Use of Seafood Processing Wastes (Blue Crab and Herring Scrap) as Protein Substitutes in Rainbow Trout Diets

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Abstract: Laboratory and field growth trials were conducted to determine the feasibility of using blue crab (*Callinectes sapidus*) or Atlantic herring (*Clupea harenous*) cannery waste as dietary protein substitutes in pelleted rainbow trout (*Salmo gairdneri*) feeds. In lab and field experiments, triplicate groups of trout were fed 3 nutritionally complete diets: (1) a commercial diet (38.8% protein); or 1 of 2 experimental diets containing either (2) blue crab scrap (35.9% protein) or (3) herring byproducts (33.9% protein). Complete replacement of conventional fish meal as a protein source in rainbow trout diets with blue crab or herring waste significantly impaired growth performance factors in both laboratory and field trials. Trout fed the experimental diets consumed less feed, grew more slowly and less efficiently and, in field growth trials, suffered higher mortalities than those fed the commercial diet. This study suggests that blue crab byproducts are poor total substitutes for fish meal as a source of raw protein in rainbow trout diets. However, they may prove suitable as low-cost dietary protein supplements in salmonid feeds, particularly if excess chitin and calcium is removed and the sulfur amino acid content is fortified. Herring cannery wastes may be acceptable as protein supplements if crude protein levels are regulated.

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Disposal of crustacean wastes, including shell, viscera, and attached flesh, is a significant problem for seafood processors and a major constraint on the industry. For example, commercial landings of blue crab (*Callinectes sapidus*) in the Chesapeake Bay yielded >95 million pounds in 1982 (Natl. Oceanic and Atmos. Adm. 1983). Approximately 86% of this poundage is considered waste and represents a large, expensive disposal problem (Meyers and Rutledge 1971). At present, processors primarily rely on costly landfill disposal. This economic liability of processors in the Chesapeake and other regions is further exacerbated by large commercial landings of finfish which also generate substantial volumes of waste. Moreover, problems with seafood waste disposal will continue to intensify as the number of landfill sites diminish, transportation and handling costs escalate, associated air and water pollution problems increase, and government regulations concerning seafood waste treatment become more restrictive.

One potential solution that may partially resolve the seafood waste disposal problem and concurrently benefit fish farmers is the use of seafood scrap as a diet ingredient in manufactured fish feeds. Aquaculturists are continually plagued with the problem of finding a reliable, affordable source of raw protein for prepared fish feed (Crawford et al. 1974). Cultured fish have a high dietary protein requirement and protein is the most expensive constituent in fish feed (Halver 1972). Seafood wastes, from readily available but underutilized species such as crustaceans, may serve as an alternative or supplemental source of protein in fish feed.

Most studies on recycling crustacean wastes as aquacultural feed ingredients have emphasized using particular crab and shrimp species as a carotenoid source to enhance the pigmentation and market value of cultured fish flesh (Bouthillier 1961, Saito and Regier 1970, Spinelli et al. 1974, Choubert and Luquet 1983). In contrast, consideration of crustacean wastes as an alternative source of animal protein in fish feeds has received little attention. The purpose of this study was to evaluate the feasibility of using seafood waste as a dietary protein substitute in pelleted rainbow trout (*Salmo gairdneri*) feeds. In this study, growth response, feed conversion efficiency, and survival of rainbow trout fed a commercial diet were compared with those fed 1 of 2 experimental diets containing either blue crab scrap or Atlantic herring (*Clupea harengus*) cannery residue.

Methods

This study consisted of 2 experiments, a laboratory study with small fish (mean initial weight, 16.2 g) and a field study with larger fish (44.3 g). Methods and materials described here apply to both experiments unless otherwise indicated.

Diets and Nutrition

Dried seafood waste for the 2 experimental diets were provided by seafood processors in Hampton, Virginia. Nutritionally complete experimental diets were manufactured by the Department of Grain Science and Industry, Kansas State University, Manhattan, Kansas, using either blue crab or herring waste at 25% and 15% of the diet, respectively, in combination with commercial ingredients.

The commercial diet was prepared by the Ralston Purina Company, St. Louis, Missouri. Physical-chemical properties of the 3 diets were alike in all aspects except protein quality and quantity. All feeds were in the form of extruded (floating) pellets of equivalent size, color, texture, and water stability. Feeds were processed in a similar fashion and stored under identical conditions for comparable periods of time.

All diets were nutritionally complete, satisfying the known requirements for rainbow trout (National Research Council 1981). Proximate analysis indicated that protein, energy, fat, fiber, and ash content did not vary considerably among diets (Table 1). Amino acid analysis indicated that the protein quality of all diets was similar and adequately balanced for rainbow trout (Table 2).

