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A PELLETIZED DIET FOR CAPTIVE BENTHIC CRUSTACEANS

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In recent years, several species of crab have come under increasing study by scientists. Fluctuations in populations of important commercial species (the blue crab) and the commercial potential of others (the rock crab and deep sea red crab) have led to this increased attention. But in lab situations, researchers have had problems keeping their specimens alive and healthy for long periods. It has been difficult to insure that crabs get sufficient nutrients in traditional laboratory diets.

This project developed a feed in pellet form that proved attractive to and healthy for laboratory-reared rock crabs, Cancer irroratus. *The pelletized diet contained approximately 50 percent animal and 50 percent plant protein (reflecting the indiscriminate nature of scavenging crabs). Compared to commercially used crustacean (shrimp) feed and beef cubes, the pellet diet proved more effective in stimulating growth and in enhancing survival. Of the crabs on the pellet diet attempting to molt, 80 percent succeeded, while less than half of those on the other diets successfully shed their shells and thus perished. Likewise, the pellet-fed crabs showed significant weight gain, while the others showed no weight gain at all.*

Though crabs may prove invincible to efforts at farming their populations for commercial harvesting, a beneficial and appetizing feed form would be necessary for such an effort.

--The Editors

INTRODUCTION

There is an increased interest in the study of crustacean ecology, behavior, and physiology in the laboratory. Several species also may prove adaptable to mariculture (see review in Brown, 1977). However, few diets are commercially available for either maintenance or mariculture, and many researchers use no supplementary feeding. In some mariculture studies, the water is fertilized to increase growth of food plants, and in others, bivalves or chopped fish supply nutrients. Diets have been

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developed for maintaining penaeid shrimp (Kanazawa et al., 1970; Andrews et al., 1972), but they have not always been satisfactory. A soft diet given to crabs in a recirculating system (Winget et al., 1976) also proved unsatisfactory, and there has been no indication that the organisms could be maintained on it for long periods. Bardach et al. (1972) suggested developing a pelletized feed for use with such crustaceans as shrimp and lobster.

The study of the ecology and behavior of *Cancer irroratus* in a recirculating laboratory system required a diet that would enable the crabs to live for extended periods and maintain high survival during molt. The object of this study was to develop a food source which would provide essential nutrients at relatively low cost and which would be easily manufactured, stored, and handled. Additional objectives were to make the food attractive to the crabs and resistant to disintegration before being consumed. If successful, such a diet might subsequently be modified for use in commercial mariculture.

METHODOLOGY

The common rock crab, *Cancer irroratus*, was fed three different diets to determine the suitability of each. Twenty to 50 crabs were used in each series: tests that lasted from two to 15 months. Temperature was maintained between 10 and 15°C in a 945-liter testing facility, which was cleaned by both biological and mechanical filters. Levels of ammonia, nitrite, nitrate, pH, dissolved oxygen, and salinity were monitored regularly and were stable. Ten percent of the artificial sea water was changed on a monthly schedule to reduce the buildup of nitrogenous waste products. All experimental crabs were kept in the same recirculated sea water; therefore, dietary groups did not experience differences in temperature and water quality.

All crabs used in the diet study had also been tested for locomotor activity. Different series of these tests lasted for periods of up to six months and incorporated different photoperiods, but in any given series photoperiod was uniform for crabs on all diets, both before and during activity measurements. When activity tests ended, photoperiod for all crabs was maintained at ambient outdoor light-to-dark (L:D) ratios. A more complete description of the apparatus used and the activity testing procedure can be found elsewhere (Rebach, 1977).

The first diet consisted of scrap beef obtained from local supermarkets. It was trimmed of all excess fat and cut into cubes approximately one cm on a side. The protein content of the beef was 21%. The cubes weighed approximately 0.5 g each, and were kept frozen until the day of use. Each crab consumed one or two cubes per day. The second diet was a commercial flake or chip-shaped feed, containing 30% protein, that has been used in shrimp mariculture. There were approximately 40 flakes per gram.

