Effects of Feeding Diets Containing 34 or 38% Protein at Two Feeding Frequencies on Growth and Body Composition of Channel Catfish

Carl D. Webster
James H. Tidwell
Julia A. Clark
Daniel H. Yancey

ABSTRACT. Channel catfish, *Ictalurus punctatus*, fingerlings were stocked (13,585 fish/ha) in twelve 0.04-ha earthen ponds and fed to satiation with diets containing either 34 or 38% protein (79.1 or 88.8 mg protein/kcal), either once or twice daily for 170 days. Experimental diets with the proper levels of essential amino acids, vitamins, and minerals were formulated by a commercial feed mill. No significant differences ($P > 0.05$) in growth and body composition of channel catfish were found when analyzed by protein level, feeding frequency, or their interaction. Average individual fish weight at harvest was 461 g. Net production was 4,152 kg/ha. Percentage protein, fat, and ash in the waste (head, skin, viscera, and frame) were 41.5, 41.4, and 12.2%, respectively, while fillet had 65.7, 30.4, and 4.0%, respectively.

INTRODUCTION

Farm-raised channel catfish, *Ictalurus punctatus*, is the most valuable aquaculture species in the United States, with live sales

Carl D. Webster, James H. Tidwell, Julia A. Clark, and Daniel H. Yancey, Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601 USA.

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worth $273 million (Harvey 1990). There is increasing concern with product quality, primarily in regard to the amount of fat in cultured fish. Excess fat in cultured channel catfish results in decreased dress-out yields and a shorter shelf-life of processed fish. Lovell and Ammerman (1974) reported that in the early 1970's, the amount of body fat in processed, cultured channel catfish was 8%. By the early 1980's, this percentage had increased to 12% (Brooks et al. 1982). Increased fattiness may be influenced by diet composition, feeding practices, and fish size.

Two decades ago, channel catfish grow-out diets contained 35% crude protein (P) and 2.8 kcal digestible energy (DE)/g of diet (Hastings and Dupree 1969). A typical commercial diet used for grow-out of channel catfish now contains 32% crude protein and 3.0 kcal DE/g of diet (Reis et al. 1989). This increase in DE/P ratio of commercial diets, coupled with feeding to satiation, allows fish to grow faster and larger during a production season. Kamarudin (1984) reported that channel catfish fed a diet containing 26% protein had lower dressout percentage and higher body fat than fish fed a diet containing 32% protein. Prather and Lovell (1971) showed that channel catfish fed a diet containing 44% protein had higher body weight than fish fed a diet containing 32% protein.

Intensive feeding and increased feeding frequency may also influence weight gain and body composition, and increase body fat levels. Lovell (1979) reported that fish fed once daily consumed the same amount of food and had similar growth as fish fed twice daily. The objective of this study was to evaluate the effects of feeding frequency at two dietary protein levels on growth and on body composition of channel catfish grown to marketable size.

MATERIALS AND METHODS

Diets

Fish were fed one of two extruded diets formulated by a commercial feed mill (Delta Western, Indianola, Mississippi) to contain either 32 or 38% protein and 4.3 kcal gross energy/g of diet (74.4 or 88.8 mg protein/kcal of diet, respectively) (Table 1). Diets were

analyzed for crude protein, fat, moisture, and gross energy. Crude protein was determined using a LECO-FP228 nitrogen determinator[1] (Sweeney and Rexroad 1987). Although the low protein diet was formulated to contain 32% protein, the assay revealed that it contained 34% protein. A possible explanation for this may be variation in crude protein of the feed ingredients. Crude fat was determined by the acid-hydrolysis method (Association of Official Analytical Chemists 1984). Moisture was determined by placing 15 g of the diet in a drying oven (95°C) for 24 hours (Association of Official Analytical Chemists 1984). Gross energy was determined with a bomb calorimeter (Association of Official Analytical Chemists 1984). Diets were stored in bags in a freezer (−30°C) until fish were fed.

Grow-Out

Channel catfish fingerlings (average weight: 35.0 g) were stocked on May 4, 1990 in twelve 0.04-ha earthen ponds at the Aquaculture Research Center, Kentucky State University, at a density of 13,585 fish/ha. Ponds were approximately 1.5 m deep and were supplied with water from a reservoir which was filled by rain runoff. Water levels in ponds were maintained at a constant depth by periodic additions. One week after stocking, an infection of *Flexibacter columnaris* was diagnosed. All fish were fed a medicated (Romet) sinking feed (Zeigler Bros.) for 7 days. Mortalities were recorded and removed.

