The Progressive Fish-Culturist 54:92–96, 1992

Effect of Protein Level and Feeding Frequency on Growth and Body Composition of Cage-Reared Channel Catfish

CARL D. WEBSTER, JAMES H. TIDWELL, AND DANIEL H. YANCEY

Aquaculture Research Center, Kentucky State University
Frankfort, Kentucky 40601, USA

Abstract.—Channel catfish (*Ictalurus punctatus*) fingerlings were stocked in eight 1.25-m^3 floating cages at densities of 320 fish/m^3 and fed to satiety once or twice daily for 105 d with diets containing either 34 or 38% protein. Experimental diets were formulated by a commercial feed mill with recommended levels of essential amino acids, vitamins, and minerals. Fish fed a diet containing 38% protein had significantly ($P < 0.05$) higher total length, individual weight, weight gain, and specific growth rate than fish fed a diet containing 34% protein. Feeding frequency (feeding fish once or twice daily) did not affect growth and body composition, but did affect dressing percentage; fish fed twice daily had a higher ($P < 0.05$) percentage than those fed once daily. No significant differences ($P > 0.05$) were found when body composition was analyzed in relation to dietary protein level, feeding frequency, and their interaction. These data indicate that channel catfish reared in cages may require a diet with a higher percentage of protein (38%) than fish reared in ponds and that feeding more than once daily is not beneficial.

Cage culture allows fish to be reared in ponds that would be difficult to harvest by seine, allows direct observation of feeding activity and health of fish, and makes it easier to treat fish diseases and parasites (Schmittou 1970). Several fish species have been successfully cultured in cages, including the Mayan cichlid (*Cichlasoma urophthalmus*; Nava et al. 1989a), redhead cichlid (*C. synspilum*; Nava et al. 1989b), channel catfish (*Ictalurus punctatus*; Schmittou 1970; Beem et al. 1988), Mozambique tilapia (*Oreochromis mossambicus*;[1] Gaigher and Krause 1983), Nile tilapia (*O. niloticus*; Guerrero 1980), striped bass (*Morone saxatilis*; Woods et al. 1983), and rabbitfish (*Siganus canaliculatus*; Tacon et al. 1990).

Many of the nutritional requirements have been specified for formulating channel catfish diets for pond culture. However, rearing fish in cages reduces the availability of natural foods and may alter nutritional specifications of the diet (Lovell 1973). Protein requirements of channel catfish may be influenced by culture method. Lovell (1973) reported that channel catfish reared in cages had higher growth rates when fed diets containing 35 and 40% crude protein compared with fish fed a diet with 30% crude protein. However, Newton and Robison (1981) reported no significant differences in growth, food conversion, survival, and net production of channel catfish fed diets containing 33 and 36% crude protein.

There is increasing concern in aquaculture with the amount of fat in cultured fish. Two decades ago, formulated diets contained 35% protein (P) and 2.8 kcal digestible energy (DE) per gram diet (Hastings and Dupree 1969). Commercial diets now contain 32% protein and 3.0 kcal DE/g diet (Reis et al. 1989). This increase in DE:P ratio of commercial diets, coupled with feeding to satiation, allows fish to grow faster. However, excess fat in cultured channel catfish results in decreased dressed yields and a shorter shelf life of processed fish. Kamarudin (1984) reported that channel catfish fed a diet containing 26% crude protein and 9.9 kcal DE/g protein had a lower dressing percentage than fish fed a diet containing 32% crude protein and 8.5 kcal DE/g protein.

The purpose of this study was to evaluate the effects of two diets with different protein levels fed with different frequencies (once or twice daily) on growth and body composition of channel catfish reared in cages.

Methods

Channel catfish fingerlings (average individual weight, 20.0; SD, 1.3 g) were stocked 27 May 1990 into eight 1.25-m^3 floating cages moored over the deepest area (4 m) of a 1.0-hectare pond (average depth, 2.0 m) on the Agricultural Research Farm, Kentucky State University, Frankfort. Four hundred fingerlings were hand-counted and randomly stocked into each cage. For 105 d fish were fed one of two extruded diets formulated to contain 32 or 38% protein and 2.2–2.4 kcal of digestible energy (DE)/g of diet (Table 1). Diets were for-

[1] The names preferred by the American Fisheries Society for the *Oreochromis* species cited in this paper are *Tilapia mossambica* and *T. nilotica*.

mulated and extruded by a commercial feed mill (Delta Western, Indianola, Mississippi) for use in this study and were similar to diets used in the catfish industry. Fish were fed once (0800 hours) or twice (0800 and 1530 hours) daily to satiation. After 40 min, all uneaten pellets were removed with a hand net and their weight was subtracted (after conversion to a dry-matter basis) from the amount fed. The 2 × 2 factorial design had two replications per treatment combination.

