GROWTH RESPONSE OF CAGE-CULTURED CHANNEL CATFISH FED TWO COMMERCIAL DIETS

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Abstract: Six cages (1 m^3 each) suspended in a Virginia pond were each stocked with 100 channel catfish (*Ictalurus punctatus*) fingerlings (127 mm TL, average) to evaluate 2 commercial fish feeds, each replicated 3 times. Both commercial diets were nutritionally complete and expanded 4-mm diameter pellets of comparable texture, color, and water stability. The daily feeding rate was 3% of biomass during the 124-day feeding period. Growth, net production, and feed utilization efficiencies with commercial trout feed were significantly greater than with commercial catfish cage feed. Survival was not influenced by diet type. The observed differences in catfish growth, production, and feed utilization efficiencies were primarily attributed to the higher levels of methionine, lysine, and metabolizable energy in the commercial trout feed.

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Cage culture of channel catfish represents a relatively new and simple method of catfish farming that is becoming increasingly popular in the southeastern United States. Cage culture of catfish, as the name implies, is a method of rearing catfish from fingerlings to a marketable (edible) size in floating enclosures suspended in aquatic environments. The major advantages of cage culture over the conventional form of open pond culture include: (1) rapid, easy, and complete harvest; (2) convenient manipulation of the harvest to meet market demands; (3) direct observation of feeding activity and health of fish; (4) economical treatment of fish diseases and parasites; (5) efficient use of under-exploited aquatic environments; and (6) increased potential for both single and multi-species culture (Schmittou 1969). Cage culture may also eliminate the need for expensive harvesting equipment and reduce problems with natural predators, undesirable fish species, and off-flavors.

In the past, cage culture of channel catfish was constrained by the lack of commercially available, nutritionally complete catfish feeds. Lovell (1972) noted that most of the early guidelines for formulating practical catfish feeds were developed for open pond culture where natural foods supplement the diet. He suggested that such feeds, particularly their protein composition, may be inadequate for use in many types of intensive culture systems such as cages, pens, raceways, or tanks which reduce or eliminate the availability of natural foods. Since catfish confined in cages cannot forage freely, they are almost entirely dependent on artificial feed to satisfy their nutritional requirements. At present, prepared fish feeds containing all of the dietary essentials are widely available for use in intensive fish culture systems.

Two basic types of nutritionally complete artificial diets, one formulated for rearing catfish in cages and the other developed for rearing trout in raceways, are commonly used to rear channel catfish from fingerlings to a marketable size in cages. A number of researchers (Douglass and Lackey 1973, Holmes et al. 1974, Kilambi et al. 1977, Pennington and Strawn 1977) have demonstrated the feasibility of rearing channel catfish in cages on artificial catfish feed (Purina catfish chow). Artificial trout feed (Purina trout chow) has also been used successfully in channel catfish cage culture studies (Schmittou 1969, Collins 1970, Douglass and Lackey 1974, Hill 1974). Variations in environmental conditions, stocking densities, cage sizes, feeding rates and frequencies, and genetic characteristics of the fish stocks preclude a valid comparative analysis of these 2 types of prepared diets. However, results of these studies and a limited evaluation by Hurst (1973) suggest that production of cage-cultured channel catfish may be greater on prepared diets of trout feed than on catfish feed, particularly in geographic areas with relatively short growing seasons. The purpose of this study was to evaluate the effects of 2 nutritionally complete artificial diets on growth, production, feed utilization efficiencies and survival of channel catfish reared in cages under identical environmental conditions.

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METHODS

The experiments were conducted in an earthen pond (0.2 ha surface area, 3 m mean depth) located in the Piedmont province of Virginia at the Reynolds Homestead Agricultural Station, Patrick County. Mill Creek, a 1st-order forest stream, provided the only source of water for the pond. Six cages (each 91 × 121 × 91 cm deep or 1 m^3), constructed of pine frames enclosed with vexar plastic screening (12-mm mesh), were suspended at the pond surface by styrofoam floats (0.4 m^3/cage). The cages were randomly positioned and anchored in open water to promote water circulation. A spacing of at least 2 m was maintained between cages; water depth beneath the cages averaged 1 m.

