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Effects of Feeding Diets with and without Fish Meal on the Production of Channel Catfish, *Ictalurus punctatus*, Stocked at Varying Densities

EDWIN H. ROBINSON and MENGHE H. LI
Thad Cochran National Warmwater Aquaculture Center, Mississippi State University, Stoneville, Mississippi, USA

Animal protein, generally fish meal, has traditionally been used in the diet of channel catfish. However, our previous research indicates that animal protein is not needed for growing stocker-size catfish to food fish when the fish are stocked at densities typical of those used in commercial catfish culture. Whether this holds when fish are stocked at high densities is not known; thus, we conducted an experiment to evaluate the effect of feeding diets with and without fish meal to channel catfish stocked in earthen ponds at different densities. Two 32% protein practical diets containing 0% or 6% menhaden fish meal were compared for pond-raised channel catfish, Ictalurus punctatus*, stocked at densities of 14,820, 29,640, or 44,460 fish/ha. Fingerling channel catfish with average initial weight of 48 g/fish were stocked into 30, 0.04 ha ponds. Five ponds were randomly allotted for each fish meal level × stocking density combination. Fish were fed once daily to satiation for two growing seasons. There was a significant interaction between stocking density and fish meal*

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Address correspondence to Edwin H. Robinson, Thad Cochran National Warmwater Aquaculture Center, Mississippi State University, P.O. Box 197 Stoneville MS, 38776. E-mail: ed@drec.msstate.edu

for net production; net production increased in fish fed a diet containing fish meal compared with those fed an all-plant diet at the highest stocking density, but not at the two lower stocking densities. Net production of fish fed diets with and without fish meal increased as stocking density increased. Viewing the main effect means, weight gain decreased and FCR increased for fish stocked at the two highest densities, and survival was significantly lower at the highest stocking density. Visceral fat decreased in fish at the two highest stocking densities. Body composition data were largely unaffected by experimental treatment except for a reduction in percentage of filet fat in fish at the highest stocking density, and fish that were fed diets containing fish meal had a lower percentage of fillet protein and a higher percentage of fillet fat. It appears that at stocking densities two to three times higher than generally used, animal protein (fish meal) may be beneficial in the diet of channel catfish. In regard to stocking densities, high stocking results in higher overall production, but the average fish size decreased as stocking density increases.

KEYWORDS *channel catfish,* Ictalurus punctatus*, fish meal, stocking density, growth*

INTRODUCTION

Proteins of animal origin, particularly fish meals prepared from whole fish, are considered to be nutritionally superior to proteins of plant origin. Although there are exceptions, the superiority of animal proteins is primarily based on the fact that they generally contain a higher level of indispensable amino acids and are more highly digestible by channel catfish, *Ictalurus punctatus,* than plant proteins. Commercial channel catfish diets have traditionally contained relatively high levels of protein supplied in part by animal protein supplements, but there is a growing body of evidence that animal protein can be reduced or eliminated in diets for food-size catfish (Robinson & Li 1994, 1999, 2006; Robinson, Li & Manning, 2000). The studies that we have conducted thus far concerning eliminating animal protein from catfish diets have been conducted with channel catfish stocked at rates from about 14,820 to 24,700 fish/ha. Since catfish stocking densities vary greatly from farm to farm and from time to time, we wanted to see if fish meal becomes a limiting factor on fish growth at high stocking densities. Therefore, we conducted the study reported here to evaluate diets with and without menhaden fish meal fed to channel catfish stocked into earthen ponds at densities of 14,820, 29,640, and 44,460 fish/ha.

MATERIALS AND METHODS

Two 32% protein practical diets containing 0% or 6% menhaden fish meal (Table 1) were formulated using ingredients typically used in commercial catfish diets to meet or exceed all known nutritional requirements of channel catfish (NRC, 1993). The experimental diets were not formulated to be isocaloric, because in commercial diet formulations there is no practical way to adjust digestible energy and maintain dietary fat and fiber levels in the desirable ranges. The all-plant diet had a digestible energy to protein (DE:P) ratio of 9.1 and the diet containing 6% fish meal had a DE:P ratio of 9.3. The diets were manufactured as extruded floating pellets in an experimental diet mill at the Delta Western Research Center (DWRC), Indianola, Mississippi. Fresh lots of each diet were manufactured monthly. All dietary ingredients were obtained from the DWRC and were from commercial sources. Dietary protein levels were verified by the combustion method (AOAC, 2000) using an FP-2000 protein determinator (Leco Corp., St. Joseph, Michigan).

