficiency ratio on the gains of gonad weight was also the highest in *Undaria pinnatifida* (30.8%), and the lowest in *Sargassum thunbergii* (10.4%). In the case of vegetables, radish leaf was the best (23.1%), and the efficiencies of lettuce and Chinese cabbage were relatively low. From the standpoint of goand index at the end of rearing, spinach (26.1%) was higher than that of *Undaria pinnatifida* (24.1%). The gonad index of the latter was lower than that of radish leaf and lettuce. *Sargassum sagamianum* showed the lowest index.

The results of growth of the sea urchins under different regimes of temperature and light are shown in Table 4. Concerning the experiment of temperature, higher temperature induced higher mortality. All individuals in the 30℃ test group died after 30 days. On the contrary, 100% survival characterized at the 10℃ test group. The sea urchins in the 20℃ and 25℃ test groups showed minus growth. The increment of body weight of the sea urchins reared at 10℃ was, however, 2.38 g. Higher temperature is correlated with lower growth of gonad, and the gonad index of the individuals reared at 10℃ was the highest (20.6%).

With regard to the light regime, the mortality of the sea urchins in the continuous light group was 27%, which was higher than that in the continuous dark one (17%). The gain in body weight in the continuous dark group was 1.4 times as great as those in the continuous light one. Conversely, the mean gonad index in the former (19.29%)was lower than that in the latter (26.18%). Comparing these results with those of the natural light group, gains in body weight and goand index of natural group were higher than those of continuous light or dark regime.

DISCUSSION AND CONCLUSIONS

Vegetables such as lettuce and spinach were often utilized in the culture of lobster, mysids, isopods, amphipods, etc., as a vitamin source (Kinne, 1975). In the culture experiment of abalone, *Haliotis discus hannai,* 26 kinds of terrestrial plant leaves including vegetables were recently examined by Rho and Yoo(1984). These authors indicated that the food value of Chinese cabbage was better than that of *Ulva pertusa* which had been known as the most available food for abalone.

With respect to feeding habits of the sea urchins, *Strongylocentrotus pulcherrimus,* many examinations on stomach contents (Kawana ; 1938, Ohshima et al., 1957), selectivity of food (Nakamura and Yoshinaga ; 1962) and artificial diet (Nagai and Kaneko ; 1975) were carried out. Lasker and Giese (1954) studied the nutrition of *Strongylocentrotus purpuratus* under laboratory condition. Their results indicated that this species was not always herbivorous. In the experiments of Ohshima et al. (1957) and Lasker and Giese (1954), the sea urchins occasionally ingested animal products such as beef, squid, fish and shellfish. Nagai and Kaneko(1975) examined eight kinds of commercial products (fish meal, milk casein, yellow corn, soybean meal, gelatin, lucern, agar and yeast), three kinds of natural

Table 4. Effects of temperature and ligh on body and gonad growth of the sea urchin, *Strongylocentrotus pulcherrimus*

Factors	Stocking		Yield				Body	Mor-	Rearing periods
	No.	MBW± S.D (g)	No.	MBW± S.D (g)	MGW± S.D (g)	MGI± S.D (%)	gain (g)	tality (%)	
Temperature									
10℃± 1	30	6.81± 0.57	30	9.19± 0.96	1.90± 0.32	20.60± 2.49	2.38	0	Dec. 30,'84 – Mar.14,'85
15℃± 1	30	6.88± 0.59	29	7.97± 0.93	0.99± 0.25	12.44± 2.83	1.09	3	〃
20℃± 1	30	6.62± 0.59	20	6.50± 0.84	0.38± 0.18	5.71± 2.07	−0.12	33	〃
25℃± 1	30	6.81± 0.59	13	6.57± 0.51	0.48± 0.18	7.22± 2.38	−0.24	57	〃
30℃± 1	30	6.79± 0.52	0	–	–	–	–	100	〃
Light									
Continuous dark	30	7.23± 0.64	25	10.90± 1.51	2.11± 0.45	19.29± 2.72	3.67	17	Dec. 9,'84 – Mar.14,'85
Continuous light	30	6.49± 0.46	22	9.16± 1.40	2.43± 0.69	26.18± 4.89	2.67	27	〃
Natural light	30	7.05± 0.66	24	10.75± 1.11	3.01± 0.56	27.89± 3.39	3.70	20	〃

foods (green and brown algae and shellfish) and a synthetic salt mixture for the foods of *Stronglylocentrotus pulcherrimus.* The results of this study showed that this species was omnivorous. Although many investigators have studied the feeding habit of the sea urchins, and although Lasker and Giese (1954) reported that fresh vegetables were ingested by the sea urchins, the utilization of vegetables for the sea urchins culture has not yet been adequately considered.

