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Catfish Protein Nutrition

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Catfish Protein Nutrition

Preface

This bulletin presents data from studies conducted at the Delta Branch Experiment Station in Stoneville that provide new information on practical requirements of catfish for protein quantity and quality. Recommendations are given on dietary protein and animal protein concentrations of commercial catfish feeds. English units are used to present technical data because the bulletin is intended to be useful to a broad audience, including practicing nutritionists, catfish producers, catfish feed manufacturers, and scientists.

Introduction

Feed cost is the major variable operating cost associated with channel catfish production, and commercial feeds contain a liberal amount of expensive, high-quality protein. Channel catfish can assimilate relatively high levels of dietary protein; feeds used for catfish grow out have traditionally contained up to 35% dietary protein. Consequently, considerable research effort has been expended to determine the quantity and quality of dietary protein necessary to achieve optimum performance of catfish.

The optimum level and quality of dietary protein to include in commercial catfish diets are dependent on several factors, including the balance between energy and protein in the diet, the amino acid composition of the diet, and feeding rate. Protein is needed to promote catfish growth, while less expensive feed ingredients like corn and wheat are sufficient for providing energy. The problem is that catfish readily use expensive dietary protein as an energy source as well. Catfish diets should be balanced to ensure that adequate levels of protein and the less-expensive energy sources are supplied in proper proportions to minimize the use of protein for energy and to maximize protein deposition.

The quality of protein sources used in catfish feeds must be taken into account to ensure that amino acid requirements are met. Protein quality is dictated primarily by the concentrations and bioavailability of indispensable amino acids in the protein. Indispensable amino acids are nutrients that are not synthesized in the body and must be supplied in the diet. Proteins of animal origin, particularly fish meals prepared from whole fish, are considered nutritionally superior to proteins of plant origin. Animal proteins generally contain a higher level of indispensable amino acids and are more highly digestible by catfish than plant proteins. Commercial catfish feeds have typically contained relatively high levels of protein supplied in part by animal protein supplements. However, there is a growing body of evidence that dietary protein levels can be reduced and that animal protein can be reduced or eliminated in feeds for food-size catfish.

Feeding rate may also affect the optimum dietary protein level. Fish fed at a restricted rate may require more or higher-quality protein, particularly if feeding is severely restricted. In practice, though feeding rates may vary considerably, most commercial catfish producers generally do not restrict feed below 80 pounds to 120 pounds per acre per day. Recommendation on the quantity and quality of protein needed in catfish diets given in this bulletin are suitable for producers feeding in this range. This publication summarizes various studies conducted at the National Warmwater Aquaculture Center in Stoneville on the protein nutrition of channel catfish grown from fingerlings to marketable-size catfish.

Protein Requirement Studies

A series of practical feeding studies to investigate protein requirements (both quantity and quality) of channel catfish has been conducted over the last several years in Stoneville. All experiments were conducted in 0.1-acre earthen ponds stocked at rates of 6,000 to 10,000 fish per acre and managed according to industry practices. Five ponds were typically used for each treatment. All fish were fed all they would consume (to satiation) once daily for the duration of the experiment (generally 150 days), except in experiments where restricted feeding was a part of the experimental protocol. All feeds were practical-type floating pellets prepared from ingredients typically used in commercial catfish formulations (Table 1). Fish size, stocking density, and other essential details are given in tables for the respective experiments. Dietary treatments for each experiment are given in Table 2.