Fingerling channel catfish with initial weights of 48 g/fish were stocked into 30, 0.04-ha earthen ponds at a rate of 14,820, 29,640, or 44,460 fish/ha at the DWRC. Five ponds were used for each stocking density × fish meal level combination. Fish were fed once daily to apparent satiation for two growing seasons. Fish were fed as much diet as they

TABLE 1 Ingredient Composition of Experimental Diets (Expressed as Percentages on an As-Fed Basis)

	Fish meal (%)	
Ingredient	0	6
Soybean meal (48%[1])	57.1	48.3
Menhaden fish meal (61%)	0.0	6.0
Corn, grain	25.3	28.8
Wheat middlings	15.0	15.0
Calcium phosphate (dibasic)	1.0	0.33
Vitamin premix[2]	0.05	0.05
Trace mineral premix[2]	0.1	0.1
Catfish offal oil[3]	1.5	1.5
DE/P ratio[4] (kcal/g)	9.14	9.34
Dietary protein by analysis (% on a 90% dry matter basis)	31.5	31.5

[1]Numbers in parentheses represent percentage crude protein.
[2]Catfish vitamin and trace mineral premixes were the same as described by Robinson and Li (1996).
[3]Sprayed on the finished diet pellets.
[4]DE/P ratio = digestible energy to crude protein ratio. DE was estimated based on tabular values of NRC (1993) and Robinson and Li (1996).

would consume within 20 minutes to achieve apparent satiation. During the winter, fish were fed according to recommended winter feeding schedules (Robinson & Li, 1996). Amounts of diet consumed by fish in each pond were recorded daily to determine diet consumption per fish at the end of the study. During the two growing seasons, water temperature and dissolved oxygen were monitored in early morning, mid-afternoon, and throughout the night using an YSI model 58 polarographic oxygen meter (Yellow Springs Instrument Company, Yellow Springs, Ohio). Emergency aeration, provided by a 0.5 horse power electrical aerator (Model AF-55, Air-O-Lator Corp., Kansas City, Missouri) was used in each pond when dissolved oxygen levels decreased to 4 mg/L. Ammonia, nitrite, and pH were measured weekly from May to September with a field kit (Hach Chemical Co., Ames, Iowa). Chloride concentration was maintained at 50 mg/L and above to alleviate possible nitrite toxicity. Water quality was maintained in ranges considered adequate for optimum channel catfish performance (Tucker & Robinson, 1990). Dead fish were removed from ponds, weighed, and recorded for correction of feed conversion ratio (FCR).

At the end of the study, all fish were harvested and weighed. Thirty fish ranging in size from about 680 g to 1135 g were taken from each pond to determine processing yield. The fish from each pond were killed by stunning with a 40-volt electric pulse (Sylvester Inc., Louisville, Mississippi) followed by cranial concussion, and weighed collectively. The visceral fat was removed and weighed. Then the heads were removed mechanically (Baader North America, Indianola, Mississippi) and the carcasses were eviscerated manually. The carcasses (with skin, but without head and viscera) were weighed, filleted, and skinned with a fillet machine (Baader North America). Fillets were trimmed by hand and weighed. Visceral fat content and yields of carcasses, shank fillets, and nuggets were determined as percentages of whole body weight. Fillets (one fillet per fish, 10 fish per pond) were stored at –20°C for later proximate analyses.

Samples of individual fillets were ground into a paste using a food processor, and part of the paste was lyophilized for 16 to 18 hours before protein and fat analyses. Proximate analyses were conducted in duplicate on individual fillet samples. Crude protein (combustion method), crude fat (ether extraction), and moisture (oven drying) of fillet samples were determined using methods described by the AOAC (2000).

Data were subjected to analysis of variance (Steel, Torrie, & Dickey, 1997) and Fisher's protected least significant difference procedure with Statistical Analysis System version 8.0 software (SAS Institute Inc., Cary, North Carolina). Ponds were used as the experimental units, and variation among ponds within a treatment was used as the experimental error in tests of significance. A significance level of $P \leq 0.05$ was used.

RESULTS

There was a significant interaction between stocking density and fish meal level for net production (Table 2); fish meal increased production at the highest stocking density, but not at the two lower stocking densities. Net production of fish fed diets with and without fish meal increased as stocking density increased. Viewing the main effect means, weight gain decreased and FCR increased for fish stocked at the two highest densities, and survival was significantly lower at the highest stocking density (Table 2).