Diets were analyzed for crude protein, fat, moisture, and gross energy. Crude protein was determined with a LECO FP-228 nitrogen determinator (LECO Corp., St. Joseph, Michigan) (Sweeney and Rexroad 1987). Diets contained 34 and 38% protein, dry-weight basis. The increase (to 34%) over the nominal 32% protein is unexplained, but may have been due to higher protein levels in the ingredients used for that diet. Crude fat was determined by the acid hydrolysis method, moisture was determined by placing a 15-g sample in a drying oven (95°C) for 24 h (AOAC 1984), and digestible energy values were calculated from the diet ingredients (NRC 1983). Diets were stored in plastic-lined bags at −30°C until fish were fed.

Each cage had a wooden frame and was constructed of 10-mm polyethylene mesh with removable lids. A panel of polyethylene net (2-mm mesh, 8 cm high) was installed around the top of the inside of each cage to prevent loss of floating diet. Density of fish in these cages was 320 fish/m^3. Cages were anchored to a floating dock with a 2-m separation between cages.

Temperature and dissolved oxygen were monitored twice daily (0800 and 1630 hours) outside the cages at a depth of 0.75 m with a YSI model 57 oxygen meter (Yellow Springs Instrument Co., Ohio). Dissolved oxygen did not decline to below 4.0 mg/L and no emergency aeration was required. Weekly measurements of pH were recorded with an electronic pH meter (Accumet 900, Fisher Scientific), and total ammonia nitrogen and nitrite were measured with a DREL/5 spectrophotometer (Hach Co., Loveland, Colorado). Alkalinity was measured by titration with the DREL/5.

Because of an infection of *Flexibactor columnaris* in fish in one of the cages, the study was ended 2 weeks early. Fish were harvested on 9 September 1990 and were not fed for 24 h before harvest. Total number and weight of fish in each cage were determined at harvest. Fifty fish were randomly sampled from each cage; they were individually weighed (g) and measured (total length, cm). Ten fish were randomly sampled from each cage to analyze dressing percentage, abdominal fat, and body weight. Fish were skinned by machine and dressed by removing heads and viscera. Abdominal fat was removed, weighed, and reported as percentage of total weight. Carcass and waste of three fish sampled from each cage were homogenized separately in a blender and analyzed for protein, fat, moisture, and ash. Protein was analyzed with the LECO FP-228 nitrogen determinator; fat was analyzed by ether extraction; and moisture was measured by drying samples in an oven (95°C) for 24 h.

TABLE 1.—Composition of two diets fed to channel catfish juveniles reared in cages.

Component	Diet	
	34% protein	38% protein
Ingredients (% of total)		
Corn grain	40.15	26.70
Soybean meal (48% protein)	48.75	60.60
Fish meal	8.00	10.00
Dicalcium phosphate	1.40	1.00
Vitamin mix[a]	0.10	0.10
Mineral mix[b]	0.10	0.10
Catfish oil	1.50	1.50
Ascorbic acid	0.025	0.025
Proximate composition		
Moisture (% of wet weight)	10.1	8.6
Protein (% of dry weight)	34.0	38.2
Lipid (% of dry weight)	4.5	4.5
Digestible energy, DE (kcal/g diet)[c]	2.91	3.22
Protein : DE ratio (mg protein/kcal)	116.8	118.0

[a] Vitamin mix provided the following per kilogram of diet: biotin, 0.20 mg; choline, 1,792.6 mg; folic acid, 2.68 mg; niacin, 113.15 mg; pantothenic acid, 45.47 mg; B_6, 16.65 mg; riboflavin, 16.48 mg; thiamin, 13.92 mg; B_{12}, 20.76 mg; E, 76.77 mg; K, 4.48 mg; A, 4,401.34 IU; D, 2,200.00 IU; ascorbic acid, 580 mg.

[b] Mineral mix provided the following in percent or per kilogram of diet: potassium, 1.20%; chloride, 0.08%; magnesium, 0.20%; sodium, 0.06%; sulfur, 0.31%; copper, 19.38 mg; iron, 380.08 mg; manganese, 126.83 mg; selenium, 0.36 mg; zinc, 245.27 mg; iodine, 0.0002%.

[c] Digestible energy values were calculated from the diet ingredients (NRC 1983).