Experimental Conditions

Trout used in the laboratory growth trial were provided by the Wytheville National Fish Hatchery, Wytheville, Virginia. Laboratory trials were con-

Table 1. Formulation and proximate analysis (% weight composition) of the commercial and 2 experimental diets.

Item	Commercial[b]	Herring scrap	Crab scrap
Formulation			
Blue crab meal		0	25
Herring meal		15	0
Soybean meal		30	30
Wheat flour		25	25
Corn		19	9
Feather meal		5	5
Corn oil		3	3
Limestone		1	1
Phosphate		1	1
Salt		0.5	0.5
Vitamin mix		0.5	0.5
Proximate analysis			
Protein	38.8	33.9	35.9[b]
Fat	2.7	3.7	3.6
Fiber	5.4	6.0	8.0
Ash	12.7	7.5	13.6
Energy (kcal/g)	4.3	4.6	4.3

[a] Purina Trout Chow, Ralston Purina Co., St. Louis, Mo.
[b] Corrected for chitin.

Table 2. Essential amino acid composition of the commercial, herring scrap, and crab scrap diets as percent of protein.

Amino acid[a]	Commercial	Herring scrap	Crab scrap
Arginine	6.01	7.18	5.83
Histidine	2.28	1.90	2.29
Isoluecine	5.85	2.66	4.16
Leucine	10.59	9.69	8.31
Lysine	6.09	5.45	6.16
Methionine[b]	3.07	2.00	1.95
Phenylalanine	5.35	1.26	5.07
Threonine	4.03	4.05	4.06
Valine	5.39	6.49	5.83

[a] Triptophan was destroyed upon hydrolysis.
[b] Sulfur amino acids were determined by performic acid oxidation prior to hydrolysis.

ducted in Cheatham Hall on the campus of Virginia Tech. Trout were stocked at random into 9 20-liter plastic tanks at 10 fish/tank. Each tank received flowing (2 liters/minute), aerated, 12° to 16 C, dechlorinated, municipal water. Dissolved oxygen, total alkalinity, hardness, and pH values averaged 10.2, 45, 40 mg/1, and 6.8, respectively. Overhead fluorescent lamps provided an average light intensity of 200 lux at the water surface; photoperiod was maintained on an 8-hour light, 16-hour dark cycle.

Each of the 3 diets was allocated at random to 3 groups of trout (3 x 10 fish/diet). Fish were acclimated to the experimental conditions for 14 days prior to the study. During this time, fish assigned the experimental diets were fed a mixture containing 50% commercial feed and 50% their designated experimental diet. During acclimation, fish were fed twice daily (0900 and 1900 hours) at 2% live body weight. Thereafter, fish were fed their assigned diet for 70 days on the same schedule at 3% body weight, adjusted every 2 weeks.

Field experiments were conducted from November 1981 to May 1982 in a 0.6-ha pond located at the Reynold's Homestead Agricultural Experiment Station, Patrick County, Virginia. Trout used in the field trial were obtained from a commercial hatchery in Rural Retreat, Virginia. Fish were distributed randomly among 9 cages (1 m^2 each) at a density of 100 fish/cage. The cages, constructed of wood frames enclosed with Vexar plastic screening (12-mm mesh), were suspended at the pond surface by styrofoam floats and moored to a floating dock. A spacing of 2 m was maintained between the cages; water depth below the cages averaged 1 m.

Each of the 3 diets was randomly assigned to 3 cages (3 x 100 fish/diet). Fish were maintained on a natural photoperiod and acclimated to environmental conditions for 14 days prior to the experiment. During the acclimation period all fish were fed the commercial diet once daily (1000 hours) at 2% body weight. Thereafter, fish were fed their assigned diets once daily for 176