Based on individual treatment means, there were few differences in visceral fat and processed yield data (Table 3). The size of the fish processed was smaller in the group fed a diet containing no fish meal at the highest stocking density, and carcass yield was lower for these fish. Visceral fat decreased in fish at the two highest stocking densities.

Body composition data were largely unaffected by experimental treatment except for a reduction in percentage of filet fat in fish at the highest stocking density, and fish that were fed diets containing fish meal had a

TABLE 2 Means of Production Characteristics of Pond-Raised Channel Catfish Stocked at Three Densities and Fed a 32% Protein Diet with or Without Fish Meal for Two Growing Seasons

Stocking density (fish/ha)	Fish meal (%)	Net production (kg/ha)	Diet consumption (g/fish)	Weight gain[1] (g/fish)	Diet conversion (diet/gain)	Survival (%)
Treatment means[2]						
14,820	0	13,739 d	2,192	1,083	2.03	85.6
14,820	6	12,667 d	2,082	1,063	1.96	80.6
29,640	0	17,989 c	1,655	774	2.14	78.4
29,640	6	19,209 bc	1,738	812	2.14	79.8
44,460	0	20,459 b	1,421	629	2.26	73.2
44,460	6	23,793 a	1,504	695	2.17	76.9
Pooled SEM		859	47.2	24.6	0.06	2.7
Main effect means[3]						
14,820		13,203	2,137 u	1,073 u	2.00 v	83.1 u
29,640		18,599	1,696 v	793 v	2.14 u	79.1 uv
44,460		22,126	1,463 w	662 w	2.22 u	75.1 v
	0	17,396	1,756	829	2.14	79.1
	6	18,557	1,775	856	2.10	79.1
ANOVA (*P* values)						
Stocking density (SD)		<0.001	<0.001	<0.001	0.006	0.02
Fish meal (FM)		0.10	0.62	0.16	0.30	0.98
SD × FM		0.050	0.065	0.20	0.71	0.23

[1]Initial weight was 48 g/fish.
[2]Treatment means represent average values of five ponds. Individual treatment means followed by different letters were different ($P \leq 0.05$) by Fisher's protected LSD procedure. A LSD procedure was conducted for individual means only if there was an interaction.
[3]Main effect means within a column followed by different letters were different (P ≤ 0.05) by Fisher's protected LSD procedure.

TABLE 3 Means of Processing Yield[1] of Pond-Raised Channel Catfish Stocked at Three Densities and Fed a 32% Protein Diet with or Without Fish Meal for Two Growing Seasons

Stocking density (fish/ha)	Fish meal(%)	Weight of processed fish (g/fish)	Visceral fat (%)	Carcass[2] yield (%)	Fillet yield (%)	Nugget yield (%)
Treatment means[3]						
14,820	0	972 a	2.89	67.1 a	37.1	9.16
14,820	6	947 a	3.22	66.9 a	36.9	9.22
29,640	0	918 a	2.55	66.9 a	36.0	8.91
29,640	6	956 a	2.77	67.0 a	36.9	9.12
44,460	0	833 b	2.24	65.9 b	37.9	9.35
44,460	6	974 a	2.60	67.2 a	37.6	9.62
Pooled SEM		30.7	0.14	0.28	0.84	0.21
Main effect means[4]						
14,820		960	3.05 u	67.0	37.0	9.19
29,640		937	2.66 v	66.9	36.5	9.01
44,460		904	2.42 v	66.6	37.8	9.49
	0	908	2.56 y	66.6	37.0	9.14
	6	959	2.86 x	67.0	37.2	9.31
ANOVA (*P* values)						
Stocking density (SD)		0.20	<0.001	0.26	0.29	0.07
Fish meal (FM)		0.04	0.01	0.09	0.84	0.28
SD × FM		0.04	0.86	0.03	0.69	0.86

[1]Processing yield is expressed as a percentage of whole fish weight.
[2]Without head and viscera, but with skin.
[3]Treatment means represent average values of five ponds per treatment with 30 fish per pond. A Fisher's protected LSD procedure was not conducted for individual means because there was no interaction.
[4]Main effect means within a column followed by different letters were different ($P \leq 0.05$) by Fisher's protected LSD procedure.

lower percentage of fillet protein (Table 4). Fillets from these fish also contained a higher level of fat ($P < 0.09$).