Table 1. Percentage ingredient composition of basal diets used in the various experiments.[1]

Ingredients	Pct. protein	
	28	32
Soybean meal (48%)[2]	26.3	36.1
Cottonseed meal (41%)[2]	12.0	12.0
Menhaden fish meal (61%)[2]	4.0	8.0
Meat and bone/blood meal (65%)[2]	4.0	0.0
Corn screenings	46.2	36.7
Wheat middlings	4.0	4.0
Dicalcium phosphate	1.25	1.0
Trace mineral premix[3]	0.025	0.025
Vitamin C-free premix[4]	0.1	0.1
Stay C[5]	0.125	0.125
Catfish oil	2.0	2.0
DE/P ratio[6]	10.0	9.1

[1]A general description of diets used in each experiment is given in sections covering specific experiments. In this table, percentage ingredient composition is presented on an as-fed basis.
[2]Percentage of protein.
[3]Meets National Research Council (1983) requirements for catfish (Nutritional Requirements of Warmwater Fishes and Shellfishes, National Academy of Science, Washington DC).
[4]Meets National Research Council (1983) requirements for catfish (Nutritional Requirements of Warmwater Fishes and Shellfishes, National Academy of Science, Washington DC), except for vitamin C.
[5]Stay C™, manufactured by Hoffmann LaRoche, Inc. of Nutley, NJ, has 15% activity.
[6]DE/P = digestible energy to protein ratio.

Table 2. Dietary treatments for each experiment.

Experiment number										
1 (% protein)	2 (% protein)	3 (% protein)	4 (% protein)	5 (% protein/ feeding rate)	6 (% protein/ feeding rate)	7 (% protein)	8 (% animal protein)	9 (% animal protein)	10 (% protein/ animal protein)	11 (% protein/ animal protein)
26	16	28	28	24/S[1]	28/80[3]	28	8 (MFM[4])	0	28/0	26/0
28	20	32	32	24/R[2]	28/100[3]	32	8 (MBBM[5])	8	28/8	26/2
32	24			28/S	28/120[3]				32/0	26/4
35	28			28/R	28/S				32/8	26/6
	32			32/S	32/80					28/0
				32/R	32/100					28/2
					32/120					28/4
					32/S					28/6
										32/0
										32/2
										32/4
										32/6

[1]S = satiation.
[2]R = restricted.
[3]Maximum feeding rate (pounds/acre/day).
[4]Menhaden fish meal.
[5]Meat and bone/blood meal.

EXPERIMENT 1

In Experiment 1, diets containing 26%, 28%, 32%, or 35% protein were evaluated using large (half pound) channel catfish fed once daily to satiation (Table 3). Weight gain was not significantly different among fish fed the different diets. Percentage dressout was lower for fish fed the 35% protein diet. Percentage protein in fillets was lower for fish fed the 26% protein diet. No significant differences were observed in percentage visceral fat or fillet fat and moisture among fish fed the various diets. The cause of the reduced percentage dressout in fish fed the 35% protein diet is not known, but it was likely caused by factors other than diet. For example, the sample size may have been too small to determine difference accurately. Generally, percentage dressout in catfish is not affected significantly unless the fish are fed diets containing less than 26% protein.

Results from Experiment 1 suggest that low-protein diets can be used for grow out of large, stocker-size catfish when the fish are fed all they will consume. Feed conversion ratio data are not presented because the data were based on a 500-fish sample.

EXPERIMENT 2

From work conducted in Stoneville and from research reported in the scientific literature, it appeared that catfish could be raised on diets containing as little as 24% protein if the fish were fed to satiation. However, there were no data available on catfish fed diets containing less than 24% protein. Thus, in Experiment 2, we evaluated diets ranging from 16% to 32% protein for grow out of channel catfish fed once daily to satiation (Tables 4-5).

Fish fed the 24% or 28% protein diets had the highest rates of weight gain. Although fish fed the 16% and 20% protein diets did not grow as well as those fed higher dietary levels of protein, their growth was rather remarkable considering that dietary protein was

Table 3. Mean of performance, dressout, and body composition data of channel catfish fed diets containing various concentrations of dietary protein (Experiment 1).[1]

Dietary protein[2]	Weight gain[3]	Carcass dressout	Visceral fat	Fillet composition		
				Fat	Protein	Moisture
%	*lb/fish*	*%*	*%*	*%*	*%*	*%*
26	0.98	63.3 a	2.7	5.6	15.8 b	77.3
28	0.96	63.5 a	3.0	5.2	16.4 ab	76.8
32	0.93	62.4 ab	2.9	5.4	16.6 a	76.5
35	0.93	61.8 b	2.9	5.2	16.9 a	76.4