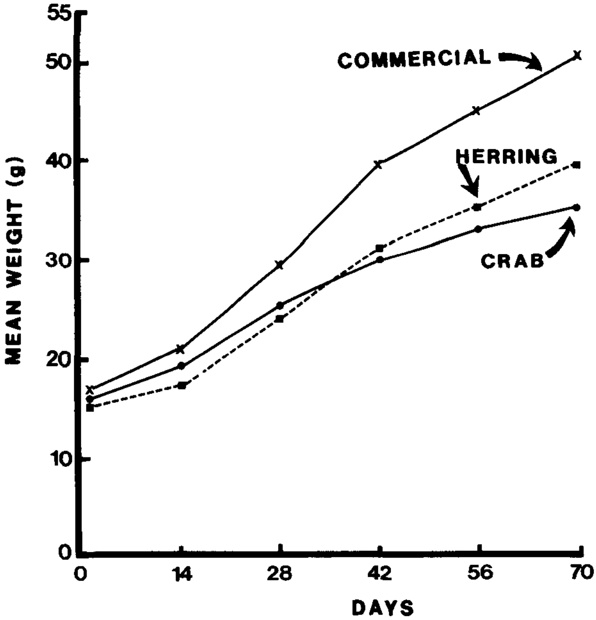

Figure 1. Growth of rainbow trout fed either a commercial diet or 1 of 2 experimental diets containing blue crab or herring scrap in laboratory growth trials.

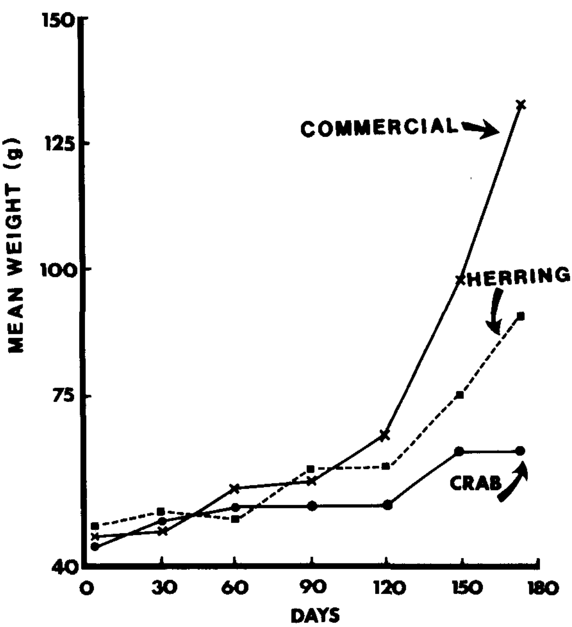

Figure 2. Growth of rainbow trout fed either a commercial diet or 1 of 2 experimental diets containing blue crab or herring scrap in field growth trials.

days at 0.5% to 3% body weight, depending on water temperatures and feeding activity. Dead fish were removed promptly without replacement. Subsamples (10 fish/cage) were weighed every 14 days for growth analysis and to recalculate feeding rates. Water temperatures, recorded daily from maximum-minimum thermometers suspended 0.4 m below the surface, ranged from 3.3° to 17.2° C, averaging 9.4° C throughout the 176-day study. Treatment effects were subjected to analysis of variance and means were compared using the *F*-test (Sokal and Rohlf 1969).

Results and Discussion

Growth

Growth response patterns of rainbow trout to the 3 diet types were similar in both laboratory and field experiments (Figs. 1, 2). However, weight gain of trout which were fed the commercial diet under laboratory conditions was consistently higher than for fish fed either experimental diet. During the first 28 days of the laboratory study, growth rates of trout on all diets were nearly equivalent (Fig. 1). Thereafter, the decline in growth for fish fed the herring and crab scrap diets reflected a depression in appetite or impalatability of these diets evidenced by the quantity of unconsumed feed remaining in the tanks, and, to a lesser extent, a reduction in feed conversion efficiency. Reduced growth exhibited by fish on all diets during the last 4 weeks of the study was probably the result of the relatively cool water temperatures (averaging 13° C) caused by a faulty refrigeration unit thermostat. Daily weight gain for fish fed the commercial, herring scrap, and crab scrap diets was 0.48, 0.35, and 0.27 g, respectively. At harvest (70 days), individual weight gain of trout fed the commercial diet was significantly greater ($P < 0.05$) than for fish fed either the herring scrap or crab scrap diets (Table 3).

Growth of cage-cultured trout fed the commercial diet was consistently better than that of fish fed either the herring or crab scrap diets (Fig. 2). The uniformly slow growth evident for cage-cultured trout during the first half of the growing season presumably was the result of poor acclimation of the fish to caged conditions, feeding schedules and rates, and below optimum water temperatures. Growth and feeding activity, regardless of the diet type, was closely related to water temperature. During mid-winter (days 60–90), water temperatures averaged 4.4° C. Pond surface waters were frequently frozen requiring ice removal; growth and feeding rates were correspondingly diminished. Maximum growth occurred in the spring (days 120–176) at a mean water temperature of 15° C. Although trout were reared under identical thermal regimes, daily weight gain of trout receiving the commercial diet was nearly twice that of fish fed the herring scrap diet and almost 5 times greater than that of fish fed the crab scrap diet. At harvest (176 days), weight gain of cage-cultured trout fed the commercial diet was significantly higher ($P < 0.01$) than trout fed either of the experimental diets (Table 3).

