Effects of Dietary Protein Level on Growth and Body Composition of Channel Catfish Reared in Cages

Carl D. Webster
Laura S. Goodgame-Tiu
James H. Tidwell
Eddie B. Reed, Jr.

ABSTRACT. Channel catfish fingerlings (84 g) were stocked in 1.25-m^3 cages at a rate of 250 fish/cage and fed to satiety once daily with diets containing 27, 32, 37, or 42% protein for 12 weeks. The diets were similar to commercial formulations, composed of soybean meal, corn, fish meal, and vitamin and mineral supplements. The protein to energy ratio (P/E) was increased by substituting soybean meal and fish meal (5:1) for corn. Fish meal constituted a fixed percentage (15%) of the total protein of the diets.

Growth of channel catfish fed diets with increasing dietary protein levels was not significantly different ($P > 0.05$) among treatments. Average final weight, total length, survival, food conversion ratio (FCR), and specific growth rate (SGR) were 312 g, 31.3 cm, 84.8%, 1.47 and 1.48%/day, respectively. Protein efficiency ratio (PER) was significantly higher ($P < 0.05$) for fish fed a diet containing 27% protein compared to fish fed the other three diets.

Dressing percentage was not significantly different ($P > 0.05$) among treatments and averaged 54.9%. Percentage protein in carcasses of fish fed the diet containing 27% protein was significantly lower (58.1%) compared to fish fed diets containing 32, 37, and 42% protein (61.2, 62.2, and 63.0%, respectively), whereas percentage fat was significantly higher (36.6%) than in fish fed the diet containing

Carl D. Webster, Laura S. Goodgame-Tiu, James H. Tidwell and Eddie B. Reed, Jr., Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601 USA.

Journal of Applied Aquaculture, Vol. 4(2) 1994

37% protein (32.1%) ($P < 0.05$). Percentage protein and fat of waste (skin, head, and viscera) were not significantly different ($P > 0.05$) among treatments. The results indicate that channel catfish reared in cages can be fed a diet with 27% protein, when fed to satiation, without adverse effects on weight gain and feed conversion; however, muscle fat content was higher and protein content was lower than in fish fed higher (32, 37, and 42%) protein levels.

INTRODUCTION

Growth of channel catfish, *Ictalurus punctatus*, reared in ponds has been reported to be optimal when fish were fed diets containing protein levels ranging from 25 to 45% (Tiemeier and Deyoe 1969; Page and Andrews 1973; Prather and Lovell 1973; Reis et al. 1989). This variation in optimum protein level may be due to differences in feeding practices, environmental conditions, fish size, and energy content of the diet (Lovell 1989). Presently, most commercial catfish diets contain 32% protein. However, recent studies indicate that diets with lower protein levels may be adequate if fish are grown in ponds (Brown and Robinson 1989; Li and Lovell 1992a and 1992b; Robinson and Robinette 1993). This is of importance since protein is the most expensive component in prepared diets.

Cage culture allows for the rearing of fish in ponds that would otherwise be difficult to harvest by seine (Schmittou 1970). Many of the diet formulations for channel catfish diets have been evaluated for pond culture. However, rearing fish in cages reduces the availability of natural foods (Lovell 1972) and may require altered nutritional specifications of the diet. There are conflicting data on protein requirements of channel catfish reared in cages. Lovell (1972) reported that channel catfish reared in cages had higher growth rates when fed diets containing >35% protein compared to fish fed a diet with 30% protein. This is in agreement with Webster et al. (1992a) who reported that channel catfish fed to satiation with a diet with 38% protein had higher weight gains than fish fed a diet with 34% protein. However, Newton and Robison (1981) reported no significant differences in growth and production when channel catfish were fed diets containing 33 and 36% protein. Li and Lovell (1992a and 1992b) reported that growth of channel catfish fed a diet with a lower level of protein (26%) was similar to fish fed diets containing higher levels of protein in ponds, if fed to satiation. The purpose of this study was to evaluate the effect of dietary protein level in practical diets on growth and body composition of channel catfish reared in cages and fed to satiation.