Fish were fed all they could consume either once (0900) or twice (0900 and 1530) daily for 170 days. Each treatment combination in the 2 × 2 factorial arrangement (protein level × feeding frequency) was replicated in three ponds. Diets were placed inside a 3.0-m diameter floating feeding ring in the pond. Rings were made from 1-cm diameter plastic pipe and had a 0.58-cm plastic mesh skirt extending 20 cm below the water surface. After 20 minutes, all uneaten pellets were removed with a net, and their weight was subtracted from the amount fed.

1. Use of trade or brand names does not imply endorsement.

Dissolved oxygen (DO) and temperature of all ponds were monitored twice daily (0800 and 1430) with a YSI Model 57 oxygen meter. When the DO level of any pond was predicted (graphically) to decline to below 4.0 mg/l, emergency aeration was provided. Total ammonia nitrogen (TAN) and nitrite were measured twice weekly (at 1300) with a Hach DREL/5 spectrophotometer, and pH was measured twice weekly (at 1300) with an electronic pH meter (Accumet 900, Fisher Scientific). Through the duration of the study, these water quality parameters averaged ($\pm$ SE): morning water temperature, 23.7 $\pm$ 0.1°C; afternoon water temperature, 25.1 $\pm$ 0.1°C; morning DO, 7.0 $\pm$ 0.2 mg/l; afternoon DO, 10.6 $\pm$ 0.8 mg/l; total

TABLE 1. Composition of two diets fed to channel catfish fingerlings raised in earthen ponds. Protein and lipid percentages are expressed on a dry-weight basis.

	Diet	
	32% Protein	38% Protein
Ingredient		
Corn grain	40.15	26.70
Soybean meal (48% protein)	48.75	60.60
Fish meal (60% protein)	8.00	10.00
Dicalcium phosphate	1.40	1.00
Vitamin mix[1]	0.10	0.10
Mineral mix[2]	0.10	0.10
Catfish oil	1.50	1.50
Ascorbic acid	0.025	0.025

	Diet	
	32% Protein	38% Protein
Chemical analyses		
Dry matter (%)	89.9	91.4
Protein (%)	34.0	38.2
Lipid (%)	4.5	4.5
Gross energy (Kcal/g)	4.3	4.3
Protein/gross energy ratio (mg protein/kcal)	79.1	88.8
Energy/protein ratio (kcal/g of protein)	13.2	11.8

[1] Vitamin mix contains (per kg of diet): biotin, 0.20 mg/kg; choline, 1792.6 mg/kg; folic acid, 2.68 mg/kg; niacin, 113.15 mg/kg; pantothenic acid, 45.47 mg/kg; B_6, 16.65 mg/kg; riboflavin, 16.48 mg/kg; thiamin, 13.92 mg/kg; B_{12}, 20.76 mg/kg; E, 76.77 mg/kg; K, 4.48 mg/kg; A, 4401.34 IU/kg; D, 2200.00 IU/kg; Ascorbic acid, 580 mg/kg.

[2] Mineral mix contains (per kg of diet): potassium, 1.20%, chloride, 0.08%; magnesium, 0.20%; sodium, 0.06%; sulfur, 0.31%; copper 19.38 mg/kg; iron, 380.08 mg/kg; manganese, 126.83 mg/kg; selenium, 0.36 mg/kg; zinc, 245.27 mg/kg; iodine, 0.0002%.

ammonia nitrogen, 0.80 ± 0.28 mg/l; nitrite, 0.06 ± 0.03 mg/l; pH, 8.4 ± 0.2.

Harvest Data

Fish were harvested by seine on October 21, 1990. Fish were not fed 24 hours prior to harvest. Total number and weight of fish in each pond were determined at harvest. Fifty fish were randomly sampled from each pond and were individually weighed to the nearest gram and measured (total length) to the nearest centimeter.