Channel catfish fingerlings (127 mm TL, average) were obtained from a commercial hatchery in Kernersville, North Carolina. One hundred catfish fingerlings per cage were stocked on 1 June 1980. Subsamples of 20 fish per cage were used to estimate initial weights. Initial mean weight per fingerling was 39 g. Initial estimated total fish weights per cage were: 3.45, 3.75, 4.34, 4.82, 3.69, and 3.22 kg for cages 1, 2, 3, 4, 5, and 6; respectively.

To evaluate the effects of 2 types of commercial fish feeds (Purina catfish cage chow and trout chow), one of the 2 feed types was randomly assigned to each cage, thereby providing 3 replicates of each treatment (3 replicates × 2 diets). Catfish were fed a rate of 3% body weight per day, 7 days a week (between 900 and 1100 hours) during the 124-day growing season. Daily feeding rates between 2 and 3% body weight have been reported to provide the optimum production and feed conversion ratios for channel catfish (Swingle 1958, Simco and Cross 1966, Bardach et al. 1972). Both commercial feeds were nutritionally complete, expanded (floating), 4-mm diameter pellets. Crude protein and gross energy levels for both feeds were determined by micro-Kjeldahl and bomb calorimetry (Table 1). The gross energy values for trout feed and catfish feed were 4.66 and 4.55 kcal/g, respectively. These values were used to estimate metabolizable energy of the feeds based on assumed physiological fuel values of: 3.5, 2.5, and 8.1 kcal/g for protein, carbohydrate, and lipid, respectively (Wilson et al. 1977). The 2 rations were also assayed for amino acid content based on 24-hour hydrolysates. Performic acid oxidation prior to hydrolysis was used for determination of sulfur amino acids, methionine and cystine. Tryptophan content was destroyed upon hydrolysis. The amino acid values are reported as percentages of the total of all amino acids determined for each sample to compensate for possible analytical errors. Subsamples (10%) of the fish in each cage were weighed every 14 days for growth analysis and to recalculate the amount of feed provided.

Table 1. Crude protein, metabolizable energy, protein to energy ratio (P/E), and dietary essential amino acid content of 2 feed types fed to caged channel catfish during 124-day trial.

Parameter	Trout Feed	Catfish Feed
Protein[a] (% of diet)	36.9	35.7
Energy[b] (kcal/g)	3.09	2.92
P/E (mg P/kcal)	119	122
Arginine[c]	5.6	6.2
Histidine	2.6	2.4
Isoleucine	5.1	4.8
Leucine	10.2	10.6
Lysine	6.4	6.0
Methionine[d]	3.0	2.6
Phenylalanine	5.4	5.2
Threonine	3.4	3.5
Valine	5.9	5.6

[a] Crude protein was determined via the micro-Kjeldahl procedure.
[b] Metabolizable energy was estimated using caloric values of 3.5, 2.5, and 8.1 kcal/g for protein, carbohydrate and lipid, respectively. Carbohydrate and lipid levels were estimated from gross energy values determined via bomb calorimetry.
[c] Amino acids expressed as a percent of total amino acids.
[d] Sulfur amino acids were determined using performic acid oxidation prior to hydrolysis.

At the end of the study (124 days), all fish were counted, measured, and weighed individually to compute yield, net production, survival, and feed utilization efficiency. Yield (total weight) was determined by weighing each fish and summing the weights for each cage. Net production was determined as the difference between initial total weight and final total weight per cage. Survival (expressed on a percentage basis) was calculated by dividing number of survivors by total number of fish stocked. All dead fish were promply removed, without replacement. Weights of dead fish were not estimated or included in the final production values. Feed utilization efficiency values were determined by dividing weight gain per cage by amount of feed fed during the growing season. Treatment effects (diet types) were evaluated by Student's *t*-test using the 1-sided alternative.