MATERIALS AND METHODS

Juvenile channel catfish (average individual weight, 84.0 ± 2.0 g) were stocked on 1 July 1992 into twelve 1.25-m^3 floating cages moored over the deepest area (4 m) of a 1.0-ha pond (average depth = 2.0 m) located at the Agricultural Research Farm, Kentucky State University, Frankfort, Kentucky, USA. Two hundred and fifty juveniles were hand-counted and randomly stocked into each cage. Each cage had a wooden frame with a removable lid and was constructed of 10-mm polyethylene mesh. An 8.0-cm panel of polyethylene mesh (0.2-mm) was installed around the top of the inside of each cage to prevent loss of the floating diet. Cages were anchored to the dock with a minimum distance of 2 m between cages.

Fish were fed one of four extruded (floating) diets formulated to contain either 27, 32, 37 or 42% protein for 12 weeks (Table 1). Diets were extruded by a commercial feed mill (Integral Fish Foods, Inc., Grand Junction, Colorado) and were similar to diets fed commercially, being composed of fish meal, soybean meal, corn, fat, and vitamin and mineral supplements. Fish meal was added to maintain a fixed percentage (15%) of the total protein of each diet. Dicalcium phosphate was increased in diets as fish meal decreased to meet the available phosphorus requirement of channel catfish. Fish were fed once daily (1830) all they could consume in 40 minutes. Uneaten diet was removed and the weight subtracted (after conversion to dry-weight basis) from the amount fed. There were three replications of each treatment (diets).

Diets were analyzed for crude protein, fat and moisture. Crude protein was determined using the Kjeldahl method, crude fat was determined by the acid-hydrolysis method, and moisture was determined by placing a 10-g sample in a drying oven (95°C) until constant weight (AOAC 1990). Digestible energy values were calculated using tabular values for the diet ingredients (NRC 1983). Diets were stored in plastic-lined bags (−15°C) until needed.

TABLE 1. Ingredient and chemical composition (dry-matter basis) of four diets with different protein levels fed to channel catfish reared in cages.

	Protein (%)			
	27	32	37	42
		Ingredients (% of total)		
Menhaden fish meal	6.80	8.00	9.25	10.50
Soybean meal	34.00	45.00	56.00	67.00
Ground corn	54.65	42.95	31.20	18.95
Dicalcium phosphate	2.00	1.50	1.00	1.00
Cod liver oil[1]	1.50	1.50	1.50	1.50
Premix[2]	1.00	1.00	1.00	1.00
Ascorbic acid	0.05	0.05	0.05	0.05
		Chemical analysis[3]		
Protein (%)	27.8±0.2	33.4±0.6	37.8±0.3	42.2±0.0
Fat (%)	9.0±0.7	8.2±0.6	8.6±0.4	7.8±0.1
Moisture (%)	8.8±0.8	6.5±0.4	7.8±0.2	10.4±0.0
DE (kcal/g of diet)[4]	2.3	2.5	2.8	3.0
P:DE[5]	120	133	135	134

[1]Sprayed on after processing; BHT added at 0.02% of dietary lipid.

[2]Premix had vitamin and mineral supplements that supplied the following (mg or IU/kg of diet): A, 4400 IU; D_3, 2200 IU; E, 40 IU; K, 4.5 mg; thiamin, 12 mg; riboflavin, 12 mg; pyridoxine, 16.7 mg; pantothenic acid, 26 mg; niacin, 130 mg; biotin, 0.20 mg; folic acid, 2.7 mg; B_{12}, 0.004 mg; zinc, 45 mg; manganese, 1100 mg; iron, 90 mg; copper, 12 mg; iodine, 112 mg; cobalt, 1.5 mg; selenium, 0.5 mg.

[3]Proximate composition of diets are means ± SE of two replications.

[4]DE = digestible energy; values were calculated using tabular values for the diet ingredients (NRC 1983).

[5]P:DE = protein to energy ratio; expressed as mg protein/kcal.