[1]Data were based on a sample of 500 fish per pond. Stocking rate was 10,000 fish per acre. Fish were fed to satiation once daily. Means within a column followed by the different letters were different ($P \leq 0.05$).
[2]Digestible energy to protein ratios: 26% protein diet, 10.8 kcal/g protein; 28%, 10.1 kcal/g; 32%, 9.1 kcal/g; and 35%, 8.4 kcal/g.
[3]Mean initial weight was 500 pounds per 1,000 fish.

Table 4. Mean of performance data of channel catfish fed diets containing various concentrations of dietary protein (Experiment 2).[1]

Dietary protein[2]	Weight gain[3]	Feed consumption[4]	FCR[5]	Survival	Hematocrit
%	*lb/fish*	*lb/fish*		*%*	*%*
16	0.62 b	0.93 ab	1.49 a	96.6	27.1
20	0.65 b	0.95 ab	1.46 ab	97.6	27.9
24	0.72 a	1.01 a	1.40 bc	91.0	28.3
28	0.73 a	0.98 a	1.35 cd	96.0	28.0
32	0.68 ab	0.88 b	1.30 d	92.5	27.3

[1]Means within a column followed by the different letters were different ($P \leq 0.05$).
[2]Digestible energy to protein ratios: 16% protein diet, 16.2 kcal/g protein; 20%, 13.1 kcal/g; 24%, 11.3 kcal/g; 28%, 9.7 kcal/g; and 32%, 8.9 kcal/g.
[3]Mean initial weight was 60 pounds per 1,000 fish. Stocking rate was 10,000 fish per acre.
[4]Fish were fed to satiation once daily.
[5]Feed conversion ratio.

Table 5. Mean of dressout and body composition data of channel catfish fed diets containing various concentrations of dietary protein (Experiment 2).[1]

Dietary protein[2]	Carcass dressout	Visceral fat	Fillet composition			
			Protein	Fat	Moisture	Ash
%	%	%	%	%	%	%
16	55.1	5.2 a	15.7 c	8.2 a	74.4 b	1.10 b
20	55.7	4.5 b	15.6 c	7.8 a	75.0 ab	1.15 ab
24	56.2	3.8 c	16.1 bc	5.8 b	76.4 a	1.21 a
28	56.5	3.2 d	17.2 ab	5.2 bc	76.1 ab	1.21 a
32	57.0	3.1 d	18.2 a	4.4 c	76.1 ab	1.12 b

[1]Means within a column followed by the different letters were different ($P \leq 0.05$).
[2]Digestible energy to protein ratios: 16% protein diet, 16.2 kcal/g protein; 20%, 13.1 kcal/g; 24%, 11.3 kcal/g; 28%, 9.7 kcal/g; and 32%, 8.9 kcal/g.

reduced by as much as 40% to 50% of that found in a typical commercial channel catfish diet.

Feed conversion ratios of fish fed diets containing less than 28% protein were somewhat higher. There was more visceral fat in fish fed diets containing less than 28% protein, but percentage dressout was not significantly different among fish fed the various diets. Since fish fed the 16% protein diet had 60% more visceral fat, it is logical to expect carcass dressout to be lower than fish fed 28% or 32% protein diets. It is possible that there were differences in dressout that we were unable to detect.

Although it may be more economical to use a diet containing 16% protein, it is not recommended since fish fed diets containing less than 26% protein are generally fattier. The increase in fat deposition in fish fed low-protein diets may be related to the digestible energy to protein ratio in the diet. As the ratio increases above the optimum range of about 8.5 to 9.5 kcal/g protein, fattiness is significantly increased. Data from this study suggest that 24% dietary protein is adequate for maximum growth of channel catfish fed to satiation.