Water temperatures were recorded daily from maximum-minimum thermometers suspended 40 cm below the water surface. Mean monthly water temperatures ranged from a minimum of 20.7 C during October to a maximum of 28.8 C during August. Pond water temperatures averaged 25 ± 3 C during the 124-day growing season. Daily and monthly water temperature variations never exceeded 13 C. Water temperatures always remained above 10 C, the point at which channel catfish have reported to cease active feedings (Simco and Cross 1966, Bulow 1967, Shrable et al. 1969, Collins 1970, Hill et al. 1972). Throughout most of July, August, and September, water temperatures were within the optimum (26 to 30 C) reported for growth and feed conversion efficiencies of channel catfish (Bulow 1967, Schrable et al. 1969, Collins 1970).

RESULTS AND DISCUSSION

Growth

Weight gain by channel catfish maintained on commerical trout feed diet was consistently higher than that for fish fed commercial catfish feed (Fig. 1). Growth and feeding activity, regardless of diet type, were closely related to water temperature. Maximum growth occurred during midsummer (weeks 8 through 16) at mean water temperatures above 26 C. The increased growth rates and food consumption during this period agrees closely with the optimum temperature range (26 to 30 C) reported for growth, feed conversion, and digestive efficiency of channel catfish (Bulow 1967, Schrable et al. 1969, Collins 1970, Kilambi et al. 1977). The relatively slow growth during the early part of the growing season was assumed to be due to poor acclimation of the fish to caged conditions and artificial feeding, and below optimum water temperatures. Reduced weight gain during the last 2 weeks of the study was largely the result of rapidly decreasing water temperatures.

Although catfish were reared under identical thermal regimes, mean weight gain per day for catfish receiving trout feed (2.31 g) was 46% greater than for fish fed commercial catfish feed (1.58 g). Reported daily weight gain values for cage cultured catfish reared on commerical trout feed have also been generally higher, averaging 5.17 g (Collins 1970), 2.79 g (Douglass and Lackey 1974), and 2.16 g (Hill 1974), than those of channel catfish fed commercial catfish feed, 3.29 g (Pennington and Strawn 1977), 1.57 g (Kilambi et al. 1977), 1.15 g (Douglass and Lackey 1973), and 0.93 g (Holmes et al. 1974). At harvest, mean individual weight gain of catfish sustained on commercial trout feed diet (247 g) was significantly greater ($P < 0.005$) than for those fish fed commercial catfish feed (146 g).

Survival

Survival in all cages, except number 6, was relatively high, averaging 84% (Table 2). The heavy mortality (40%) in cage 6 was attributed to a bacterial