Food conversion (FC) and specific growth rate (SGR) were calculated as follows: FC = total diet fed (kg)/total wet weight gain (kg); SGR (%/d) = $[(\log_{10} W_t - \log_{10} W_i)/T] \times 100$; W_t is the average weight of fish at time t, W_i is the average weight of fish at time 0, and T is the culture period in days.

Data were analyzed with the SAS General Linear Models procedure (SAS Institute 1988) for significant effects of protein level, feeding frequency, and their interaction. All percentage and ratio data

TABLE 2.—Total length, weight, survival, harvest weight per cage, and overall weight gain per cage of channel catfish reared in cages and fed diets containing 34 or 38% protein either once or twice daily. Values are means ± SE of four replications. Means within a column with different letters were significantly different ($P < 0.05$). NS = not significant ($P > 0.05$).

Main effect	Total length (cm)	Weight (g)	Survival (%)	Harvest weight/cage (kg)	Weight gain/cage (kg)
Diet (% protein)					
34	26.41 ± 0.19 x	162.77 ± 3.95 x	87.06 ± 1.95 x	54.12 ± 3.58 x	39.09 ± 3.35 x
38	27.50 ± 0.18 y	187.42 ± 4.35 y	80.38 ± 4.99 x	65.40 ± 1.39 y	50.11 ± 1.44 y
Feeding frequency					
Once daily	26.82 ± 0.19 x	171.09 ± 4.22 x	86.13 ± 4.14 x	59.69 ± 4.58 x	44.65 ± 4.45 x
Twice daily	27.08 ± 0.19 x	179.10 ± 4.25 x	81.31 ± 3.89 x	59.83 ± 3.87 x	44.55 ± 3.70 x
	Probability of no effect (from analysis of variance)				
Protein level	0.0473	0.023	NS	0.0427	0.0481
Feeding frequency	NS	NS	NS	NS	NS
Protein × feeding frequency	NS	NS	NS	NS	NS

were transformed to arcsine values before analysis (Zar 1984).

Results and Discussion

Average monthly morning water temperatures (±SE) ranged from a low of 25.0 ± 4.1°C for June to a high of 27.5 ± 0.1°C for September; afternoon water temperatures ranged from a low of 26.0 ± 1.2°C for June to a high of 28.5 ± 0.7°C for September. Morning dissolved oxygen averaged 6.4 ± 0.7, 6.5 ± 0.1, 6.2 ± 0.3, and 7.0 ± 1.2 mg/L for June, July, August, and September, respectively; afternoon values were 8.7 ± 1.3, 8.5 ± 0.2, 8.7 ± 1.3, and 8.6 ± 0.4 mg/L, respectively. Total ammonia nitrogen averaged 0.05 ± 0.02 mg/L; alkalinity, 84.5 ± 3.72 mg/L; nitrite, 0.03 ± 0.02 mg/L; and pH, 9.28 ± 0.19 during the study and were within accepted values for growth of channel catfish (Boyd 1979).

The results of this study indicated at length, weight, net production, specific growth rate, and food conversion in cage-cultured channel catfish fed a diet containing 38% protein were significantly improved compared with those fed a diet containing 34% protein. Neither feeding frequency nor the interaction between frequency and protein level had any effect on these measurements (Tables 2, 3). Fish fed diets with 34 and 38% protein averaged 162.8 and 187.4 g, respectively. Percent survival ranged from 78.3 to 89.8% and no statistically significant differences ($P > 0.05$) were found among treatments.

Dressing percentage was significantly ($P < 0.05$) higher (63.2%; Table 3) in fish fed twice daily compared with fish fed once daily (59.5%). No significant difference ($P > 0.05$) in dressing percentage was found when analyzed by protein level or the interaction of protein level and feeding frequency. Food conversion, average fish weight, net weight gain, and dressing percentage reported in

TABLE 3.—Dressing percentage, specific growth rate (SGR), and food conversion (FC) of channel catfish reared in cages and fed diets containing 34 or 38% protein either once or twice daily. Values are means ± SE of four replications. Means within a column with different letters were significantly different ($P < 0.05$). NS = not significant ($P > 0.05$).