Temperature and dissolved oxygen (DO) were monitored twice daily (0800 and 1630) outside the cages, at a depth of 0.75 m, using a YSI Model 58 oxygen meter. If the DO was graphically predicted to decline below 4.0 mg/L, aeration was provided using a paddle-wheel connected to a tractor power take-off (PTO). Weekly measurements of pH were recorded using an electronic pH meter (pH Pen, Fisher Scientific). Total ammonia nitrogen, nitrite, and alkalinity were measured weekly using a DR 2000 (Hach Co., Loveland, Colorado).

Prior to the start of the study, fish were fed a floating, medicated (Romet-30) diet for 5 days due to an infection of *Edwardsiella ictaluri* (ESC). Four weeks later, another outbreak of ESC occurred and fish were fed their respective experimental diets with nitrofuracin added. The antibiotic was added to corn oil and top-dressed onto the diets so that the oil was 0.5% of the diets. This was fed for 5 days. At the conclusion of the study, fish were disposed of and not used for food.

Fish were harvested on 24 September 1992 and were not fed 24 h prior to harvest. Total number and weight of fish in each cage were determined at harvest. Twenty-five fish were randomly sampled from each cage and individually weighed (g) and measured for total length (cm). Ten fish were randomly sampled from each cage for analysis of dressing percentage, abdominal fat, and body weight. Fish were skinned by hand and dressed by removing head and viscera. Abdominal fat was removed, weighed, and reported as a percentage of total weight. Carcasses and waste (head, skin, and viscera) of three fish sampled from each cage were homogenized separately in a blender and analyzed for protein, fat, and moisture as previously described for the diets, except that fat was analyzed by ether extraction (AOAC 1990).

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

Data were analyzed using the SAS ANOVA procedure (Statistical Analysis Systems 1988) for significant differences among treatment means. Means were analyzed by Duncan's multiple range test.

All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984).

RESULTS

Water Quality

Average morning water temperature (±SE) was 23.7±1.3°C, while afternoon water temperature averaged 24.6±1.3°C. Morning dissolved oxygen level averaged 6.0±2.0 mg/L, while the afternoon level was 7.9±2.7 mg/L. Total ammonia nitrogen, nitrite, alkalinity, and pH averaged 0.70±0.31 mg/L, 0.016±0.013 mg/L, 116±0 mg/L, and 8.66±0.53, respectively, during the study. All water quality parameters measured were within accepted values for growth of channel catfish (Boyd 1979).

Growth

Final individual weight, total length, total cage weight, and net weight gain were not significantly different ($P > 0.05$) among treatments and averaged 312 g, 31.3 cm, 62.5 kg, and 39.6 kg, respectively (Table 2). Survival averaged 84.8% and was not significantly different ($P > 0.05$) among treatments. Mortality during the study was associated with the ESC infection. Feed consumption, feed conversion ratio (FCR) and specific growth rate (SGR) were not significantly different ($P > 0.05$) among treatments and averaged 303 g/fish, 1.47 and 1.48%/day, respectively (Table 2).

Dressing Percentage and Body Composition

Dressing percentage was not significantly different ($P > 0.05$) among dietary protein levels and averaged 54.9% (Table 3). Abdominal fat (as a percentage of total body weight) was not significantly different ($P > 0.05$) among treatments and averaged 2.96%. Mean protein content of the carcass was significantly lower ($P < 0.05$) in fish fed the diet containing 27% protein (58.1%) compared to fish fed diets containing 32, 37, and 42% protein (61.2, 62.2, and

TABLE 2. Mean final weight, total length, total weight of fish/cage, percentage weight gain, survival, feed consumed, feed conversion ratio (FCR), and specific growth rate (SGR) of channel catfish reared in cages fed diets containing four different protein levels. Values are means (± SE) of three replications. No significant differences ($P > 0.05$) were found among treatments.