When intensive indoor culture of sea urchins is undertaken commercially, fresh stocks of algae may not always be available depending on season and daily weather condition. Consequently, the evaluation of other available food sources should be examined for food value. Nagai and Kaneko (1975) cultivated sea urchins over a period of five months on artificial foods which were composed of white fish meal, shellfish meal, milk casein, gelatin, soybean meal, yellow corn, alfalfa, yeast and agar-agar. These authors reproted that this foreign diet generated a 24% increment in wet weight. However, this growth rate was not compared with that of natural algal food.

In the selectivity experiment of this study, the tendencies towards particular vegetables were almost the same in both the small and large group, they were, however, consumed at a higher rate by the small ones. The comparatively lower consumption of vegetables by the larger individuals could be due to feeding habits developed during a longer exposure to the natural surroundings.

The feeding amount per g of body weight for the small sea urchins was more than that of the large ones. This phenomenon has been also remarked on in the studies by Tsunoda et al. (1970). The results of non-selective feeding habit were study, the food value and utility of vegetables can not be compared with any other results.

Taking into consideration the results of all three experiments discussed above, algae can be substituted for vegetables such as spinach, radish leaf, lettuce and Chinese cabbage in sea urchin culture. The nutritional efficiencies of these foreign diets seem to be higher than those of algae. In particular, radish leaf, which is usually regarded as waste product, will be very economical in sea urchins culture. Since vegetables are available throughout the year they will be more available for the intensive indoor culture of sea urchins. However, as vegetables rapidly deteriorate in comparison with algae, more care in water quality will be demanded. A carnivorous feeding habit occasionally appeared also in this study. Although animal products are not major food items for the sea urchins, the food value of algae or vegetables mixed with animal products should be examined in detail.

Gonad growth in most marine invertebrates appears to depend primarily on nutrition supply, temperature and photoperiod (Kinne, 1975). It is known that reproduction in sea urchins is also affected by evironmental factors such as temperature and light condition. Boolootian (1963) demonstrated that long day photoperiod (LD, 14 : 10) stimulated the production of eggs while short day photoperiod (LD, 6 : 18) stimulated the production of spermatozoa in *Strongylocentrotus purpuratus.* Interaction of temperature and light in regard to gamete growth and maturation have been similar to those of selective feeding habit from the standpoint of preference. In this experiment, the high feeding rate on spinach, radish leaf and lettuce was remarkable indicating that vegetables can be utilized as the principal food in sea urchins culture.

The results of selective and non-selective feeding experiment did not correspond to those of long term culture during 95−114 days. This disagreement can be explained by different food values and feeding effects of diets. The growth of body weight in long term culture was the highest for *Undaria pinnatifida.* However, vegetables were in general more effective than algae. The gonad gain obtained from the equation mentioned previously ($y = -0.177 + 0.114x$) was also the highest for *Undaria* *pinnatifida*, and lettuce among vegetables. Chinese cabbage, which showed the second highest value in body weight gain among the vegetables, was the lowest in gonad gains. Thus, considering different food values for body and gonad growth, spinach and radish leaf will be adequate during the gonad growth season from October to February and Chinese cabbage and lettuce will be suitable during March to September.

As to gonad index at harvesting, spinach, radish leaf and lettuce showed higher values than *Undaria pinnatifida*. According to Nakamura and Yoshinaga(1962), this alga was found to be the most palatable for *Strongylocentrotus pulcherrimus*, and *Ulva pertusa* was found to be eaten only after complete consumption of this brown alga. The suitability of *Undaria pinnatifida* was also noted in our report on this species (Boolootian, 1963), and gonad growth, test growth and food consumption in *Strongylocentrotus intermedius* throughout the season was investigated by Fuji (1967). While the effects of light and temperature on gonad development in indoor sea urchin culture needs more detailed investigation, natural photoperiod and temperature were found to be the best environment in this study. Temperature seems to be more important than photoperiod. In particular, temperatures above 20℃ induced minus growth with high mortality. Negative growth of the sea urchins has been already found in *Strongylocentrotus purpuratus* (Ebert, 1967) and *Paracentrotus lividus* (Régis, 1979). The negative growth in this experiment seems to have been induced by physiological deficiencies which had induced by excessive high temperautre.

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