Main effect	Dressing percentage	SGR (%/day)	FC
Diet (% protein)			
34	60.47 ± 0.93 x	2.07 ± 0.05 x	2.43 ± 0.04 y
38	62.23 ± 0.67 x	2.24 ± 0.04 y	1.72 ± 0.11 x
Feeding frequency			
Once daily	59.49 ± 0.95 x	2.14 ± 0.06 x	2.00 ± 0.25 x
Twice daily	63.21 ± 0.53 y	2.17 ± 0.07 x	2.14 ± 0.18 x
	Probability of no effect (from analysis of variance)		
Protein level	NS	0.042	0.0024
Feeding frequency	0.019	NS	NS
Protein × feeding frequency	NS	NS	NS

this study are in agreement with other published results (Newton et al. 1980; Newton and Robison 1981).

In this study, growth and food conversion of channel catfish fed once or twice daily were not different. This is in agreement with Lovell (1979) and Noeske-Hallin et al. (1985) who reported that food consumption and weight gain for channel catfish fed once or twice daily were similar. Proximate composition of channel catfish juveniles was not significantly ($P > 0.05$) affected by dietary protein level or feeding frequency. Percentages of moisture, protein, and fat of waste (head, skin, and viscera) were (± SE) 36.8 ± 0.8, 34.8 ± 2.1, and 43.3 ± 3.7%, respectively; values for carcass (fillet and frame) averaged 29.0 ± 0.4, 59.3 ± 1.9, and 26.9 ± 3.4%, respectively. Noeske-Hallin et al. (1985), however, reported increased fat levels in channel catfish fed twice daily compared with fish fed once daily in the morning.

Many of the nutritional requirements of channel catfish have been investigated by pond culture methods, which allow fish to eat natural foods in addition to formulated diets (Lovell 1973). Dietary protein requirements of fish reared in intensive culture systems, such as cages, may be higher because natural foods are less available. For instance, Helfrich et al. (1984) reported that cage-reared channel catfish fed a commercial trout diet with 37% protein grew faster than fish fed a catfish diet with 36% protein. These results agree with ours but may have been confounded by the different types of diets fed. Commercial trout diets contain higher levels of methionine, lysine, and fish meal than catfish diets, which use soybean meal as the principal protein source.

Our results also agree with those of Lovell (1973) who found that channel catfish reared in cages appear to require higher dietary protein levels than fish grown in ponds. Lovell (1973) reported that growth of channel catfish fed a diet containing 30% protein was lower than growth of fish fed diets containing 35 and 40% protein. Channel catfish reared in cages in the present study had higher growth rates than reported by Newton and Robison (1981), but lower rates than reported by Newton et al. (1980). During our study, fish did not demonstrate aggressive feeding even though water temperatures were within the range considered optimal for catfish growth. Helfrich et al. (1984) reported that maximum growth of channel catfish juveniles reared in cages occurred when water temperatures were above 26°C. Higher growth rates and food consumption correspond with the optimum temperature range (26–30°C) reported for growth of channel catfish (Bulow 1967; Collins 1971; Kilambi et al. 1977).

Protein is the most expensive dietary component in catfish diets and is a primary concern in diet formulation. Feed producers want to provide the minimum level of protein that will supply essential amino acids to give acceptable growth of fish. Data from previous studies indicated that optimal levels of protein for channel catfish were between 25 and 45% (Hastings and Dupree 1969; Page and Andrews 1973; Brown and Robinson 1989). This range may be due to differences in experimental conditions (feeding method and stocking density), size of fish, and culture conditions. Our study suggests that diets with a higher percentage of protein than the industry standard (32%) should be fed to channel catfish reared in cages. However, no differences in body composition were found, which may have been due to similar protein : energy ratios of the diets.

Acknowledgments

We thank Darrell Baker, Keenan Bishop, Jackie Lamb, Hank Schweickart, and Mac Stone for their technical assistance. We also thank John Sedlacek for use of his laboratory and Karla Richardson for typing this manuscript. This study was partially funded by a grant from the Southern Regional Aquaculture Center (87-CRSR-2-3218), a U.S. Department of Agriculture USDA/CRS grant to Kentucky State University under agreement KYX-89-88-03A, and a USDA 1890 Institution Capacity Building Grant.

References

AOAC (Association of Official Analytical Chemists). 1984. Official methods of analysis, 14th edition. AOAC, Arlington, Virginia.

Beem, M. D., G. E. Gebhart, and O. E. Maughan. 1988. Winter polyculture of channel catfish and rainbow trout in cages. Progressive Fish-Culturist 50:49–51.

Boyd, C. E. 1979. Water quality in warmwater fish ponds. Alabama Agricultural Experiment Station, Auburn University.

Brown, P. B., and E. H. Robinson. 1989. Comparison of practical catfish feeds containing 26 or 30% protein. Progressive Fish-Culturist 51:149–151.