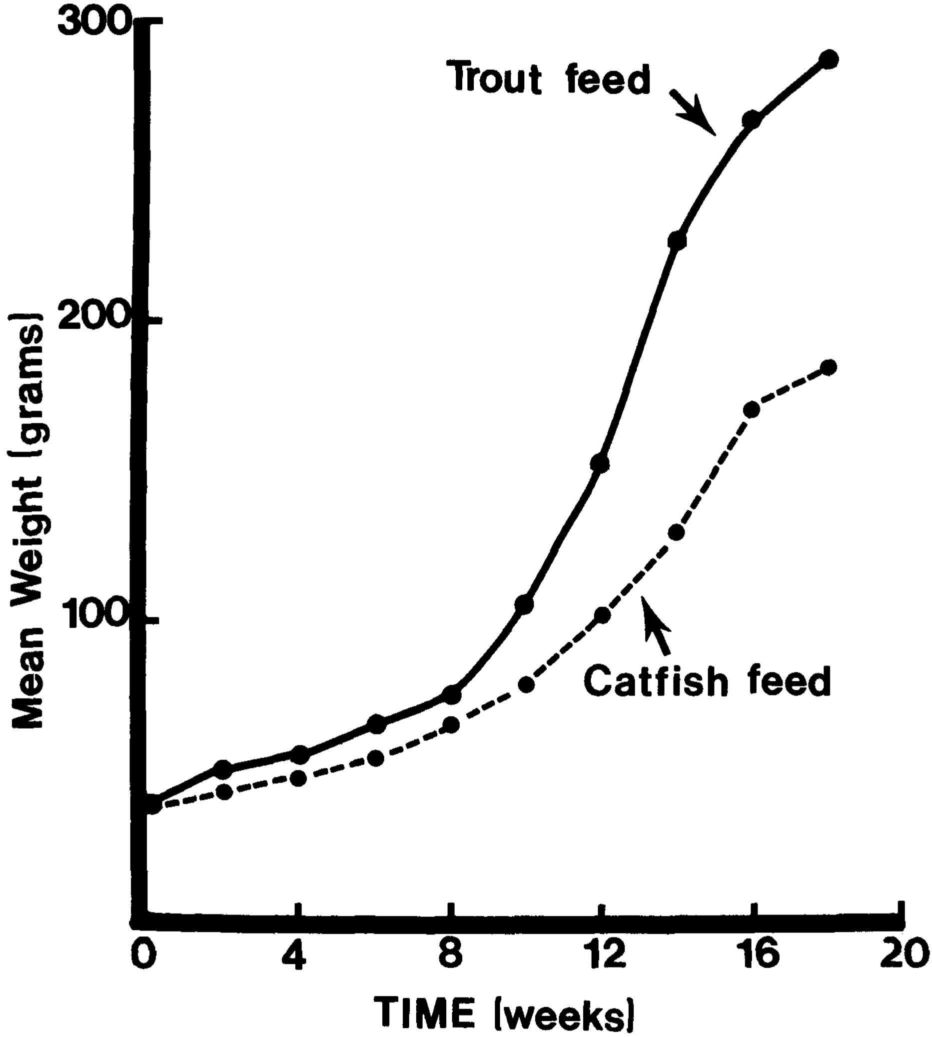

Fig. 1. Mean weight (g) of channel catfish reared on 2 commercial diets as a function of time (weeks).

infection (*Aeromonas* sp.). One month after stocking when dead fish began appearing in cage 6 and some of the other cages, all fish were treated with oxytetracycline dissolved in vegetable oil and sprayed over the feed at a rate of 1.83 g AI/kg of feed. After 3 weeks of treatment, no further mortalities occurred and treatments were discontinued. Similarly successful results for treating infected channel catfish with tetracycline were reported by Collins (1970). Most losses were due to bacterial disease; a few fish escaped during sampling or died of unknown causes. Survival was generally higher for catfish fed trout feed, but no significant differences in survival between treatments (diets) were detected ($P > 0.05$).

Table 2. Comparison of yield (total weight), net production, mean individual weight, survival and feed utilization efficiency values for channel catfish reared for 124 days on 2 diets in cages suspended in Reynolds Pond, Patrick County, Virginia.

Diet type	Cage no.	Yield (kg)	Net production (kg)	Mean weight gain (g/fish)	Survival (%)	Feed utilization efficiency (%)
Trout feed	1	23.6	20.6	272	89	0.56
	3	24.3	19.9	303	82	0.50
	5	26.3	22.6	284	96	0.64
	$\bar{X}$	24.7	21.0	287	89	0.56
Catfish feed	2	16.5	12.8	202	84	0.49
	4	16.8	12.0	191	90	0.42
	6[a]	9.4	6.3	164	60	0.42
	$\bar{X}$	16.7	12.4	196	87	0.46

[a] Values for cage 6 were deleted from statistical computations due to high mortality (40%) encountered during study.

