FORMULATION OF ARTIFICIAL DIETS FOR FEEDING LOBSTER (*HOMARUS AMERICANUS*) HELD IN POUNDS

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INTRODUCTION

Historically lobster pound operators have considered the feeding of their lobsters an investment. Feeding adds some weight to the new (soft) shell lobster and should reduce cannibalism among other lobsters. Lobsters in a pound are usually fed salted herring at the rate of sixty pounds (one bushel) per thousand pounds of lobster. How often this is done depends largely on the water temperature which affects the lobster's rate of feeding.

Herring used for pound feeding, however, varies in quality and availability. Availability may become more of a problem with Department of Commerce quotas on herring catch levels and potential limits on the amount of bait fish that can be imported from Canada. The quality problems with herring are oil content and occasional rancidity. Excessive oil can be harmful to lobsters and, in some cases, may even cause mortality. The herring fed to lobsters cost a minimum of $3.00 per bushel in 1978, or $160.00 per ton. At 30% dry matter, this cost is $533.00 per ton of dry matter.

The objective of this study was to develop an artificial diet suitable for pound feeding of the American lobster. The artificial diet should be comparable in price to herring but should not present problems of quality and availability.

PRELIMINARY STUDY

Very little research has been reported on pound feeding of adult American lobsters. Preliminary dietary formulations were based on a study of the natural dietary intake of adult lobsters (Leavitt, 1977). The summary of data obtained from this study is given in Table 1. A preliminary diet was formulated from commercially available feed ingredients (Table 2), using data for natural intake of hard shell lobsters. This diet maintained adult lobsters under laboratory conditions. Diets based on this formulation were used in further studies.

As can be seen in Table 1, there are significant differences between the dietary intake of adult hard shell lobsters and adult soft shell lobsters in total mineral content, total calcium, gross energy and crude protein content. Since filling out and hardening of soft shell lobsters is of prime concern in holding lobsters, and protein is usually the most costly ingredient in dietary formulation, the significance of mineral content and composition, as well as protein content, in artificial diets was examined.

FACILITIES

Dietary feeding trials were conducted in either one of two facilities. Field trials were conducted at the Tidal Falls Lobster Pound, Hancock, Maine through the cooperation of Mr. Herb Hodgkins. At this facility lobsters on each test diet were placed in individual wooden storage crates and either held in a floating lobster car or sunk in the pound itself.

Laboratory trials were conducted in fiberglassed wooden tanks with closed circulating artificial sea water (Instant Ocean). Salinity was held at 30 ppm ± 3 ppm and temperature was held at 18°C ± 1°C. Tanks were equipped with a layered filter of synthetic sponge, activated charcoal and dolemite. These filters were able to maintain a proper pH level (7.0), and nitrifying bacteria in the sponges kept ammonia to minimal levels.

DIETARY MINERAL STUDIES

Effect of Varying Calcium-Phosphorus Ratios

Materials and Methods: Semi-purified diets with calcium-phosphorus ratios of 2.0, 1.0 and 0.1 (Table 3) were fed to adult lobsters held in storage crates at Tidal Falls Lobster Pound. Twenty-four lobsters were placed on each diet and twelve lobsters were held as a starvation control. Lobsters were fed three times per week for six weeks. The lobsters were initially weighed in air and reweighed at three week and six week intervals. Growth was determined as the change in air weight over the six-week period. Semi-purified ingredients were used to insure an exact calcium-phosphorus ratio (Ca/P).

Results and Discussion: The results of feeding diets with varying calcium-phosphorus ratios are shown in Figure 1. Starvation controls lost weight over the entire testing period. Although all lobsters fed artificial diets gained weight during the first three weeks of feeding, by the end of the sixth week lobsters fed two of the artificial diets, with calcium-phosphorus ratios of 0.1 and 2.0, had lost weight and those fed the diet with a Ca/P of 1.0 had gained significantly more than the other treatments. These results are similar to those obtained by Gallagher et al (1978) with juvenile lobsters, in which growth was significantly better on diets with calcium-phosphorus ratios of 1.0 or lower as compared to lobsters fed diets with calcium-phosphorus ratios of 1.5 or higher. The results from these studies indicate that dietary Ca/P can significantly affect growth in lobsters.