Fifteen fish were randomly sampled from each pond for analysis of fillet yield, abdominal fat, and body weight. Three of these fish were randomly sampled for analysis of body composition. Fish were skinned by machine and dressed by removing head and viscera. Fillet and abdominal fat were removed, weighed, and reported as percentage of the whole fish. Fillet and waste (head, viscera, skin, and frame) from the fish were homogenized separately in a blender and analyzed for moisture, protein, fat, and ash. Protein was analyzed using the macro-Kjeldahl method; fat was analyzed by ether extraction; moisture was determined by drying in a convection oven (95°C) for 24 hours; and ash was determined using a muffle furnace at 316°C for 2 hours (Association of Official Analytical Chemists 1984).

Food conversion ratio (FCR) and specific growth rate (SGR) were calculated as follows: FCR = total diet fed (kg)/total wet weight gain (kg); SGR (%/day) = $(\log W_t - \log W_i/T) \times 100$, where W_t is the weight of fish at time t, W_i is the weight of fish at time 0, and T is the culture period in days.

Statistical Analysis

Data were analyzed using the SAS General Linear Models procedure (Statistical Analysis Systems 1988) for significance among protein level, feeding frequency, and their interaction (Zar 1984). All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984).

RESULTS AND DISCUSSION

Fish Growth

There were no significant differences ($P > 0.05$) in individual fish length, individual fish weight, survival, food conversion ratio (FCR), specific growth rate (SGR), and net production (kg/ha) for channel catfish fed either a 34 or a 38% protein diet either once or twice daily (Table 2). Percentage survival was low; this was probably due to the epizootic that occurred following stocking. However, percentage survival was not significantly different ($P > 0.05$) among treatments.

Results from this study are in agreement with those found by Brown and Robinson (1989), who found no differences in growth of channel catfish fed diets containing either 26% or 30% crude protein. Simco and Cross (1966) reported that growth of channel catfish fed diets containing 30, 40, and 50% crude protein were not significantly different. Lovell (1972) reported that there were no significant growth differences of channel catfish fed diets containing 35% and 40% crude protein. Growth rates and food conversions reported in this study are in agreement with other published results (Dunham and Smitherman 1983; Robinson et al. 1985).

Other studies have found differences in channel catfish growth when dietary protein levels were more divergent. Channel catfish fingerlings fed a diet containing 35% crude protein had higher weight gains than fish fed a diet containing 25% protein (Page and Andrews 1973; Murray et al. 1977). Reis et al. (1989) found that channel catfish fed a diet containing 31% crude protein had lower weight and protein gains than fish fed a diet containing 39% crude protein. Food conversion, dressing percentage, and fat gain were not different. Lovell (1972) reported that channel catfish fed a diet containing 30% protein were significantly smaller than fish fed diets containing 35 and 40% protein.

The lack of significant differences in weight gain and food conversion in channel catfish fed diets containing 34 or 38% protein (79 or 89 mg protein/kcal, respectively) suggests that protein/energy ratios of the diets were within an optimal range for fish growth. Protein is the most expensive dietary component in catfish diets and is a

TABLE 2. Mean ± SE net production, length, weight, survival, food conversion ratio (FCR), specific growth rate (SGR), fillet weight, visceral fat weight, percentage visceral fat, and percentage fillet yield for channel catfish fed diets containing either 34 or 38% protein either once or twice daily. Means followed by different letters were significantly different ($P < 0.05$).

	34% Protein		38% Protein	
	One feeding per day	Two feedings per day	One feeding per day	Two feedings per day
Net production (kg/ha)	4,003.6±197.6a	4,198.3±204.8a	4,233.8±377.7a	4,172.1±316.2a
Length (cm)	36.3±1.0a	35.0±1.0a	36.5±0.7a	36.4±0.0a
Weight (g)	472.3±42.7a	426.2±36.4a	474.9±26.7a	470.9±8.4a
Survival (%)	78.5±0.9a	82.8±0.8a	74.4±6.2a	70.2±8.1a
FCR	1.51±0.13a	1.48±0.03a	1.46±0.07a	1.50±0.01a
SGR (%/day)	1.72±0.03a	1.75±0.03a	1.76±0.06a	1.75±0.05a
Fillet weight (g)	138.5±16.7a	117.4±10.0a	130.8±11.5a	131.3±6.8a
Visceral fat weight (g)	17.8±2.3a	16.0±1.8a	17.9±3.1a	17.5±0.8a
Visceral fat (%)	3.49±0.16a	3.67±0.30a	3.62±0.38a	3.59±0.02a
Fillet yield (%)	27.88±0.49a	28.12±1.12a	27.05±0.55a	26.99±0.31a