EXPERIMENT 3

In Experiment 3, channel catfish were fed either a 28% or 32% protein diet once daily to satiation. There were no significant differences in weight gain or feed conversion ratios between fish fed the two diets (Table 6). Fillet fat was higher in fish fed the 28% protein diet, but carcass dressout was not significantly affected by diet. An increase in fillet fat in fish fed the 28% protein diet was unexpected since there are generally no significant differences in body fat of fish fed 28% or 32% protein diets. This study demonstrates that channel catfish growth and feed conversion are basically the same whether the fish are fed 28% or 32% protein, as long as they are fed as much as they can consume. These results are similar to those of other studies conducted at Stoneville.

EXPERIMENT 4

Experiment 4 also compared 28% and 32% protein diets. Fish fed the 28% protein diet converted feed the same as those fed the 32% protein diet, but they actually gained more weight because they consumed more

Table 6. Mean of performance, dressout, and body composition data of channel catfish fed a 28% or a 32% protein diet (Experiment 3).[1]

Dietary protein[2]	Weight gain[3]	Feed consumption[4]	FCR[5]	Carcass dressout	Visceral fat	Fillet composition		
						Protein	Fat	Moisture
%	lb/fish	lb/fish		%	%	%	%	%
28	1.03	1.24	1.27	60.6	2.9	15.2	6.6 a	76.1 b
32	0.92	1.27	1.37	61.3	3.0	14.7	5.1 b	78.9 a

[1]Means within a column followed by the different letters were different ($P \leq 0.05$).
[2]Digestible energy to protein ratios: 28% protein diet, 10 kcal/g protein; and 32%, 8.7 kcal/g.
[3]Mean initial weight was 77 pounds per 1,000 fish. Stocking rate was 6,000 fish per acre.
[4]Fish were fed to satiation once daily.
[5]Feed conversion ratio.

Table 7. Mean of performance, dressout, and body composition data of channel catfish fed a 28% or a 32% protein diet (Experiment 4).[1]

Dietary protein[2]	Weight gain[3]	Feed consumption[4]	FCR[5]	Carcass dressout	Visceral fat	Fillet composition		
						Protein	Fat	Moisture
%	*lb/fish*	*lb/fish*		*%*	*%*	*%*	*%*	*%*
28	0.75 a	1.00 a	1.35	61.8	3.1	17.6	7.6	74.2
32	0.61	0.83	1.34	62.2	3.4	17.1	6.1	75.1

[1]Means within a column followed by the different letters were different ($P \leq 0.05$).
[2]Digestible energy to protein ratios: 28% protein diet, 10.2 kcal/g protein; and 32%, 9.1 kcal/g.
[3]Mean initial weight was 80 pounds per 1,000 fish. Stocking rate was 10,000 fish per acre.
[4]Fish were fed to satiation once daily.
[5]Feed conversion ratio.

feed (Table 7). We did not expect this response, and there is no logical reason the fish consumed more of the 28% protein feed. This response has not been observed in other studies we have conducted. There were no significant differences in fillet fat or carcass dressout between the two groups of fish. These data support the contention that dietary protein can be reduced from 32% to 28% in catfish fed once daily to satiation.

EXPERIMENT 5

Since all previous research on dietary protein level had been conducted with fish fed to satiation, Experiment 5 was conducted to evaluate dietary protein level and feeding rate. Catfish were fed either a 24%, 28%, or 32% protein diet to satiation or at a restricted rate not to exceed 120 pounds per acre per day.

There were no differences in weight gain or feed conversion ratio regardless of feeding rate or dietary protein level (Table 8). Fish fed the 24% protein diet were fattier and had a reduced carcass dressout (Table 9). Feeding rate did not affect fattiness or dressout.

Upon examination of feed consumption data, it was apparent that there were no differences in the amount of feed consumed between fish on the two treatments.

Table 8. Mean of performance data of channel catfish fed diets containing various concentration of dietary protein at two feeding rates (Experiment 5).