The third, pelletized diet was prepared by mixing all of the ingredients listed in Table 1, except the gelatin, for one-half hour. Then 250 g of gelatin (which acted as a binder) were added to 1000 cc boiling water, stirred, added to the other ingredients, and mixed for another five minutes. The product was then run through a pellet mill three times. The final dimensions of each pellet were: diameter, 4.8 to 5.6 mm; and length, 1.27 to 1.91 cm. Each pellet weighed approximately 0.5 g. The moisture content of the pellets, which varied from 20 to 23%, was reduced to 9% by oven drying at 80°C for 24 h. This procedure avoided the added cost of having to use mold inhibitors and refrigeration. The final protein percentage was approximately 31%.

Table 1 - Ingredients of Pelletized Diet

Ingredient	gms/5000 gm Batch	Percentage Dry Wt.
Fish Meal	1250	25
Ground Yellow Corn Meal	1250	25
Milled Soy Bean Meal	750	15
Wheat Bran	250	5
Wheat Middlings	250	5
Corn Fermentation Solubles	250	5
Crab Meal	225	4.5
Alfalfa	150	3
Bone Meal	75	1.5
Vitamin Pre-Mix	50	1
Menhaden Fish Oil	250	5
Gelatin	250	5

The three diets were compared by feeding them to 20 to 50 isolated crabs per series, during and/or after activity measurements. (All crabs fed on pellets for one month prior to the beginning of testing.) Each crab was offered approximately one gram of feed per day. The weight of each crab was measured to the nearest 0.1 g biweekly, and each value was used as a data point in calculating regression lines.

RESULTS

A total of 211 crabs was tested during the period 1975-77. The average weight of the crabs was approximately 60 g at the start of the experiment. The regression lines and correlation coefficients compared weight change with time and were calculated using all recorded weights of each crab (Fig. 1). Thus, the effect of each diet on survival and weight was considered. The equations for the regression lines are: $\hat{Y} = 0.57 + 0.53X$ ($N = 468$) for the pellet diet, $\hat{Y} = 2.33 + 0.03X$ ($N = 196$) for the beef diet and $\hat{Y} = 0.82 - 0.20X$ ($N = 28$) for the flake diet. Significant change in weight occurred only for crabs on the pellet diet, and they ($r = 0.3$, $\underline{P} < 0.01$) experienced a weight gain over time.