DISCUSSION

Although animal protein, typically fish meal, has traditionally been used in channel catfish diets, research data from previous studies support the hypothesis that animal protein is not necessary in the diets of channel catfish grown from stockers to food size (Robinson & Li, 1994, 1999, 2006; Robinson, Li, & Manning, 2000). Data from the present study also support this thesis, at least for channel catfish stocked at a typical density of 14,820 fish/ha. However, when stocking densities were increased by two- to three-fold, net production increased in ponds in which the fish were fed diets containing fish meal. The increased production was apparently due to a slightly better weight gain for fish fed diets containing fish meal. Though not significant on an individual fish basis, when translated into net production, there was a difference. The reason for this response appears to be

TABLE 4 Means of Fillet Composition[1] of Pond-Raised Channel Catfish Stocked at Three Densities and Fed a 32% Protein Diet with or Without Fish Meal for Two Growing Seasons

Stocking density (fish/ha)	Fish meal (%)	Moisture (%)	Protein (%)	Fat (%)
Treatment means[2]				
14,820	0	76.9	17.1	5.12
14,820	6	76.3	16.9	6.05
29,640	0	76.5	17.5	5.00
29,640	6	76.8	16.9	5.41
44,460	0	77.2	17.4	4.43
44,460	6	78.0	16.6	4.56
Pooled SEM		0.39	0.23	0.36
Main effect means[3]				
14,820		76.6	17.0	5.58 u
29,640		76.6	17.2	5.21 u
44,460		77.6	17.0	4.50 v
	0	76.9	17.3 x	4.85
	6	77.0	16.8 y	5.34
ANOVA (*P* values)				
Stocking density (SD)		0.02	0.57	0.02
Fish meal (FM)		0.63	0.001	0.09
SD × FM		0.18	0.36	0.52

[1]Fillet composition is expressed as a percentage of wet tissue.

[2]Treatment means represent average values of five ponds per treatment with 10 fish per pond. A Fisher's protected LSD procedure was not conducted for individual means because there was no interaction.

[3]Means of main effects within a column followed by different letters were different ($P \leq 0.05$) by Fisher's protected LSD procedure.

related to diet intake; although we attempted to feed the fish to satiety, in essence diet was restricted at the higher stocking densities. Diet intake decreased on a per fish basis as stocking density increased. We know from previous studies that when diet is restricted, higher protein diets are beneficial (Li & Lovell, 1992; Li et al., 2006). It may be that diets containing fish meal provided additional nutrients or energy that improved fish weight gain. However, this is speculative because all diets were formulated to meet or exceed the nutrient and energy requirements of channel catfish. Also, if the data are viewed overall without regard to stocking density, there were no significant differences in performance of fish fed diets with or without fish meal. But, it may be that we underestimated the energy content of the diets containing fish meal and that the additional weight gain of the fish was due to an increase in energy intake of fish fed diets containing fish meal. This seems to be indicated by the increase in visceral fat in fish fed fish-meal diets and by fillet composition data in which fish fed diets with fish meal had less fillet protein and a somewhat higher level of fillet fat (4.85% vs. 5.34%).

As stocking density increased, individual fish weights decreased, but net production increased because there were more fish in each pond. The reduction in individual fish weights was due to a decrease in diet consumption and an increase in FCR as stocking densities increased. Apparently the fish were unable to consume enough diet at the higher stocking densities to meet energy needs. This is evidenced by the fact that visceral fat and fillet fat decreased in fish at the higher stocking densities. This response is typical of what we have seen in the past in regard to high stocking densities (Li et al., 2003). The reason for the reduced diet intake is unclear. At first glance, one might attribute such a response to poor water quality because of the high density of fish and of the high feeding rates, but the water quality parameters we commonly measure (oxygen, temperature, nitrite, and ammonia) remained in a range suitable for catfish throughout the study regardless of experimental treatment (Tucker & Robinson, 1990). The response may be due to unknown stressors resulting from crowding at the higher stocking densities. Survival decreased at the highest stocking density, which indicates that the fish were under some sort of stress.

In conclusion, at stocking densities typically used in the commercial catfish industry, animal protein does not appear to be needed in the diet for growing stocker-size catfish to food fish. However, at densities two to three times higher than generally used, animal protein (fish meal) may be beneficial. In regard to stocking densities, high stocking results in higher overall production but the average fish size decreases as stocking density increases. At the highest stocking density, average fish size was at the low end of the desirable range for a marketable catfish even after two growing seasons.

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