primary concern in diet formulation. Feed producers desire to provide the minimum level of protein in a diet that will supply essential amino acids and nitrogen to support acceptable weight gain in fish. Data from previous studies indicated that optimal levels of protein were between 25-45% (Hastings and Dupree 1969; Tiemeier et al. 1969; Page and Andrews 1973; Prather and Lovell 1973; Murray et al. 1977; Brown and Robison 1989). This range may be due to differences in experimental conditions (feeding methods and stocking density), size of fish, and the effects of dietary energy. The results from this study indicate that the two dietary protein levels evaluated were not divergent enough to give differences in fish growth. A diet with a lower protein level, i.e., 26%, should be evaluated in future studies to determine the minimum level of protein that a channel catfish diet can contain when commercial stocking densities are used.

In this study, feeding frequency had no effect on growth and food conversion. These results are similar to those found by Lovell (1979). The effect of feeding frequency on food consumption varies during the growing season. Rate of stomach evacuation decreases with decreasing water temperature, and fish fed more frequently consumed less food, due to the continual presence of food in the gut (Lovell 1979). In this study, only two of the five months had water temperatures higher than 26°C. These temperatures may have reduced food consumption in fish fed twice daily. This is in agreement with Lovell (1979) who reported that when water temperatures declined below 26°C, fish fed twice daily consumed less food than fish fed once daily.

Body Composition

No significant ($P > 0.05$) differences in fillet weight, abdominal fat weight, percentage fillet yield, and percentage abdominal fat were found among treatments (Table 2). Overall percentage fillet yield was 27.5%, and percentage abdominal fat was 3.59%. Percentage composition (dry weight basis) of waste (head, skin, viscera, and frame) were not significantly different ($P > 0.05$) among treatments (Table 3). Percentage protein, fat, and ash averaged 41.5%, 41.4%, and 12.4%, respectively. Percentage moisture in

TABLE 3. Mean ± SE percentage moisture, protein, fat, and ash (dry-weight basis) of waste (head, skin, frame, and viscera) for channel catfish fed diets containing either 34 or 38% protein once or twice daily. Means followed by a different letter are significantly different ($P < 0.05$).

Main effect	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Diet (% protein)				
34	65.62±0.66a	40.98±1.09a	41.30±1.24a	12.68±1.22a
38	66.15±0.80a	41.96±1.73a	41.49±1.69a	11.79±0.71a
Feeding frequency				
Once daily	65.70±0.43a	40.56±0.92a	43.19±1.27a	11.34±0.82a
Twice daily	66.07±0.95a	42.38±1.76a	39.59±1.21a	13.14±1.09a

fillet was significantly different ($P < 0.05$) when analyzed by protein level, but not by either feeding frequency or their interaction (Table 4). Percentage protein, fat, and ash were not significantly different ($P > 0.05$) among treatments and averaged 65.7%, 30.3%, and 4.0%, respectively.

This study suggests that growth and body composition of channel catfish were not affected when fish were fed diets containing 34 or 38% crude protein, once or twice daily, to satiation. No differences in abdominal fat and fillet fat levels were found among treatments. Percentages of abdominal and fillet fat found in this study were in agreement with previously reported values (Reis et al. 1989; Tidwell and Robinette 1990).

The level of digestible energy in a diet affects the amount of food consumed by fish, and the ratio of energy to protein in the diet will influence conversion efficiency of the diet (Reis et al. 1989). An excessively high ratio may increase fat deposition in fish, whereas when the ratio is too low, protein is used as an energy source. Mangalik (1986) reported that by increasing the level of digestible energy in a low protein (27%) diet, growth of channel catfish was reduced because fish did not consume enough feed to meet their daily protein requirement. When he increased digestible energy in a high protein (37%) diet, there was an improvement in growth and food conversion. Diets used in this study were similar in energy-to-protein ratio and may explain why no differences in body composition were found.

This study suggests that increasing protein level to 38% in a channel catfish diet does not significantly reduce body fat and does not significantly increase weight gains in channel catfish compared to fish fed a diet containing 34% protein. Growth and body composition of channel catfish fed diets with lower protein levels, i.e., 26-30%, should be compared to fish fed a diet containing 32% protein (industry standard).