Effect of Salt Mix Source

Materials and Methods: A base diet was formulated from conventional feed ingredients using criteria in Table 1 for hard shell lobsters (Table 4). To the base diet, no salt was added for treatment 1, 10% Modified Bernhardt-Tomeralli salt mix was added for treatment 2, and 10% artificial sea salt (Instant Ocean) was added for treatment 3. The basal diet had a Ca/P of 0.89. Each diet was fed once a day to five adult lobsters held under laboratory conditions for five weeks. Growth was measured as the change in air weight over the five-week period.

Results and Discussion: Results from the growth experiments are shown in Table 5. Although there are no significant differences between treatments, some interesting observations can be made. The diet with no mineral supplementation supported growth equivalent to either of the diets containing mineral mix. This result could indicate that dietary mineral supplementation is not necessary in diets formulated from conventional feed ingredients. The basic diet had a calculated mineral content of 5-6%. It is also interesting to note that artificial sea water salts (Instant Ocean) are a better salt supplement than the previously tested Modified Bernhardt-Tomeralli mix (Gallagher et al, 1978). This could be due to the presence of trace elements in Instant Ocean not present in the other salt mix.

Mineral Supplementation of Soft Shell Lobster Diets

Materials and Methods: Thirty-six soft shell lobsters were obtained from the Tidal Falls Lobster Pound. Twelve lobsters were placed on each of three diets. The diets were a basic unsupplemented diet, a 50% CaH_2PO_4 supplemented diet, and a herring control (Table 6). Lobsters were held in wooden storage crates at the lobster pound and fed three times a week for six weeks. Growth was measured as the change in air weight over the six-week period.

Results and Discussion: Results from the growth study are shown in Table 7. There were no significant differences in growth between any of the diets. This result is surprising since past evidence has indicated that the need for mineral in the diet is increased in newly molted (soft shell) lobsters (Ennis, 1974; Weiss, 1971; Leavitt, 1977) (see Table 1). There are two possible explanations for this result: 1) mineral found in gut contents in previous studies may have been incidentally present in gut and been egested as pseudo-feces having no effect on growth (Williams, 1911: Herrick, 1885) or 2) the lobster may be capable of fulfilling its mineral needs through dissolved minerals in sea water.

Using the results from the three studies above, a winter feeding trial was initiated.

Winter Field Trial

Materials and Methods: Four diets were fed to impounded lobsters from October to February. Compositions of diets are given in Table 8. There were ten lobsters in each diet group. Lobsters were held in wooden storage crates and sunk in the pound by means of concrete blocks. The lobsters were fed twice weekly for a period of fourteen weeks. Growth was measured as the change in air weight over the fourteen-week period.

Results and Discussion: Results of the winter feeding trial are given in Table 9. Herring, Instant Ocean diet and least-cost formulation 2 gave increases in weight while least-cost formulation 1 resulted in a decrease in weight even though it was supplemented with herring. These studies indicate that it is possible to formulate diets that are as good as herring for pound feeding.

DIETARY PROTEIN STUDIES

Effect of Protein-Energy Ratio

Protein is usually the most expensive ingredient in a ration. Therefore, in formulating a diet to replace herring in pound feeding, it would be necessary to keep this ingredient at a minimum and still meet the requirement of the animal. Data from natural intake studies (Table 1) showed that while the per cent crude protein in the diet changed with stage of molt the protein-energy ratio remained constant for hard shell and soft shell lobsters. Therefore, studies were initiated to investigate the effects of protein-energy ratio on growth of adult lobsters when 1) protein varied in the diet and 2) when energy varied in the diet.

Materials and Methods: Lobsters in early premolt (hard shell) states (D_0-D_1) were selected for growth studies. Six groups of twelve lobsters each were maintained on different diets. Compositions of the six diets are given in Table 10. Each diet group was held in a recirculating closed artificial sea water system. Lobsters were fed three times daily at 8:00 a.m., 5:00 p.m. and 11:00 p.m. for eight weeks. Growth was measured as the change in air weight over an eight-week period.

Results and Discussion: Results from the protein-energy ratio growth study are given in Tables 11 and 12. Although there were no significant differences in growth on any of the diets, there are some interesting trends. When the protein level in the diet remained constant at 33% (Table 11), best growth was obtained on the diet with the highest energy content therefore the lowest protein-energy ratio. When the energy content of the diet remained constant (Table 12), best growth was again obtained on the diet

with the lowest protein-energy ratio even though this diet provided the lowest per cent protein (16%). It should also be noted that when the two best diets are compared, the diet having both the higher protein content and the higher energy content resulted in the best weight gain. These data suggest the lobster is capable of good growth on artificial diets where total protein contributes only one-third of the total energy. However, the total caloric density of the diet also affects growth rate.