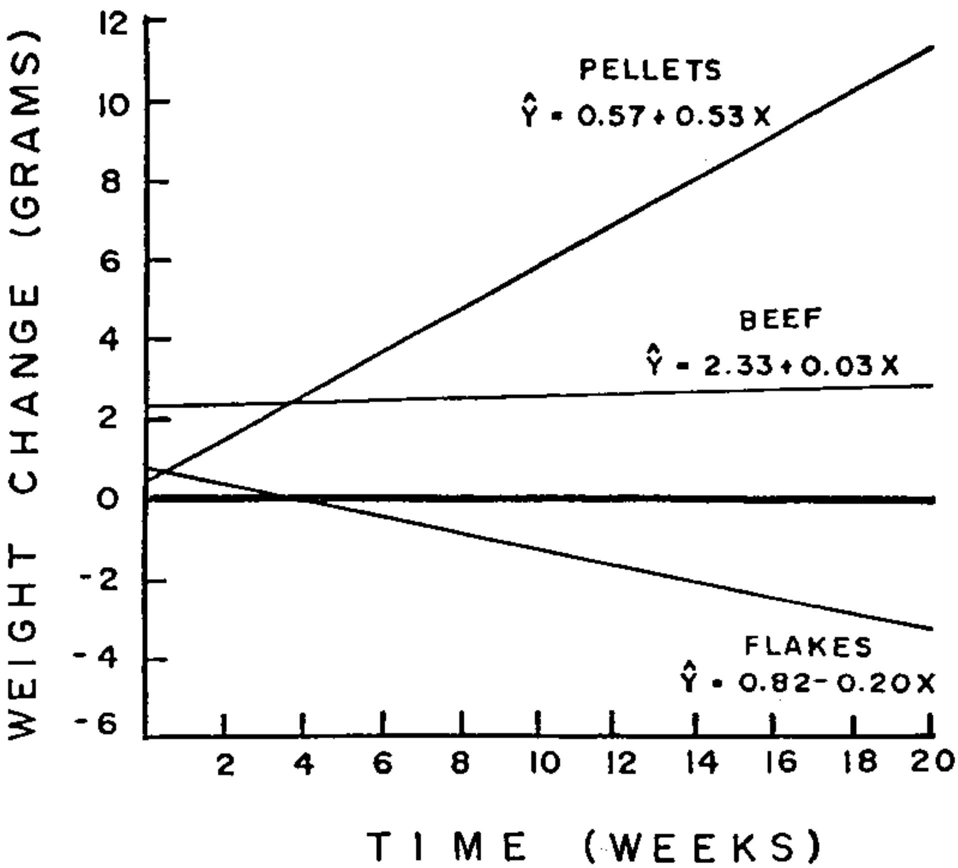

Figure 1. Comparison of weight change and diet by regression analysis.

The beef cubes were not always accepted immediately by the crabs, and spoilage occurred rapidly if the beef remained uneaten. Over a period of several months, weight gain on the beef diet was not evident. The commercial flakes descended slowly in the water column and tended to disperse easily but did not rapidly disintegrate. The crabs did not consume large quantities of this feed. The pellets fell rapidly to the bottom of the tank where they were quickly found and easily manipulated during feeding.

A comparison of the three diets in relation to percentage of protein, amino acid content, moisture, fiber, fat, calcium, phosphate, and ash can be seen in Table 2.

Table 2 - Composition of Pelletized Diet as Per Cent Sample

	Pellets	Flakes	Beef Cubes
Protein	30.97	29.23	20.70
Amino Acid			
Lys	1.83	1.59	1.77
His	0.70	0.67	0.67
Amm	0.98	1.02	0.56
Arg	1.72	1.42	1.15
Asp	2.86	2.51	2.10
Thr	1.14	1.03	0.95
Ser	1.32	1.26	0.92
Glu	4.30	4.87	3.25
Pro	1.89	1.22	0.94
Gly	2.03	1.41	1.12
Ala	1.86	1.32	1.49
Val	1.22	1.14	0.96
Met	0.67	0.56	0.56
Ileu	1.07	1.06	0.89
Leu	2.27	2.08	1.78
Tyr	1.00	0.83	0.70
Phe	1.44	1.09	0.75
Fat	7.95	5.02	6.20
Fiber	3.02	2.18	0.22
Ash	8.24	10.35	1.06
Moisture	22.50	7.41	69.93
Calcium	2.26	2.83	0.09
Phosphate	1.12	1.55	0.09

The L:D ratio in the laboratory was varied from one series to another for activity recording. Molting was induced in the laboratory using L:D ratios approximating conditions during normal molting periods. Mortality was low and regular during intermolt periods, but was higher during periods of heavy molt. Of 50 crabs that molted in the laboratory during all activity and nutrition testing, 33 of 41 on pellet diets survived (80.5%). The number of crabs that molted on the other two diets was very low. One of two molting crabs fed the flake diet survived, only to die within 17 days of molt. The few molts that occurred while crabs were on the beef diet usually ended in the death of the crab: three of the seven molting crabs fed the beef diet survived molting. After an initial weight gain from molting, one of these crabs subsequently lost 10 g and two others showed no further weight gain.

After the last series of diet tests, 37 surviving crabs were maintained for another month on the pellet diet. Of this group, 18 gained weight (15 molted, 3 lost weight (one died molting) and 16 showed no change in weight (no molts) during the month-long maintenance on pellets.

DISCUSSION

The crabs were presented with between 1.5 and 2.0% of their body weight daily with these three diets. Observation showed this to be an adequate amount for consumption, since the crabs usually rejected any more. Biddle (personal communication) reported that blue crabs kept in a similar facility consumed approximately 2% of their weight daily. Although Sick et al. (1972) offered penaeid shrimp up to 15% of their biomass/day, which produced a maximum 164% weight gain in six weeks, no indication of actual amount of consumption was given.