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TABLE 4. Mean ± SE percentage moisture, protein, fat, and ash (dry-weight basis) of fillet for channel catfish fed diets containing either 34 or 38% protein once or twice daily. Means followed by a different letter are significantly different ($P < 0.05$).

Main effect	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Diet (% protein)				
34	73.71±0.72a	66.32±2.22a	29.79±2.04a	3.99±0.11a
38	72.81±0.57a	65.14±1.48a	30.85±1.38a	3.90±0.04a
Feeding frequency				
Once daily	72.29±0.51a	63.58±1.72a	32.38±1.57a	3.75±0.11a
Twice daily	74.23±0.55b	67.88±1.57a	28.26±1.41a	4.15±0.04a

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REFERENCES

Association of Official Analytical Chemists. 1984. Official Methods of Analysis of the Association of Official Analytical Chemists, fourteenth ed. Association of Official Analytical Chemists, Inc., Arlington, Virginia.

Brooks, G. M., J. D. Jordan, J. H. McGilberry, G. B. Perkins, and S. E. Rosenberger. 1982. Oxidative Rancidity in Stored Frozen Catfish. Food and Fiber Center, Mississippi Cooperative Extension Service, Mississippi State University, Starkville, Mississippi.

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

Dunham, R. A., and R. O. Smitherman. 1983. Response to selection and realized heritability for body weight in three strains of channel catfish, *Ictalurus punctatus*, grown in earthen ponds. Aquaculture 33:89-96.

Harvey, D. 1990. Aquaculture: Situation and Outlook Report. Economic Research Service, United States Department of Agriculture, Washington, D.C.

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

Kamarudin, M. S. H. 1984. Effects of Fish Size and Isocaloric Diets of Two Protein Levels on Weight Gain and Body Composition of Channel Catfish. Master's thesis, Auburn University, Alabama.

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

Lovell, R. T. 1979. Factors affecting voluntary food consumption by channel catfish. Proceedings of the World Symposium of Finfish Nutrition and Fishfeed Technology 1:555-564.

Lovell, R. T., and G. R. Ammerman. 1974. Processing Farm Raised Catfish. Southern Cooperative Series No. 193. Alabama Agricultural Experiment Station, Auburn University, Alabama.

Mangalik, A. 1986. Dietary Energy Requirements of Channel Catfish. Doctoral dissertation, Auburn University, Auburn, Alabama.

Murray, M. W., J. W. Andrews, and H. L. Deloach. 1977. Effects of dietary lipids, dietary protein and environmental temperatures on growth, feed conversion and body composition of channel catfish. Journal of Nutrition 107:277-280.

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.

Prather, E. E., and R. T. Lovell. 1971. Effect of vitamin fortification in Auburn

No. 2 fish feed. Proceedings of the Southeastern Association of Game and Fish Commissioners 25:479-483.

Prather, E. E., and R. T. Lovell. 1973. Response of intensively fed channel catfish to diets containing various protein-to-energy ratios. Proceedings of the Southeastern Association of Game and Fish Commissioners 27:455-459.

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.

Robinson, E. H., J. K. Miller, V. M. Vergara, and G. A. Duchorme. 1985. Evaluation of dry extrusion cooked protein mixes as replacements for soybean meal and fish meal in catfish diets. Progressive Fish-Culturist 47:102-109.

Simco, B. A., and F. B. Cross. 1966. Factors affecting the growth and production of channel catfish *Ictalurus punctatus*. University of Kansas Museum of Natural History 17:191-256.

Statistical Analysis Systems. 1988. SAS/STAT User's Guide. Release 6.03 Edition. SAS Institute, Inc., Cary, North Carolina.

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.

Tidwell, J. H., and H. R. Robinette. 1990. Changes in proximate and fatty acid composition of fillets from channel catfish during a two-year growth period. Transactions of the American Fisheries Society 119:31-40.

Tiemeier, O. W., C. W. Deyoe, A. D. Dayton, and J. B. Shrable. 1969. Rations containing four protein sources compared at two protein levels and two feeding rates with fingerling channel catfish. Progressive Fish-Culturist 31:79-89.

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