Effect of Protein-Energy Ratios in Diets of Juvenile Lobsters

Juvenile lobsters of the 4th stage (4 mm carapace length) have a much faster growth rate than adult lobsters and require less space for dietary testing. Therefore, a special license was obtained from the Maine Department of Marine Resources to study dietary requirements of juvenile lobsters and compare the results with those from the adult studies.

Materials and Methods: Sixty 4th stage lobsters were divided into three diet groups. Each group was fed the three diets shown in Table 10, with protein-energy ratios of 0.07, 0.11 and 0.13. Each group was fed three times daily for thirty days. Growth was determined as the change in air weight over the thirty-day period.

Results and Discussion: Results of this growth study on juvenile lobsters are shown in Table 13. Juvenile lobsters receiving a diet with a protein-energy ratio of 0.07 obtained significantly better weight gain than juvenile lobsters receiving diets with higher protein-energy ratios. As with adult lobsters, the results indicate that protein-energy ratio can have a significant effect on growth. In addition, these results show that diet studies with juvenile lobsters will yield significant results faster than studies with adults. Studies of the diet requirements of juveniles can expedite and clarify the collection of data relating to lobster nutrition.

Effect of Yeast Source

Yeast is a common additive to marine diets as a source of the B-complex vitamins which are not readily soluble in water. This study was initiated to investigate the effects of the source of yeast supplements on lobster growth.

Materials and Methods: A base diet was formulated and supplemented with four different yeast sources, comprising 13.3% of the total diet. Diet composition is shown in Table 14. Salted herring was fed to one group as a control. Twelve lobsters were placed on each of the five diets and held in wooden storage crates at Tidal Falls Lobster Pound. Lobsters were fed three times weekly for four weeks. Growth was measured as the change in air weight over the four-week period.

Results and Discussion: Results of the growth trials using different yeast sources are given in Table 15. Best growth was obtained with the artificial diet supplemented with brewer's yeast. This diet and yeast source supported better growth than even the herring control. Lobsters fed the artificial diet supplemented with Coors yeasts had the poorest growth; in fact, they lost weight. When yeast sources were compared for total per cent protein, thiamine, niacin and riboflavin content (Table 16), Coors yeast also had a lower niacin content (9.5 mg/%) than brewer's or Torutein (both 15 mg %). However, Blue Label yeast supplement, which gave good weight gain had low vitamin levels. In comparing the protein composition of the four yeast sources, the Coor's yeast which supported the poorest growth also had the lowest per cent protein. These results would indicate that the protein content of the yeast supplement is more important to growth under pound storage conditions than the vitamin content of the yeast.

CONCLUSIONS

From the studies presented and discussed above, several conclusions can be drawn:

1) Calcium-phosphorus ratios in artificial diets can affect growth (weight gain) in adult lobsters; a Ca/P of 1.0 gave best growth.

2) No mineral mix is necessary in artificial diets formulated from conventional feed sources as long as the calcium-phosphorus ratio in the feed mixture is near 1.0.

3) Mineral supplementation of artificial diets fed to soft shell lobsters does not significantly affect weight gain in these lobsters.

4) Adult and juvenile lobsters fed artificial diets with varying protein-energy ratios showed best weight gain on those diets with the lowest protein-energy ratios (0.07).

5) Diet studies using juvenile lobsters resulted in growth data that were more quickly obtained and showed statistical significance when compared to the same studies using adults.

6) Yeast sources do not significantly affect growth of adult lobsters in pound conditions as long as protein content of sources is constant.

7) It is possible to formulate an artificial diet from conventional feed sources which will result in growth as good as, or better than, herring under pound conditions. Such a diet is presently being fed in commercial pounds.

APPENDIX

Table 1. Mean proximate analysis values to be used as a dietary formulation standard.

Constituent	Soft Shell	Hard Shell
Crude Protein (%)	12.00 ± 2.00^{a}[1]	34.00 ± 3.00^{b}
Gross Energy (kcal/g)	1.04 ± 0.25^{a}	2.14 ± 0.24^{b}
Protein-Energy Ratio (g protein/kcal)	0.16 ± 0.04^{a}	0.17 ± 0.01^{a}
Ether Extract (%)	0.58 ± 0.17^{a}	0.59 ± 0.21^{a}
Total Mineral (%)	60.00 ± 2.00^{a}	48.00 ± 3.00^{b}

[1]Means with different superscript are significantly different at the $\alpha = 0.05$ level.