Table 3. Performance factors of rainbow trout fed a commercial diet or 1 of 2 experimental diets (blue crab scrap or herring scrap) for 70 days in laboratory tanks ($N = 30$ fish/treatment) and for 176 days in floating cages in the field trial ($N = 300$ fish/treatment).[1]

Item	Crab scrap	Herring scrap	Commercial diet
Laboratory trial			
Initial weight (g)	16.2	15.3	17.1
Weight gain (g)	18.8	24.8	33.8
Mortality (%)	6.7	3.3	3.3
Feed conversion (feed/gain)	2.79	2.35	1.84
Field trial			
Initial weight (g)	43.1	45.6	44.3
Weight gain (g)	18.0	46.4	88.5
Mortality (%)	22.3	31.7	8.7
Feed conversion (feed/gain)	8.30	4.32	3.11

[1] Each value is the mean of 3 replicates. Within rows, underlined values are not significantly different ($P > 0.05$).

Feed Conversion

Feed conversion efficiency (feed fed/weight gain) in both laboratory and field trials was consistently better for trout reared on the commercial diet than for those fed either of the experimental diets (Table 3). In the laboratory, trout fed the commercial diet consumed about 20% more feed and gained about 45% more weight than those fed the crab scrap diet. In the field study, mean feed conversion rates of trout differed significantly ($P < 0.01$) among all 3 diet types. Trout fed the commercial diet consumed about twice as much food and gained nearly twice as much weight as those fed the herring scrap diet. Those on the herring scrap diet consumed almost twice as much food and gained about 3 times more weight than those fed the crab scrap diet. Feed consumption and conversion and weight gain generally were reduced during periods when water temperatures were below 9° C. The more efficient feed conversion rates of trout sustained on all diets in the laboratory likely reflected a more constant and optimal thermal regime, increased feeding frequencies, and the smaller size of the fish. Large fish generally use a greater percentage of their feed ration for maintenance, growing more slowly than smaller-sized ones.

Survival

In the laboratory trials, survival of trout maintained on all diets was high, averaging 97% for those fed the commercial and herring scrap diets and 93% for those fed the crab scrap diet. The incidental mortality experienced was attributed mainly to handling stress or failure of the fish to recover from the anesthesia (tricaine methanesulfonate, MS-222). No disease problems or body abnormalities were observed.

In contrast, survival of trout in the field study was strongly influenced by diet type. Survival of trout fed the commercial diet was significantly higher ($P < 0.05$) than those fed the experimental diets. No significant differences in survival were observed between fish fed the 2 experimental diets. Most losses occurred during the last 2 weeks of the study and were the result of a bacterial infection (*Columnaris* sp.); a few fish escaped during sampling or died of unknown causes. During this period, all fish were offered feed treated with oxytetracycline dissolved in vegetable oil and sprayed over the feed at a concentration of 1.5 g active ingredient/kg of feed. This treatment was moderately successful in reducing mortality, but after 2 weeks, additional losses continued and the experiment was terminated.

Diets and Nutrition

The preceding observations suggest that substitution of blue crab or herring meal for fish meal as a protein source in rainbow trout diets significantly impaired growth, feed conversion efficiency, and survival. The adverse influence of blue crab and herring scrap in trout feed may be related to a number of nutritional factors, particularly reduced protein quantity and quality, and increased mineral content. Meyers and Rutledge (1971) emphasized that a major problem in the use of crustacean meals in animal rations is the high proportion of exoskeletal materials (chitin and calcium), resulting in a protein level frequently less than 25%.

A substantial amount of data are available on the nutritional requirements of trout and salmon (Natl. Res. Council 1981). When reared in intensive culture systems, these species require a nutritionally-complete balanced ration of protein (essential amino acids), fats, carbohydrates, vitamins, and minerals. The gross protein requirement for fingerling (6–8 weeks) salmonids is about 40% of the diet, and this value is reduced to about 35% of the diet for older fish (Delong et al. 1959). The estimated crude protein requirement for maximum growth of rainbow trout is about 40% of the diet (Satia 1974, Zeitoun et al. 1976). However, rainbow trout fed practical diets at protein levels of 35%, 40%, and 45% over a wide range of thermal regimes showed no differences in growth (Cho and Slinger 1978).

Although crude protein levels of all 3 diets used in this study were similar and considered sufficient to satisfy the protein requirements of rainbow trout, the commercial feed contained about 8% more protein than the blue crab diet and about 14% more protein than the herring scrap diet. It is conceivable that these lower amounts of gross protein resulted in the poor performance of fish maintained on the experimental diets. However, factors other than gross protein levels may be responsible for the poor performance. This is suggested by the fact that trout on the diet containing the least amount of total protein (herring scrap) had a higher weight gain and better food conversion efficiency than did trout fed a diet containing a higher protein level (crab scrap).

Altered protein quality is another possible explanation for the inferior growth performance of trout fed the experimental diets. Protein quality in salmonid diets must be regulated by adjusting the proportions of various protein sources to supply adequate amounts of indispensable amino acids. The essential amino acid requirements of rainbow trout are not all known. The estimated amino acid requirements of coldwater fish reported by the National Research Council (1981) are based on studies with chinook salmon, *Oncorhynchus tshawytscha* (Halver et al. 1959). According to these values, all diets in this study satisfied the conventional requirements established for salmonids, with the possible exception of the sulfur amino acid content. The crab scrap diet in this study may have been marginally deficient in total sulfur amino acids, these averaged 2.5% (1.9% methionine) of the protein in a 36% protein diet. This level is below the requirement determined by Halver et al. (1959) for chinook salmon (3.8%–4.0% total), but is close to the minimum requirement recently established by Rumsey et al. (1983) for rainbow trout (2.5%–3.0% total, 1.6% methionine) in a 35% protein diet. Estimation of the sulfur amino acids present in a diet is difficult because they are subject to oxidation during processing, but fish may be able to reduce and, thereby, recover some of the oxidized methionine (Cowey 1979).

The observed differences in growth performance factors between trout fed the commercial and experimental diets also may be related to the high concentration of minerals, particularly calcium, that normally occur in crustacean meals. High levels of calcium in poultry and swine rations produced from crustacean meals can result in nutritional deficiencies (Meyers and Rutledge 1971). Information concerning the dietary mineral requirements of salmonids is limited. Minimum dietary calcium and phosphorus requirements for rainbow trout have been determined (Natl. Res. Council 1981), but maximum tolerance levels have not been established. Ketola (1979) speculated that depressed growth and eye cataracts observed in rainbow trout fed whitefish meal, a waste byproduct meal made from marine finfish scraps, were the result of excess calcium or other minerals that inhibited the absorption or utilization of zinc. Although it is possible that the poor growth of trout fed the crab scrap diet in this study may be the result of a dietary mineral imbalance, the total mineral content of this diet (13.6%) was much lower than that reported for other blue crab meals (Lubitz et al. 1943, Kifer and Bauersfeld 1969) and only slightly higher than that of the commercial diet (12.7%).

Other Factors

In addition to the nutritional characteristics of the feeds, growth performance of fish in intensive culture systems can be influenced by a number of factors including stocking densities and cage size (Kilambi et al. 1977, Tatum 1973, Trzebiatowski et al. 1981); cage location, mesh size, and water exchange rates (Whitaker and Martin 1974); feeding frequencies and periodicity (Lovell et al. 1968); genetic strain and age of the fish (Reinitz et al. 1979, Reinitz 1983); and the physical properties of the feed (Bromley and Smart 1981, Hilton et al. 1981). However, it is unlikely that any of these factors differentially influenced growth because all trout were reared under the same environmental conditions in identical cages or tanks, stocked at the same densities, and fed on a similar schedule. All trout were from the same genetic strain and were initially similar in size and vigor. All feeds were in the form of extruded pellets of similar age, size, texture, color, and water stability. These potentially confounding variables were minimized and their effects were considered negligible.

Conclusions

The results of this study demonstrated that complete substitution of blue crab or herring cannery waste for conventional fish meal as a protein source in practical trout diets significantly impaired growth performance factors in both laboratory and field experiments. In general, trout receiving the experimental diets consumed less feed and grew more slowly. In field growth trials, trout exhibited increased susceptibility to disease and higher mortality than those fed a standard commercial diet. These differences may be attributed to the comparatively low crude protein and sulfur amino acid levels and the high mineral content of the crab scrap diet. Subtle dissimilarities in odor, flavor, and palatability between the feeds also may have contributed to the observed disparity in growth performance. Regardless of the causative factors, results suggest that blue crab and herring byproducts are poor substitutes for whole finfish as a complete source of raw protein in trout feed formulations. Crustacean byproducts have high nutritional value and may be suitable as a low-cost dietary protein supplement in salmonid feeds if excess chitin and calcium is removed and the sulfur amino acid content is fortified.

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