Survival of channel catfish reared in cages suspended in ponds with high quality water and rapid exchange rates is apparently unrelated to commercial diet type. Reported survival values for cage-cultured channel catfish sustained on commercial trout averaged 99% (Schmittou 1969), 97% (Hill 1974), 93% (Douglass and Lackey 1974), and 80% (Collins 1970). Survival of channel catfish reared on commercial catfish feed averaged 95% (Kilambi et al. 1977), 93% (Pennington and Strawn 1977), and 60% (Douglass and Lackey 1973, Holmes et al. 1974). Overall survival in this study (84%) was relatively high compared to mean survival rates of channel catfish reared on commercial catfish feed in Virginia ponds (Douglass and Lackey 1973, Holmes et al. 1974), but below survival of Arkansas (94%), Kansas (93%), and North Carolina (86%) strains of channel catfish reared on commercial trout feed in other Virginia ponds (Douglass and Lackey 1974). Survival of channel catfish used in this study was very similar to that reported for the same strain by Douglass and Lackey (1974). Mortalities reported for channel catfish in cages in Virginia ponds were attributed to oxygen depletion and infections of *Chondroccus columnaris* (Douglass and Lackey 1973, 1974; Holmes et al. 1974).

Production and Feed Utilization Efficiency

Yield (total standing stock) and net production (weight gain) values for channel catfish reared in cages on trout feed were consistently higher and significantly greater ($P < 0.005$) than yield and production on catfish feed (Table 2). During the 124-day growing season, yield and net production values for catfish fed trout feed averaged 24.7 and 21.0 kg/m^3, while those fed catfish feed averaged only 16.7 and 12.4 kg/m^3, respectively. The highest mortality (40%) and the lowest production (6.3 kg/m^3) occurred in cage 6. Yield and production were below those reported for cage-cultured channel catfish reared on both commercial trout and catfish feeds in Arkansas lakes (Collins 1970, Kilambi et al. 1977), but were comparable to those obtained for caged catfish feed (Douglass and Lackey 1974) in Virginia ponds.

Feed utilization efficiency (FUE), a measure of the efficiency of converting feed into fish flesh, was consistently better for channel catfish reared on trout feed than those reared on the catfish diet (Table 2). Mean FUE for channel catfish reared in cages on trout feed (0.56) was marginally higher ($P < 0.10$) than for channel catfish fed catfish feed (0.44). Catfish fed commercial trout feed consumed an average of 37% more feed and gained 69% more weight than those fed catfish feed. This is consistent with the generally higher FUE values reported for cage-cultured channel catfish reared on commercial trout feed. FUE values for channel catfish reared in cages on trout feed averaged 0.77 in Alabama ponds (Schmittou 1969), 0.74 in an Arkansas reservoir (Collins 1970), and 0.44 in Virginia ponds (Douglass and Lackey 1974). FUE values for catfish reared in cages on catfish feed averaged 0.65 in an Arkansas lake (Kilambi et al. 1977), 0.50 in a Texas reservoir (Pennington and Strawn 1977), and 0.31 (Douglass and Lackey 1973) and 0.35 (Holmes et al. 1974) in Virginia ponds.

Nutrition (Diet Ingredients)

A substantial amount of data are available on the nutritional requirements of channel catfish and rainbow trout, *Salmo gairdneri*, (National Research Council 1973, 1977; Stickney and Lovell 1977). When reared in intensive culture systems, these species require a nutritionally complete, balanced ration of proteins (essential amino acids), fats, carbohydrates, vitamins, and minerals. The nutritional requirements of these 2 species and, as a consequence, their prepared diet formulations do not appear to vary greatly with the possible exception of protein quality (amino acid composition). Protein quality in prepared feed is regulated principally by adjusting the proportions of various protein sources to supply adequate amounts of the 10 indispensible amino acids. The known or estimated quantitative requirements of the essential amino acids (as percent of crude protein) for fingerling channel catfish are: arginine (4.3), histidine (1.5), isoleucine (2.6), leucine (3.5), lysine (5.1), methionine (2.3), phenylalanine (undetermined), threonine (2.2), tryptophan (0.5) and valine (3.0) (Wilson et al. 1977, Harding et al. 1977, Wilson et al. 1978, Lovell 1980, Wilson et al. 1980). The addition of animal protein, especially fish meal, to feed formulations generally satisfies the demand for these essential amino acids. The amino acids most commonly limiting growth in commercial feeds are methionine and lysine.