Dietary protein[1]	Feeding rate[2]	Feed consumption	Weight gain[3]	FCR[4]	Survival
%		*lb/fish*	*lb/fish*		*%*
Individual treatment means[5]					
24	Restricted	2.04	1.13	1.80	92.7
24	Satiation	2.12	1.17	1.81	94.9
28	Restricted	1.97	1.11	1.78	99.8
28	Satiation	2.05	1.16	1.76	96.7
32	Restricted	2.07	1.20	1.73	97.6
32	Satiation	2.08	1.18	1.77	91.9
Pooled means[6]					
24		2.08	1.15	1.80	93.8
28		2.01	1.13	1.77	98.2
32		2.08	1.19	1.75	94.8
	Restricted	2.02	1.14	1.77	96.7
	Satiation	2.08	1.17	1.78	94.5
Analysis of variance[7]					
Feeding rate		NS	NS	NS	NS
Dietary protein		NS	NS	NS	NS
Interaction		NS	NS	NS	NS

[1]Digestible energy to protein ratios: 24% protein diet, 11.7 kcal/g protein; 28%, 10.2 kcal/g; and 32%, 9 kcal/g.
[2]Restricted = not more than 120 pounds of feed per acre per day.
[3]Mean initial weight was 820 pounds per 1,000 fish. Stocking rate was 7,000 fish per acre.
[4]Feed conversion ratio.
[5]Least significant difference (LSD) test was not conducted because the interaction was not significant.
[6]The LSD test was not conducted because the main effects were not significant.
[7]NS = not significant ($P > 0.05$).

Table 9. Mean of dressout and body composition data of channel catfish fed diets containing various concentrations of dietary protein at two feeding rates (Experiment 5).

Dietary protein[1]	Feeding rate[2]	Dressout	Visceral fat	Fillet composition			
				Protein	Fat	Moisture	Ash
%		%	%	%	%	%	%
Individual treatment means[3]							
24	Restricted	58.3	3.2	17.7	7.4	73.6	1.17
24	Satiation	58.9	2.9	17.6	7.3	73.8	1.17
28	Restricted	60.1	2.3	17.5	6.7	74.6	1.28
28	Satiation	59.7	2.4	17.9	5.9	75.1	1.19
32	Restricted	60.3	2.2	18.4	5.4	74.7	1.29
32	Satiation	59.3	2.4	17.6	6.2	74.8	1.17
Pooled means[4]							
24		58.6 b	3.1 a	17.6	7.4 a	73.7	1.17
28		59.9 a	2.4 b	17.7	6.3 b	74.8	1.23
32		59.8 a	2.3 b	18.0	5.9 b	74.8	1.23
	Restricted	59.6	2.6	17.8	6.5	74.3	1.24
	Satiation	59.3	2.6	17.7	6.5	74.6	1.17
Analysis of variance[5]							
Feeding rate		NS	NS	NS	NS	NS	NS
Dietary protein		S	S	NS	S	NS	NS
Interaction		NS	NS	NS	NS	NS	NS

[1]Digestible energy to protein ratios: 24% protein diet, 11.7 kcal/g protein; 28%, 10.2 kcal/g; and 32%, 9 kcal/g.
[2]Restricted = not more than 120 pounds of feed per acre per day.
[3]Least significant difference (LSD) test was not conducted because the interaction was not significant.
[4]The LSD test was conducted only for variables with a significant main effect. Means pooled by dietary protein followed by different letters were different ($P \leq 0.05$, LSD test).
[5]S = significant ($P \leq 0.05$); NS = not significant ($P > 0.05$).

Table 10. Mean of performance data of channel catfish fed diets containing 28% or 32% protein at different feeding rates (Experiment 6).