Table 2. Composition of preliminary diet formulation.

Ingredient	%
Corn Gluten Feed	58
Soybean Oil Meal	15
Herring Meal	25
Whole Egg	2
Total %	100

Table 3. Composition of semi-purified calcium-phosphorus ratio diets (%).

	#1	#2	#3
Casein	14.0	14.0	14.0
Fish Meal	15.0	15.0	15.0
Albumin	1.4	1.4	1.4
Yeast	10.0	10.0	10.0
Wheat Gluten	9.0	9.0	9.0
Cornstarch	24.0	24.0	24.0
Alphacel	11.4	8.3	4.9
Cod Liver Oil	2.0	2.0	2.0
Vitamin Mix	2.0	2.0	2.0
Cholesterol	0.5	0.5	0.5
Choline Chloride	0.7	0.7	0.7
Mineral Mix	10.0	10.0	10.0
$CaCO_2$	0.0	3.1	6.5
Ca/P Ratio	0.12	1.00	2.00

Table 4. Composition of artificial diets for mineral source study (%).

Ingredient	Basal	Instant Ocean	Bernhardt-Tomeralli
Yeast	13.3	12.0	12.0
Fish Meal	22.2	20.0	20.0
Alfalfa	11.1	10.0	10.0
Flour	52.8	47.5	47.5
Cholesterol	0.6	0.5	0.5
Mineral Mix	0.0	10.0	10.0

Table 5. Effect of salt mix source on growth of adult lobsters.

Salt Mix Source	Initial Weight (g)	Final Weight (g)	Δ Weight (g)
No salt mix	419 ± 16	424 ± 20	5
10% Modified Bernhardt-Tomeralli	400 ± 33	402 ± 34	2
10% Instant Ocean	418 ± 31	423 ± 30	5

Table 6. Composition of artificial diets for mineral supplementation study (%).

	Not Supplemented	Supplemented
Yeast	5.00	5.00
Fish Meal	15.00	15.00
Alfalfa	5.00	5.00
Flour	5.00	5.00
Cholesterol	0.50	0.50
Casein	19.70	19.70
CaH_2PO_4	0.00	50.25
Sand (Non nutritive)	50.25	0.00

Table 7. Growth of adult lobsters on diets with varying total mineral content.

Diet	Initial Weight (g)	Final Weight (g)	Δ Weight (g)
No Supplement	564.6 ± 71.3	590.1 ± 71.4	25.5
CaH_2PO_4 Supplement	548.6 ± 59.8	566.2 ± 63.4	17.6
Herring Control	545.1 ± 88.3	568.2 ± 96.7	23.1

Table 8. Composition of diets for pound feeding trial (%).

Ingredient	Instant Ocean	Least Cost #1*	Least Cost #2
Whole Egg	----	10.9	27.3
Soybean Meal	----	44.4	----
Alphacel	----	13.7	----
Cod Liver Oil	----	1.0	1.0
Cholesterol	0.5	0.4	0.4
Yeast	12.0	2.0	2.0
Fish Meal	20.0	----	25.5
Alfalfa	10.0	----	----
Flour	47.5	----	----
Instant Ocean	10.0	----	----
$NaHPO_4$	----	19.3	16.9
Limestone	----	7.8	4.4
Carboxy Methyl Cellulose (binder)	----	0.5	0.5

*Least cost formulation #1 was supplemented with herring during feeding trial.

Table 9. Growth of adult lobsters fed artificial diets during winter (November-February).

	Initial Weight (g)	Final Weight (g)	Δ Weight (g)
10% Instant Ocean Rations	549 ± 66	559 ± 67	10
Least Cost Diet #1	534 ± 91	529 ± 98	-5
Least Cost Diet #2	445 ± 85	447 ± 84	2
Herring	522 ± 57	528 ± 56	6

Table 10. Composition of diets for protein-energy ratio studies (%).