	Dietary Protein (%)			
	27	32	37	42
Mean final weight (g)	319.7 ± 22.9	293.5 ± 4.3	316.2 ± 10.8	317.3 ± 10.6
Total length (cm)	31.9 ± 0.6	31.0 ± 0.2	31.4 ± 0.4	31.4 ± 0.4
Total weight (kg)	61.7 ± 2.8	60.8 ± 4.0	65.7 ± 2.8	61.6 ± 1.2
Net weight gain (%)	244.0 ± 18.9	237.7 ± 13.6	258.7 ± 11.0	263.3 ± 19.6
Survival (%)	85.5 ± 1.3	85.5 ± 2.2	87.2 ± 1.9	80.9 ± 2.8
Feed consumed (g/fish)	308 ± 18	301 ± 4	298 ± 8	303 ± 16
FCR[2]	1.52 ± 0.05	1.55 ± 0.12	1.39 ± 0.06	1.43 ± 0.04
SGR[3]	1.45 ± 0.06	1.44 ± 0.05	1.51 ± 0.04	1.52 ± 0.06

TABLE 3. Mean dressing percentage, moisture, protein, and fat (dry-matter basis) contents in carcasses and waste (skin, head, and viscera) of channel catfish reared in cages fed diets containing four different protein levels. Values are means (± SE) of three replications. Means in the same row with different letters are significantly different ($P < 0.05$).

	Dietary Protein (%)			
	27	32	37	42
Dressing percentage	54.05 ± 0.15	53.06 ± 0.54	57.46 ± 2.68	54.96 ± 0.61
Abdominal fat (%)	2.92 ± 0.22	2.85 ± 0.30	3.02 ± 0.47	3.03 ± 0.37
<u>Carcass</u>				
Moisture (%)	72.10 ± 0.48b	73.56 ± 0.49a	73.67 ± 0.04a	73.06 ± 0.05ab
Protein (%)	58.05 ± 1.35b	61.17 ± 0.64a	62.18 ± 0.59a	63.02 ± 0.44a
Fat (%)	36.61 ± 1.57a	33.47 ± 0.70ab	32.09 ± 1.58b	32.63 ± 0.58ab
<u>Waste</u>				
Moisture (%)	68.58 ± 0.34b	68.77 ± 0.46ab	69.32 ± 0.27ab	70.87 ± 1.35a
Protein (%)	41.89 ± 1.86	43.58 ± 1.87	46.06 ± 0.66	47.79 ± 3.57
Fat (%)	44.22 ± 1.70	43.64 ± 2.13	40.57 ± 1.95	38.68 ± 3.55

63.0%, respectively). Fat content was significantly higher ($P < 0.05$) in fish fed the 27% protein diet (36.6%) than in fish fed the 37% protein diet (32.1%), but not significantly higher ($P > 0.05$) than fish fed diets containing 32 and 42% protein (Table 3). Percentage moisture in carcasses of fish fed the diet containing 27% protein was significantly lower ($P < 0.05$) than in fish fed diets containing 32 and 37% protein, but not significantly different ($P > 0.05$) from fish fed a diet containing 42% protein.

Percentage protein and fat in waste (skin, head, and viscera) were not significantly different ($P > 0.05$) among dietary protein levels (Table 3). Percentage moisture was significantly lower ($P < 0.05$) in fish fed a diet containing 27% protein (68.6%) than in fish fed a diet containing 42% protein (70.9%), but not significantly different from that in fish fed diets containing 32 and 37% protein (68.8 and 69.3%, respectively).

DISCUSSION

Growth

Protein is the most expensive component in catfish diets and is a primary concern in diet formulation. Feed producers desire to provide the minimum level of protein that will supply essential amino acids to give acceptable growth in fish. Data from previous studies indicated that optimal levels of protein were between 25-45% (Hastings and Dupree 1969; Gatlin et al. 1986; Brown and Robinson 1989; Reis et al. 1989). Recently, Li and Lovell (1992a and 1992b) reported that a diet with a lower protein level (26%) could be fed to channel catfish, reared in ponds, if fish were fed to satiation. This is in agreement with reports from E. H. Robinson (pers. comm.). Data from the present study indicate that a diet with 27% protein could be fed to channel catfish reared in cages, without adversely affecting growth and body composition.