Dietary protein[1]	Feeding rate	Feed consumption	Weight gain[2]	FCR[3]	Survival
%	*lb/A/day*	*lb/fish*	*lb/fish*		%
Individual treatment means[4]					
28	≤ 80	2.21	1.41	1.57	89.5
28	≤ 100	2.77	1.58	1.76	81.8
28	≤ 120	3.05	1.71	1.78	84.4
28	Satiation	3.07	1.84	1.68	89.9
32	≤ 80	2.43	1.40	1.74	84.3
32	≤ 100	2.67	1.52	1.76	87.4
32	≤ 120	3.04	1.76	1.73	84.7
32	Satiation	3.21	1.81	1.79	86.5
Pooled means[5]					
28		2.77	1.63	1.70	86.4
32		2.83	1.62	1.75	85.7
	≤ 80	2.32 c	1.40 c	1.65	86.9
	≤ 100	2.72 b	1.54 bc	1.76	84.6
	≤ 120	3.05 a	1.73 ab	1.75	84.6
	Satiation	3.14 a	1.82 a	1.73	88.2
Analysis of variance[6]					
Dietary protein		NS	NS	NS	NS
Feeding rate		S	S	NS	NS
Interaction		NS	NS	NS	NS

[1]Digestible energy to protein ratios: 28% protein diet, 10.2 kcal/g protein; and 32%, 9 kcal/g.
[2]Mean initial weight was 58 pounds per 1,000 fish.
[3]Feed conversion ratio.
[4]Least significant difference (LSD) test was not conducted because the interaction was not significant.
[5]The LSD test was conducted only for variables with a significant main effect. Pooled means within a column followed by different letters were different ($P \leq 0.05$, LSD test).
[6]S = significant ($P \leq 0.05$); NS = not significant ($P > 0.05$).

Table 11. Mean of dressout and body composition data of channel catfish fed diets containing 28% or 32% protein at different feeding rates (Experiment 6).

Dietary protein[1]	Feeding rate	Dressout	Visceral fat	Fillet composition			
				Protein	Fat	Moisture	Ash
%	*lb/A/day*	%	%	%	%	%	%
Individual treatment means[2]							
28	≤ 80	55.6	3.0	16.2	3.8	78.0	1.13
28	≤ 100	55.2	3.3	15.5	5.0	77.7	1.13
28	≤ 120	55.1	3.4	15.9	5.2	77.4	1.14
28	Satiation	55.9	4.4	15.5	5.3	77.7	1.11
32	≤ 80	56.4	2.5	15.8	3.6	78.9	1.16
32	≤ 100	55.6	2.9	16.2	4.1	78.1	1.12
32	≤ 120	56.6	3.6	16.0	5.0	77.5	1.13
32	Satiation	56.7	3.8	16.0	5.2	77.2	1.15
Pooled means[3]							
28		55.4 y	3.5 x	15.8	4.8	77.7	1.13
32		56.3 x	3.2 y	15.8	4.5	77.9	1.14
	≤ 80	56.0	2.7 d	16.0	3.7 b	78.4	1.15
	≤ 100	55.4	3.1 c	15.8	4.5 a	77.9	1.12
	≤ 120	55.8	3.5 b	15.7	5.1 a	77.4	1.13
	Satiation	56.3	4.1 a	15.7	5.2 a	77.5	1.13
Analysis of variance[4]							
Dietary protein		S	S	NS	NS	NS	NS
Feeding rate		NS	S	NS	S	NS	NS
Interaction		NS	NS	NS	NS	NS	NS

[1]Digestible energy to protein ratios: 28% protein diet, 10.2 kcal/g protein; and 32%, 9 kcal/g.
[2]Least significant difference (LSD) test was not conducted because the interaction was not significant.
[3]The LSD test was conducted only for variables with a significant main effect. Pooled means within a column followed by different letters were different ($P \leq 0.05$, LSD test).
[4]S = significant ($P \leq 0.05$); NS = not significant ($P > 0.05$).

That is, fish fed to satiation consumed the same amount of feed as those receiving the restricted ration. These data show that although fish convert feed and grow equally well on a 24% protein diet, their dressed yield was reduced as compared with the other two diets. Based on these data, we concluded that feeding a 28% protein feed to fish fed no more than 120 pounds per acre per day provides an adequate amount of protein. Also, it appeared that the fish were satiated at this level of feeding.