Ingredient	Diet A-1	Diet A-2	Diet A-3	Diet B-1	Diet B-2	Diet B-3
Yeast	10.0	10.0	5.0	5.0	5.0	5.0
Fish Meal	30.0	30.0	15.0	5.0	15.0	10.0
Alfalfa	10.0	5.0	5.0	1.5	5.0	5.0
Flour	49.5	10.0	5.0	5.0	5.0	30.0
Cholesterol	0.5	0.5	0.5	0.5	0.5	0.5
Sand	0.0	37.8	50.2	50.0	50.2	48.0
Casein	0.0	6.8	19.7	33.0	19.7	1.5
Protein-Energy Ratio (g protein/g/kcal/g)	0.07	0.11	0.13	0.15	0.13	0.07
Caloric Density (kcal/g)	4.48	2.96	2.52	2.67	2.52	2.34
% Protein	33.00	33.00	33.00	40.00	33.00	16.00

Table 11. Growth of adult lobsters on diets with varying protein-energy ratios and constant protein level (33%).

Protein-Energy	Initial Weight (g)	Final Weight (g)	Δ Weight (g)
0.07	423.9 ± 68.4	428.4 ± 65.1	4.5
0.11	417.4 ± 47.9	419.4 ± 47.3	2.0
0.13	408.2 ± 66.0	408.5 ± 65.6	0.3

Table 12. Growth of adult lobsters on diets with varying protein-energy ratios and constant caloric density (2.3-2.6).

Protein-Energy	Initial Weight (g)	Final Weight (g)	Δ Weight (g)
0.07	412.0 ± 60.0	414.9 ± 63.0	2.9
0.13	408.2 ± 66.0	408.5 ± 65.6	0.3
0.15	427.4 ± 51.8	428.1 ± 51.6	0.7

Table 13. Growth of juvenile lobsters on artificial diets with varying protein-energy ratios.

Protein-Energy Ratio	Initial Weight (mg)	Final Weight (mg)	Δ Weight (mg)	% Survival	# of Molts
.07	104 ± 6	190 ± 20	80 ± 15[a][1]	85[a]	14
.11	104 ± 10	150 ± 11	50 ± 5[b]	70[b]	12
.13	110 ± 4	150 ± 7	40 ± 5[b]	65[b]	10

[1]Data with different superscript indicate a significant difference at the $\alpha = 0.05$ level.

Table 14. Composition of diets for yeast source study.

Ingredients	% in Diet
Yeast	13.3[1]
Fish Meal	22.2
Alfalfa	11.1
Flour	52.8
Cholesterol	0.6

[1]Sources of yeast were brewer's yeast, Torutein, Coors and Blue Label.

Table 15. Effect of yeast source on growth of adult lobsters on artificial diets.

	Initial Weight (g)	Final Weight (g)	Δ Weight (g)
Brewer's	640.2 ± 138.9	654.9 ± 139.3	+ 14.8
Torutein	599.2 ± 112.9	603.5 ± 96.4	+ 4.3
Coors	616.9 ± 77.3	595.6 ± 109.7	- 21.3
Blue Label	562.2 ± 56.7	570.7 ± 56.1	+ 8.6
Herring Control	545.1 ± 88.3	556.9 ± 104.4	+ 11.8

Table 16. Nutrient content of yeast sources.

Yeast Sources	Δ Weight (g)	Protein (g)	Lysine (% protein)	Thiamine	Niacin	Riboflavin
				mg/100 g		
Brewer's	14.8	50	8.56	15.0	40.0	4.5
Torutein	4.3	52	6.40	15.0	43.2	4.1
Coors	-21.3	35	9.70	9.5	48.0	3.9
Blue Label	8.6	52	5.70	0.2	2.0	0.5

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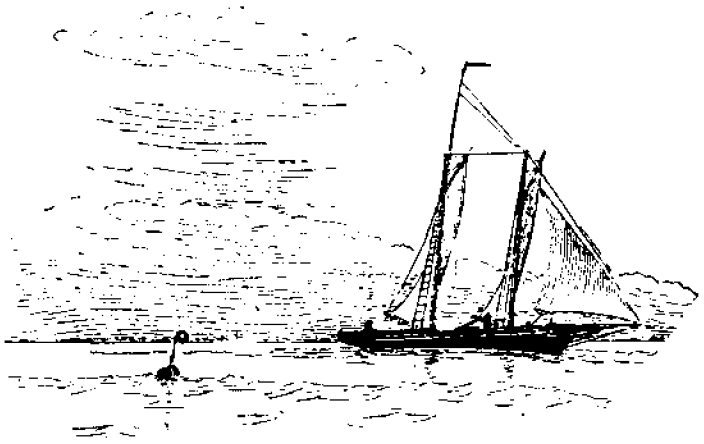

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