Reis et al. (1989) reported that channel catfish reared in ponds had higher weight gains when fed diets containing 35 and 39% protein than fish fed a diet containing 26% protein. Further, fish fed the 26% protein diet had higher fat levels in the dressed carcass than fish fed diets containing 35 and 39% protein. However, Li and Lovell (1992a) reported that weight gains of channel catfish fed to satiation on a diet with 26% protein were similar to fish fed a diet containing 38% protein. Garling and Wilson (1976) reported that a diet with 28% protein gave similar weight gains to catfish as a diet with 36% protein. These conflicting results may be due to previous studies not feeding diets in sufficient quantity for fish to achieve optimum growth. When fish are fed a restricted ration, a diet with higher protein levels may be required (Prather and Lovell 1971; Lovell 1972; Li and Lovell 1992a). However, the present study suggests that when fish are fed to satiation, diets with lower protein levels may be adequate. This is in agreement with other studies (Li and Lovell 1992b; Webster et al. 1992a and 1992b; Robinson and Robinette 1993). Li and Lovell (1992b) suggested that a possible reason for high-protein diets (36 and 40% protein) not producing higher weight gains in channel catfish than fish fed a low-protein (26%) diet might be higher concentrations of ammonia and nitrite in the ponds fed the high-protein diets. However, in the present study, all fish were reared in the same body of water and water quality parameters remained within acceptable limits (Boyd 1979).

Although fish eat to satisfy an energy requirement (Lovell 1979), environmental temperature and stomach volume are also important factors. Maximum weight gain for channel catfish has been reported to occur between 27-30°C (Andrews and Stickney 1972; Helfrich et al. 1981). In the present study, water temperature averaged 24.2°C and fish may not have had as an aggressive feeding response as the response if water temperature was higher. Dietary protein had no effect on food consumption and feed conversion. Feed consumption data are in agreement with Li and Lovell (1992b) who reported that dietary protein level did not affect feed consumption in second-year channel catfish. Feed conversion values were within acceptable values for channel catfish reared in cages (Newton and Robison 1981; Webster et al. 1992a; Webster et al. 1993).

Body Composition

Percentage of fat in the dressed carcasses tended to increase with decreasing dietary protein level. This is in agreement with other studies (Reis et al. 1989; Li and Lovell 1992a and 1992b). Robinson (in press) reported that channel catfish fed a diet containing 28% protein had a higher fat level in the carcass compared to fish fed diets containing 32 and 38% protein. Higher fat levels in the carcass may be due to lower protein to digestible energy (P/DE) ratios (Page and Andrews 1973). An increase in 2-3% fat in the carcass may affect product quality (Tidwell and Robinette 1990).

However, Robinson and Robinette (1993) reported that muscle fat in channel catfish fed a diet containing 32% protein was similar to fish fed a diet with 38% protein. This may have been due to feeding diets which contained high levels of dietary protein and optimal DE/P ratios. It appears that an increase in muscle fat is greater in fish fed diets containing lower percentages (< 28%) of protein (Robinson and Jackson 1991; Robinson and Robinette 1993).

The level of DE in a diet affects the amount of food consumed by fish, and the P/DE ratio in the diet will influence conversion efficiency of the diet (Reis et al. 1989). An excessively high ratio may cause fish to utilize protein as an energy source, whereas fish fed a diet with a low ratio may increase fat deposition in fish. Page and Andrews (1973) demonstrated that the optimum P/DE ratio for weight gain in pond-reared channel catfish was 120 mg of protein/kcal of DE. Reis et al. (1989) reported that between 110-127 mg of protein/kcal of DE was optimum. Tidwell and Robinette (1990) reported that a P/DE ratio of 116 mg of protein/kcal increased fat levels compared to fish fed a diet with a P/DE ratio of 122 mg of protein/kcal. Webster et al. (1993) reported that channel catfish fed diets containing 127-130 mg of protein/kcal of DE had increased carcass fat levels when reared in cages, compared to fish reared in ponds, indicating a diet with a higher protein to energy ratio may be required. However, results from the present study indicate that diets containing between 120-135 mg of protein/kcal do not significantly affect body composition of cage-reared channel catfish.