Since trout do not accept or assimilate plant proteins as well as catfish, prepared trout feeds usually contain more fish meal than prepared catfish feeds. One of the major sources of protein in prepared catfish feeds is soybean meal, which is deficient in the essential amino acid methionine (Andrews 1977). Lovell et al. (1964) found that adding fish meal rich in methionine to all-plant diets low in methionine improved growth of channel catfish. Synthetic-free amino acids are sometimes added to a diet formulation to correct for a deficiency in methionine or lysine. However, use of synthetic-free amino acids to supplement amino acid composition of all-plant protein feeds has met with little success. As a consequence, free methionine and lysine are thought to be poorly assimilated by channel catfish (Andrews 1977). Thus, amino acid balance may be best achieved by using combinations of natural proteins. Channel catfish have a methionine requirement of

2.3% of dietary protein in the absence of cystine (about half the methionine requirement can be replaced by cystine), whereas salmonid fishes have a methionine and cystine requirement of 4% (National Research Council 1973, 1977; Lovell 1980).

Although crude protein levels and estimated metabolizable energy of both feeds were similar, trout feed contained about 3% more crude protein and 6% more metabolizable energy than the catfish cage feed. The amounts of all essential amino acids in both feeds appeared to exceed the minimum growth requirements of channel catfish. However, of the essential amino acids, methionine and lysine were lowest in relation to minimum nutritional requirements, and it is possible that the low levels of these amino acids (particularly methionine) in the catfish feed may have been growth-limiting. The trout feed contained 15% (total dietary amino acid content) more methionine and 7% more lysine than the catfish feed.

The physical properties of the 2 feeds used in this study were as identical as possible in all respects except nutritional quality (diet ingredients). Both feeds were in the form of extruded (floating) pellets of equivalent size, texture, color, and water stability; both feeds were, presumably, similar in odor, flavor, and palatibility. The 2 feeds were processed in a similar fashion and were stored under identical conditions (cool temperatures and low humidities) for equal periods of time. However, we have no information concerning the length of time or conditions under which these feeds were stored by the processor. It is conceivable that the observed differences in growth, production, and feed utilization efficiency may, in part, be attributed to the deterioration of vitamins or other nutrients in the catfish feed.

Additional Factors

In addition to nutritional quality and physical characteristics of the feed, production of channel catfish in intensive culture systems can be influenced by a number of other factors including cage location (Schmittou 1969, Pennington and Strawn 1977), mesh size of the cage and water exchange rates (Schmittou 1969, Andrews et al. 1971, Holmes et al. 1974), stocking densities (Stickney et al. 1972, Hill 1974, Pennington and Strawn 1977), feeding frequencies and periodicity (Collins 1970, Page and Andrews 1973, Lovell 1977), and the genetic strain of the stocks (Douglass and Lackey 1974). However, it is unlikely that any of these factors would differentially influence growth since all fish were reared under similar environmental conditions in identical cages, stocked at the same densities, and fed on a similar schedule. All fish were from a single genetic strain and were initially similar in size and vigor. No substantial variation in dissolved oxygen levels or water temperatures occurred between cage locations during the study and treatments (diets) were randomly assigned to the cages. Thus, the potential influences of variable cage location, water quality, feeding schedule, and hereditary characteristics were minimized and considered negligible.

CONCLUSIONS

The results of this study clearly demonstrated that growth, net production, and feed utilization efficiencies of cage-cultured channel catfish reared on commercial trout feed were significantly higher than those fed commercial catfish cage feed. As expected, survival of channel catfish was not influenced by diet type. The observed differences in growth, net production and feed utilization efficiencies between treatments, were, most likely, due to somewhat higher levels of the 2 indispensable amino acids, methionine and lysine, as well as greater metabolizable energy content of the commercial trout feed. Subtle dissimilarities in order, flavor, palatibility, or vitamin quality between the 2 prepared feeds may also have been partially responsible for the observed differences. Regardless of the causative factors, the difference in feed cost to produce a kilogram of catfish was small. Feed costs to produce a kilogram of catfish under our experimental conditions (a relatively short growing season and cool water temperatures) averaged $1.01 on the commercial trout feed diet and $0.99 on the commercial catfish cage feed diet.

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