EXPERIMENT 6

Since there were no differences in fish fed to satiation or at a restricted rate in Experiment 5, Experiment 6 was conducted to compare a 28% and a 32% protein diet in which feed was more severely restricted. Fish either were fed once daily to satiation or were restricted to no more than 80, 100, or 120 pounds per acre per day.

There were no significant differences in weight gain and feed conversion among fish fed the 28% or 32% protein diet when compared at each feeding level (Table 10). As the feeding rate increased, feed consumption and weight gain generally increased. The exception to this trend was that feed consumption and weight gain were the same whether fish were restricted to 120 pounds of feed or fed to satiation. Apparently, this level of feeding was enough to satiate the fish. These results were similar to those from Experiment 5. Feed conversion ratio was unaffected by feeding rate.

Fish fed the 28% protein diet had a lower carcass dressout than those fed the 32% protein feed (Table 11). This response has not been consistent in our studies. In fact, there are generally no differences in carcass dressout between fish fed 28% or 32% protein diets. Concentration of dietary protein did not affect fillet fat of fish, but feeding rate did affect body fattiness. Visceral fat increased as feeding rate increased. Fillet fat increased in fish fed more than 80 pounds per acre per day. However, fillet fat content was the same in fish fed to satiation and fish fed 100 or 120 pounds per acre per day.

These results helped to refine our knowledge of protein requirements in the channel catfish further. It appears that 28% protein is adequate for catfish growth even when feed is restricted to 80 pounds per acre per day.

EXPERIMENT 7

All experiments conducted thus far supported the contention that a 28% protein diet was adequate to meet the protein requirements of catfish. However, in two of the studies, either dressed yield was slightly lower or fillet fat was slightly higher in fish fed a 28% protein diet as compared with those fed 32%. Since this response was not consistent among the experiments, and since we had hand dressed the fish ourselves, another experiment was conducted to compare 28% and 32% protein diets. The difference in this experiment was that the fish were processed using commercial equipment or hand filleted by employees from a local processing plant to mimic commercial conditions.

There were no differences in feed consumption or weight gain regardless of diet (Table 12). Feed conversion ratio was lower in fish fed the 28% protein diet. This response is inconsistent with those of the other studies and is not likely due to diet. There is no reason to expect fish to convert the 28% protein diet any better than a 32% protein diet. There were also no differences in percentage visceral fat or in carcass, fillet, and nugget dressout between fish fed the two diets (Table 12). These data indicate that there are no differences between growth and dressed yield of fish fed either a 28% or a 32% protein diet.

Table 12. Means of performance and dressout data of channel catfish fed a 28% or a 32% protein diet (Experiment 7).[1]

Dietary protein[2]	Feed consumption	Weight gain[3]	FCR[4]	Survival	Visceral fat	Dressout	Fillet	Nugget
%	*lb/fish*	*lb/fish*		*%*	*%*	*%*	*%*	*%*
28	1.44	0.84	1.70 b	96.3	3.09	60.3	36.1	8.9
32	1.39	0.79	1.77 a	96.7	3.05	60.4	35.8	9.0

[1]Means within a column followed by different letters were different ($P \leq 0.05$).
[2]Digestible energy to protein ratios: 28% protein diet, 10.2 kcal/g protein; and 32%, 9 kcal/g.
[3]Mean initial weight was 88 pounds per 1,000 fish. Stocking rate was 7,500 fish per acre. The fish were fed to satiation once daily.
[4]Feed conversion ratio.

EXPERIMENT 8

Fish meals prepared from whole fish, such as menhaden or herring, are highly palatable and digestible sources of essential amino acids, energy, phosphorus, and other nutrients. However, there is interest in replacing fish meal in catfish feeds because it is expensive and its availability is often variable. Experiment 8 was conducted to evaluate a blend of meat, bone, and blood meal (65% protein) as a replacement for menhaden fish meal in catfish feeds. The blended product is a mixture of meat and bone meal and blood meal in proportions that mimic the nutritional profile of menhaden fish meal. The product is often less expensive per unit of protein than fish meal. In this study, channel catfish were fed a 32% protein diet with either 8% menhaden fish meal or 8% meat and bone/blood meal. Fish were fed once daily to satiation.