These data indicate that channel catfish reared in cages can be fed a practical diet with 27% protein without adverse effects on weight gain or body composition, when fed to satiation, compared to fish fed practical diets containing higher percentages of protein. This would indicate that a diet with lower protein levels could be fed to channel catfish reared in cages if skillful, satiation feeding practices are used. This may allow for a reduction in the protein level in the diet and may decrease costs of production.

ACKNOWLEDGMENTS

We thank Darrel Baker, Keenan Bishop, Jackie Lamb, Hank Schweickart, Mac Stone, and Louis Weber for their technical assistance. This project was partially funded by a USDA/CSRS grant to Kentucky State University under agreement KYX-80-92-05A.

REFERENCES

Andrews, J.W. and R.R. Stickney. 1972. Interactions of feeding rates and environmental temperature on growth, food conversion, and body composition of channel catfish. Transactions of the American Fisheries Society 101:94-98.

AOAC (Association of Official Analytical Chemists). 1990. Official Methods of Analysis, 15th edition. AOAC, Inc., Arlington, Virginia.

Boyd, C.E., 1979. Water Quality in Warm-water Fish Ponds. Auburn University Agricultural Experiment Station, Auburn, Alabama.

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

Garling, D.L. and R.P. Wilson. 1976. Optimum dietary protein to energy ratio for channel catfish fingerlings, *Ictalurus punctatus*. Journal of Nutrition 106: 1368-1375.

Gatlin, D.M., W.E. Poe, and R.P. Wilson. 1986. Protein and energy requirements of fingerling channel catfish for maintenance and maximum growth. Journal of Nutrition 116:2121-2131.

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. 1981. Growth response of cage-cultured channel catfish fed two commercial diets. Proceedings of the Annual Conference of the Association of Fish and Wildlife Agencies 35:531-540.

Li, M. and R.T. Lovell. 1992a. Comparison of satiate feeding and restricted feeding of channel catfish with various concentrations of dietary protein in production ponds. Aquaculture 103:165-175.

Li, M. and R.T. Lovell. 1992b. Growth, feed efficiency and body composition of second- and third-year channel catfish fed various concentrations of dietary protein to satiety in production ponds. Aquaculture 103:153-162.

Lovell, R.T. 1972. Protein requirements of cage-cultured channel catfish. Proceedings of the Annual Conference 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 on Finfish Nutrition and Fishfeed Technology 1:555-564.

Lovell, R.T. 1989. Nutrition and Feeding of Fish. Van Nostrand Reinhold, New York.

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

NRC (National Research Council). 1983. Nutrient Requirements of Warmwater Fishes and Shellfishes, revised edition. National Academy Press, Washington, D.C.

Page, J.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 Annual Conference 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-energy ratios. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 27:455-45.

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. in press. Effects of high-protein "finishing" feeds on performance and fat content of channel catfish. Journal of the World Aquaculture Society.

Robinson, E.H. and S. Jackson. 1991. Phase-feeding catfish. Aquaculture Magazine 17(6):79-80.

Robinson, E.H. and H.R. Robinette. 1993. Effects of dietary protein level and feeding regimen on growth and fattiness of channel catfish. Journal of Applied Aquaculture 3(1/2):67-90.

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

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

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. and C. Deyoe. 1969. A review of techniques to hatch and rear channel catfish fingerlings in Kansas and proposed restrictions on nutritional requirements. Transactions of the Kansas Academy of Science 71:491-503.

Webster, C.D., J.H. Tidwell, and D.H. Yancey. 1992a. Effect of protein level and feeding frequency on growth and body composition in cage-reared channel catfish. Progressive Fish-Culturist 54:92-96.

Webster, C.D., J.H. Tidwell, J.A. Clark, and D.H. Yancey. 1992b. Effects of feeding diets containing 34 or 38% protein at two feeding frequencies on growth and body composition of channel catfish. Journal of Applied Aquaculture 1(3):67-80.

Webster, C.D., J.H. Tidwell, L.S. Goodgame, and P.B. Johnsen. 1993. Growth, body composition, and organoleptic evaluation of channel catfish fed diets containing different percentages of distillers grains with solubles. Progressive Fish-Culturist 55:95-100.

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