The composition and configuration of the pelletized feed are significant in the context of other formulated diets. Most diets described in the literature for maintenance or raising of various aquatic organisms such as tropical fish, minnows, catfish (Hastings, 1968), or crabs (Winget et al., 1976) contain the same basic ingredients. Different sources of protein (such as fish, soybean, feather, and poultry meals) are used depending on cost and availability. The pelletized diet contained 50% plant and 50% animal protein, a ratio recommended by the U.S. Fish and Wildlife Service for diets such as catfish feed (Brown et al., 1969). (Crabs, like catfish, are scavengers, eating both plant and animal material.) Protein constituted 31% by weight of the pellets; Andrews et al. (1972) found optimum growth at 28 to 32% protein for penaeid shrimp.

Kanazawa et al. (1970) indicated that it may be necessary to induce feeding behavior when using formulated diets, and the pelletized diet used menhaden fish oil to attract the crabs. It is also important for the pellet to be stable in the water until it is consumed. The fibrous components increase compression during pelleting, as does the small particle size of the ingredients, and these add to relative water stability (Hastings, 1968). The pellets sink rapidly and remain water-stable (do not disintegrate) for 48 hours. A rapidly sinking, water-stable pellet is well suited for benthic organisms, and the uniformity of such a diet allows for accurately measured portions. Furthermore, a uniform pellet would be easy to use in a mechanized delivery system to maintain or grow benthic organisms.

Nutritional and mechanical characteristics may influence the suitability of a given diet for benthic crustaceans. Observations of the crabs' behavior suggest that differences in feeding success were probably mechanical. The flakes were very small and appeared to be difficult for the crabs to manipulate. Differences in weight gain and survival may thus have been due to the physical form (pellet vs. flake) rather than to differences in nutrient profiles.

Regression analysis indicated that there was a significant increase in weight ($P<0.01$) with the pelletized diet as compared to either the beef or flake diets (Fig. 1). This might be due to increased survival and molting success in the groups fed pellets. Growth is slow in crustaceans that molt infrequently, since there is little intermolt weight change (most of the weight gain occurs immediately after molt). The regression analysis for beef indicated that the diet had no significant effect on weight change. This diet was notably low in both calcium and phosphates (see Table 2). The regression line for the flake diet indicated a general decrease of weight over time, though the correlation coefficient was not significant. Table 2 does not indicate any major differences between the components of the flake diet and the pelletized diet except for the moisture content. When expressed on a dry-matter basis, the pelletized feed contained approximately 27% more protein and 90% more fat than the flake diet.

Six percent of the pellet diet consisted of crab meal and bone meal, which are rich in calcium (a shell hardener). Spiny lobsters are known to cannibalize at molt, especially if their diet is low in calcium (Bardach et al., 1972). It is possible that the frequency and relative success of molting in crabs is due to the amount of calcium obtained from the diet. The rock crab, an inhabitant of deep and cold waters, molts only once or twice a year (Haefner, 1976). Crabs on the pellet diet molted with natural frequency, while those on the flake and beef diets had much lower molting rates and often did not attempt to molt. Crabs fed the pellets also showed the greatest amount of activity, while those fed the other two diets indicated decreasing activity levels over the course of the activity tests.

Winget et al. (1976) found no growth differences in diets ranging from 26 to 62% protein fed to blue crabs. These diets were relatively low in calcium and phosphates. In addition, they maintained the L:D cycle at 16:8 for a 60-day period while varying the testing temperature. We have found in other studies that photoperiod is of more importance in the molt cycle of rock crabs than is temperature (see also Aiken, 1969). Thus, photoperiod and nutrient levels may have affected their results.

The pelletized diet has proven satisfactory in maintenance of rock crabs for the extended periods necessary for activity testing. Crabs have been maintained on this diet through two molt cycles for periods in excess of one year. The pelletized feed may thus be used for laboratory maintenance and possibly for shedding (molting) crabs.

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