Bulow, F. J. 1967. The suitability of stripmine ponds for producing marketable channel catfish. Progressive Fish-Culturist 29:222–228.

Collins, R. A. 1971. Cage culture of catfish in reservoir lakes. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 24 (1970):489–496.

Gaigher, I. G., and J. B. Krause. 1983. Growth rates

of mozambique tilapia (*Oreochromis mossambicus*) and silver carp (*Hypophthalmichthys molitrix*) without artificial feeding in floating cages in plankton-rich waste water. Aquaculture 31:361–367.

Guerrero, R. D. 1980. Studies on the feeding of *Tilapia nilotica* in floating cages. Aquaculture 20:169–175.

Hastings, W. H., and H. K. Dupree. 1969. Formula feeds for channel catfish. Progressive Fish-Culturist 31:187–196.

Helfrich, L. A., J. C. Dean, and D. L. Weigmann. 1984. Growth response of cage-cultured channel catfish fed two commercial diets. Proceedings of the Annual Conference Southeastern Association of the Fish and Wildlife Agencies 35 (1981):531–540.

Kamarudin, M. S. H. 1984. Effects of fish size and isocaloric diets at two protein levels on weight gain and body composition of channel catfish. Master's thesis. Auburn University, Auburn, Alabama.

Kilambi, R. V., J. C. Adams, A. V. Brown, and W. A. Wickizer. 1977. Effects of stocking density and cage size on growth, feed conversion and production of rainbow trout and channel catfish. Progressive Fish-Culturist 39:62–66.

Lovell, R. T. 1973. Protein requirements of cage-cultured channel catfish. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 26 (1972):357–361.

Lovell, R. T. 1979. Factors affecting voluntary food consumption by channel catfish. Pages 555–564 *in* J. E. Halver and K. Tiews, editors. Fish nutrition and fishfeed technology, volume 1. Heenemann, Berlin.

Nava, A. F., M. A. Olvera-Novoa, and A. G. Cristiano. 1989a. Effects of stocking density on the growth of *Cichlasoma urophthalmus* cultured in floating cages. Aquaculture and Fisheries Management 20:73–78.

Nava, A. F., M. A. Olvera-Novoa, and M. G. Christiano. 1989b. Growth and feed conversion of cage-reared *Cichlasoma synspilum* at three different stocking densities. Aquaculture and Fisheries Management 20:173–178.

Newton, S. H., and W. R. Robison. 1981. Ration/density comparisons with caged channel catfish. Arkansas Academy of Science Proceedings 35:89–90.

Newton, S. H., W. R. Robison, and C. J. Haskins. 1980. Evaluation of a full-fat soybean ration for channel catfish production in cages. Arkansas Academy of Science Proceedings 34:84–85.

Noeske-Hallin, T. A., R. E. Spieler, N. C. Parker, and M. A. Suttle. 1985. Feeding time differentially affects fattening and growth of channel catfish. Journal of Nutrition 115:1228–1232.

NRC (National Research Council). 1983. Nutrient requirements of warmwater fish and shellfish. National Academy of Sciences, Washington, D.C.

Page, L. W., and J. W. Andrews. 1973. Interactions of dietary levels of protein and energy on channel catfish (*Ictalurus punctatus*). Journal of Nutrition 103: 1339–1346.

Reis, L. M., E. M. Reutebuch, and R. T. Lovell. 1989. Protein-to-energy ratios in production diets and growth, feed conversion and body composition of channel catfish, *Ictalurus punctatus*. Aquaculture 77: 21–27.

SAS Institute. 1988. SAS/STAT user's guide, release 6.03 edition. SAS Institute, Cary, North Carolina.

Schmittou, H. R. 1970. The culture of channel catfish, *Ictalurus punctatus*, in cages suspended in ponds. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 23 (1969):226–244.

Sweeney, R. A., and P. R. Rexroad. 1987. Comparison of LECO FP-228 nitrogen determinator with AOAC copper catalyst Kjeldahl method for crude protein. Journal of the Association of Analytical Chemists 70:1028–1030.

Tacon, A. G. J., N. Rausin, M. Kadari, and P. Cornelis. 1990. The food and feeding of marine finfish in floating net cages at the National Seafarming Development Centre, Lampung, Indonesia: rabbitfish, *Siganus canaliculatus*. Aquaculture and Fisheries Management 21:375–390.

Woods, L.C., J. H. Kerby, and M. T. Huish. 1983. Estuarine cage culture of hybrid striped bass. Journal of the World Mariculture Society 14:595–612.

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey.