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Evaluation of Practical Bluegill Diets with Varying Protein and Energy Levels

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Abstract.—Because bluegills *Lepomis macrochirus* are considered important both as a source of forage for largemouth bass *Micropterus salmoides* and as a sport fish, there is strong demand for juveniles and subadults for stocking purposes. Although spawning and extensive culture techniques are well established, there is a need to intensify culture systems to make juvenile production more cost effective. To move toward a more intensive culture system, we must establish basic parameters for the selection of commercial feeds. An 11-week feeding trial was conducted with juvenile bluegills (1.76 g) to evaluate the effect of dietary protein and lipid level on growth, feed efficiency, and survival. Six practical diets were formulated, with varying levels of protein (32–44%) and lipid (6–12%). Final weight (9.4–12.1 g), feed intake (12.6–14.4 g), and feed efficiency values (60.6–72.1%) increased with increasing levels of dietary protein. Increasing the lipid content by 4% in the 32%-protein diet (to 10% lipid) or the 44%-protein diet (to 12% lipid) had little influence on the performance of the fish. Although the fish grew well on all diets tested, they grew best when offered a diet containing 44% protein and 8% lipid.

Recreational fishing in small impoundments is a popular sport in the United States. Unlike large bodies of water, small impoundments have to be stocked with fish, and unlike in aquaculture, managers do not want to intensively feed these fish. A solution to the problem is to stock predator and prey fish simultaneously. A popular predator–prey combination is largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus*. In this way, bluegills provide an excellent forage for the bass (Ali and Bayne 1987) as well as an important recreational fish for anglers. The popularity of bluegills for these purposes has resulted in a demand for cultured fish for stocking.

To be successful in culturing a given species, one must consider both the biology of the fish and the economics of the operation. Since diet will influence the biological and economic returns to a commercial operation, an appropriate feed should be developed. Such a feed must be cost effective and efficiently digestible and provide the nutrients required for acceptable growth and health (Lazo et al. 1998). Because protein is one of the more costly components of diets, optimization of dietary protein and enhancement of protein retention by fish directly influences production costs. Due to limited information on the nutritional requirements of bluegills, an experiment was designed to determine favorable protein and energy levels in a practical diet formulation during the initial stages of culture.

Methods

Six practical diets (Table 1) were formulated to contain varying concentrations of protein and energy levels. Four of the diets contained 32, 36, 40, or 44% protein, with energy : protein ratios ranging from 8 to 10 kcal/g. The two remaining diets contained 32% or 44% protein, with additional energy from lipid. The diets were prepared by mixing the dry ingredients with oil in a food mixer (Hobart, Troy, Ohio) for 15 min. Hot water was added to the mash to achieve the consistency necessary to form a pelleted feed. Each formulation was passed through a 3-mm die in a meat grinder, and the resulting pellets were dried to a moisture content of less than 10%. Protein content was confirmed by micro-Kjeldahl analysis (Ma and Zuazago 1942). Diets were stored under refrigerated conditions and were milled and sieved to the desired size prior to use.

Juvenile bluegills were obtained from stocks held at the North Auburn Lower Fisheries Station facilities and hand-graded to produce a population of uniform size. The fish were stocked into a semiclosed recirculation system consisting of a series of 60-L culture tanks with a sand filter, biological filter, circulation pump, and subsurface aeration.

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TABLE 1.—Composition (g/100 g dry weight) of the test diets. In diet codes (e.g., D32/10), the first value represents the percent protein content, the second value the percent lipid content.

Ingredient	D32/10	D32/6	D36/6.5	D40/7	D44/8	D44/12
Menhaden fish meal[a]	10.00	10.00	11.25	12.50	13.75	13.75
Poultry by-product meal[b]	7.27	7.27	8.18	9.09	10.00	10.00
Soybean meal[c]	25.40	25.40	30.40	36.20	43.10	43.10
Cottonseed meal[d]	8.73	8.73	9.82	10.91	12.00	12.00
Menhaden fish oil[e]	5.94	1.94	2.24	2.74	3.97	7.97
Whole wheat[f]	9.00	9.00	9.00	9.00	9.00	9.00
Yellow corn[d]	28.90	28.87	24.77	15.62	0.49	0.49
Trace mineral premix[g]	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix[h]	3.00	3.00	3.00	3.00	3.00	3.00
Vitamin C[i]	0.04	0.04	0.04	0.04	0.04	0.04
Feed-grade monobasic calcium phosphate[j]	1.22	1.25	0.80	0.40	0.15	0.15
Alphacel[f]		4.00			4.00	

[a] Special Select, Omega Protein, Inc., Hammond, Louisiana.
[b] Flashed dried poultry by-product meal, Griffin Industries, Inc., Cold Spring, Kentucky.
[c] Dehulled, solvent-extracted soybean meal.
[d] Southern State Cooperative, Virginia.
[e] Omega Protein, Inc., Reedville, Virginia.
[f] ICN Biochemicals, Cleveland, Ohio.
[g] Composition (g/100 g premix) is as follows: cobalt chloride, 0.004; cupric sulfate pentahydrate, 0.250; ferrous sulfate, 4.0; magnesium sulfate heptahydrate, 28.398; manganous sulfate monohydrate, 0.650; potassium iodide, 0.067; sodium selenite, 0.010; zinc sulfate heptahydrate, 13.193; and filler, 53.428.
[h] Composition (g/kg premix) is as follows: thiamin HCl, 0.5; riboflavin, 3; pyroxidine HCl, 1.0; DL Ca-pantothenate, 5.0; nicotinic acid, 5.0; biotin, 0.05; folic acid, 0.18; vitamin B_{12}, 0.002; choline chloride, 100; inositol, 5.0; menadione, 2.0; vitamin A acetate (20,000 IU/g), 5.0; vitamin D, (400,000 IU/g), 0.002; dL-alpha-tocopherol acetate (250 IU/g), 8.0; and alpha-cellulose, 856.266.
[i] 150 mg active C/kg diet; Source: Stay C, (35% active, L-ascorbyl-2-polyphosphate, Hoffman-LaRoche, Inc., Nutley, New Jersey.)
[j] Cefkaphos, BASF Corporation, Mount Olive, New Jersey.

Twenty fish (1.76 ± 0.05 g [mean ± SD]) were stocked into each tank and randomly assigned one of the treatment diets. Four replicates per treatment were utilized. Twelve fish were randomly collected from the population remaining after stocking and frozen at −60°C for subsequent proximate analysis. Each diet was offered twice daily to the stocked fish over the 11-week feeding trial. The initial feeding rate of 5 g of feed per 100 g of fish per day was gradually reduced to 2.5 g of feed per 100 g of fish per day as the experiment progressed. Feeding rates were adjusted at the end of each week based on growth, feeding efficiency values, and general feeding observations. The photoperiod was maintained at 12 h light : 12 h dark using fluorescent lighting. Fish were counted and weighed every 2 weeks, and the tanks were cleaned as needed. System maintenance consisted of water exchange, siphoning of debris, and scrubbing of the culture tanks. Total ammonia nitrogen and nitrite-nitrogen were measured intermittently and remained below 0.05 mg/L. Temperature was measured daily and maintained at 29.5 ± 0.76°C, and dissolved oxygen was maintained near the saturation point.

At the conclusion of the experiment, the following variables were evaluated: initial weight, final weight, weight gain, total feed offered (g dry feed), feed efficiency (FE, defined as [weight gain · 100]/feed offered), protein conversion efficiency (PCE, defined as [protein gain · 100]/protein offered), and specific growth rate (SGR, defined as [$\log_e${final weight}—$\log_e${initial weight}]·100/d). Statistical analyses were performed using the Statistical Analysis System (SAS Institute 1988). Data were analyzed using one-way analyses of variance to determine significant ($P \leq 0.05$) differences among treatment means. The Student-Newman-Keuls multiple comparison test was used to determine significant differences among treatment means (Steel and Torrie 1980).

Results

No problems related to water quality or disease were encountered during the experiment. As indicated by their high survival (>98%), the fish were able to tolerate repeated handling and weighing. The performance of the fish under laboratory conditions is summarized in Table 2. Fish maintained on a diet containing 44% protein and 8% lipid (designated as D44/8; other diets designated analogously) exhibited significantly higher final weight (12.99 versus 9.36–10.70 g) and weight gain (643.9% versus 429.7–507.3%) than fish

TABLE 2. Responses of bluegills stocked at a mean weight of 1.76 g to test diets for 11 weeks. Values shown are the means of four replicates. Within columns numbers with different letters are significantly different ($P < 0.05$).

Diet	Final weight (g)	Total feed offered (g/fish)	FE[a]	PCE[b]	Whole-body analyses (%)[c] Dry matter	Protein	Lipid
D32/10	9.40 x	12.6 y	60.6 x	23.3 z	31.0 z	48.2 z	22.5 z
D32/6	9.36 x	12.5 y	60.8 x	24.0 z	28.9 y	52.5 z	21.4 z
D36/6.5	10.47 yx	13.1 zy	66.2 yx	26.4 z	28.6 y	52.4 z	21.9 z
D40/7	10.70 yx	13.4 zy	66.7 yx	28.5 z	28.3 y	53.8 z	26.0 z
D44/8	12.99 z	14.4 z	77.9 z	31.2 z	28.0 y	52.3 z	23.6 z
D44/12	12.06 zy	14.2 z	72.1 zy	27.1 z	28.9 y	50.1 z	22.6 z
Pool standard error[d]	0.490	0.375	2.08	1.92	0.190	0.636	1.24

[a] Feed efficiency, defined as weight gain · 100/feed offered.
[b] Protein conversion efficiency, defined as dry protein gain · 100/dry protein offered.
[c] Dry matter is expressed on an as-is basis, protein and lipid on a dry-weight basis.
[d] $\sqrt{\text{Mean square error}/n}$; $n = 4$.

maintained on diets containing lower levels of protein. Fish given D44/8 also had significantly higher feed efficiency (77.9%) than those on diets with lower levels of protein (60.6–66.7%). Total feed offered was significantly higher for fish maintained on D44/8 (14.4 g) and D44/12 (14.2 g) than for those on D32/10 (12.6 g) and D32/6 (12.5 g), with the remaining diets being intermediate. No significant differences or notable trends in the protein conversion efficiency values among fish given the various diets were found. Proximate analyses for dry matter, protein, and lipid in whole-body samples were similar among all but one of the treatments. The single exception was the proportion of dry matter in fish maintained on D32/10, which was higher than that in fish from all other treatments.

Discussion

There is a growing demand for both juvenile and subadult bluegills for stocking as prey and for recreational fishing. Yet there is limited information as to the type of practical diets that should be used in intensive production systems. This research provides information on the response of bluegill juveniles to practical diets containing varying levels of protein (32–44%) and lipids (6–12%).

Protein represents one of the major costs in practical diet formulations. Consequently, to minimize feed-related costs, the protein level of the feed and protein retention by the fish should be optimized. In the current study, bluegills demonstrated significant decreases in weight gain and FE values as the protein content was reduced from 44% to 32% of the diet. Similar results were obtained for hybrid bluegills (female green sunfish *L. cyanellus* × male bluegills) by Tidwell et al. (1992) and Webster et al. (1997) and for Nile tilapia *Tilapia nilotica* by Hafedh (1999). No significant difference in weight gain or FE and PCE values were found among fish offered the 44% protein diets with either 8% or 12% lipid, suggesting that energy was not limiting growth or protein retention. Similarly, in the low-protein diet, an increase in the proportion of lipid did not result in an increase in PCE, suggesting that 6% lipid was sufficient in a 32%-protein diet.

The SGRs that we obtained for bluegills ranged from 1.97 to 2.26 and were similar to those found in other aquaculture species. Webster et al. (1991) report an SGR of approximately 2.0 for channel catfish *Ictalurus punctatus*, and Clark et al. (1990) report a value of 3.1 for red tilapia (Mozambique tilapia *T. mossambica* × Wami tilapia *T. urolepis*). The SGR also appeared comparable to those seen in hybrid bluegills maintained in aquaria (1.98: Tidwell et al. 1992; 1.58–1.85: Webster et al. 1997) but not in ponds (2.6; Webster et al. 1992).

The bluegills used in the present study exhibited their highest growth when fed a diet containing 44% protein and 8% lipid. These results are similar to those reported by Tidwell et al. (1992) for hybrid bluegills. These authors state that the use of higher-protein feeds (35% or more) rather than the 32%-protein catfish feed that is often fed to hybrid bluegills may improve growth and production potential.

Bluegills reared in ponds are commonly maintained on low-protein diets. Such diets are affordable and promote reasonable fish growth when fish density is low. However, the use of low-protein diets has several complications. Such diets generally contain high levels of carbohydrates, which are often poorly utilized by fish (Wilson 1994) and add to the quantity of undigested material entering the culture system. Low-protein diets quite often have a high energy–protein ratio that may lead to less feed intake, resulting in reduced nutrient uptake and growth.

The proximate compositions of the bluegills maintained for 11 weeks on the various diets were similar to those reported for hybrid bluegills by Tidwell et al. (1992) and Webster et al. (1997). Whole-body composition analysis indicated that the levels of protein and lipid in the diets did not affect the final body content of these nutrients in the fish. By contrast, Webster et al. (1992) found that diet affected the fat content of hybrid bluegills but not the protein content, while Tidwell et al. (1992) and Webster et al. (1997) reported that both the lipid and protein contents of hybrid bluegills varied with diet. These variable results are probably due to different experimental conditions, such as the size and age of fish, stocking density, dietary protein quality, and abiotic factors such as water temperature (Jauncey and Ross 1982).

The proximate composition of the bluegills did not shift in the present study, indicating that the energy contents of the diets were reasonable and did not result in increased lipid deposition. There was no protein-sparing effect when dietary lipid levels were increased from 6% (in a 32%-protein diet) or 8% (in a 44%-protein diet), which further indicates that nonprotein energy was not limiting protein deposition.

Since the growth, FE, and PCE of bluegills were enhanced by an increase in the proportion of protein in the feed without a concurrent increase in lipid, we recommend that a high-protein (44%), moderate-lipid (8%) diet be utilized in the intensive culture of juvenile bluegills. However, due to factors related to market demand, desired stocking size, production targets and economics, rapid growth may not be the primary objective of the farmer. In such cases, feeds with reduced protein levels may be suitable.

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