There were no significant differences in weight gain, feed conversion ratio, visceral fat, carcass dressout, or fillet composition in fish fed the two diets (Table 13). Results suggest that meat and bone/blood meal is highly palatable to catfish and can be used to replace menhaden fish meal in catfish feeds completely.

EXPERIMENT 9

Experiment 9 was conducted to evaluate the need for animal protein in catfish diets. Channel catfish were fed a 32% protein diet that contained either 8% animal protein (4% menhaden fish meal + 4% meat and bone/blood meal) or no animal protein (primary protein source was soybean meal). Fish were fed once daily to satiation.

There were no significant differences in feed consumption, feed conversion, or weight gain of fish regardless of diet (Table 14). There were no differences in carcass dressout or fillet proximate composition between the two groups of fish. Fish fed the all-plant diet had a lower level of visceral fat. This was presumably because the all-plant diet contained less digestible energy than the diet containing animal protein. These data indicate that animal protein is not needed in channel catfish diets, at least not for fish stocked at a large size (0.4 pound).

Table 13. Mean of performance, dressout, and body composition data of channel catfish fed a 32% protein diet containing two animal protein supplements (Experiment 8).[1]

Diet[2]	Weight gain[3]	FCR[4]	Survival	Carcass dressout	Visceral fat	Fillet composition			
						Protein	Fat	Moisture	Ash
	lb/fish		*%*	*%*	*%*	*%*	*%*	*%*	*%*
Menhaden fish meal (8%)	0.61	1.33	99.9	62.2	3.4	17.0	6.2	75.1	1.2
Meat and bone/blood meal (8%)	0.59	1.36	100.1	61.9	3.4	16.0	5.8	75.8	1.2

[1]Means were not different (P > 0.05).
[2]Digestible energy to protein ratios: diet with 8% menhaden fish meal, 8.8 kcal/g protein; and diet with 8% meat and bone/blood meal, 8.5 kcal/g protein.
[3]Mean initial weight was 100 pounds per 1,000 fish. Stocking rate was 10,000 fish per acre. The fish were fed to satiation once daily.
[4]Feed conversion ratio.

Table 14. Mean of performance, dressout, and body composition data of channel catfish fed diets with or without animal protein (Experiment 9).[1]

Diet[2]	Weight gain[3]	Feed consumption	FCR[4]	Carcass dressout	Visceral fat	Fillet composition		
						Protein	Fat	Moisture
	lb/fish	*lb/fish*		*%*	*%*	*%*	*%*	*%*
Animal protein	1.28	2.18	1.71	61.1	4.1 a	17.3	5.5	75.6
No animal protein	1.20	2.09	1.73	60.7	3.2 b	17.0	4.7	76.4

[1]Means within a column followed by different letters were different (P ≤ 0.05).
[2]Digestible energy to protein ratio of the diet containing animal protein was 9.1 kcal/g protein. For diets without animal protein, it was 8.8 kcal/g protein.
[3]Mean initial weight was 400 pounds per 1,000 fish. Stocking rate was 10,000 fish per acre. The fish were fed to satiation once daily.
[4]Feed conversion ratio.

EXPERIMENT 10

Experiment 10 was conducted to compare an all-plant diet and diets containing animal protein at two protein levels, 28% and 32%. Fish were fed once daily to satiation. There were no differences in feed consumption, feed conversion, weight gain, visceral fat, or body composition of fish regardless of diet (Table 15). These data show that an all-plant diet can be used for catfish grow out without detrimental effects using fingerlings of the size typically stocked in commercial ponds. In addition, the data also show that an all-plant diet containing 28% protein is as effective as a similar diet containing 32% protein.

Table 15. Mean of performance, dressout, and body composition data of channel catfish fed experimental diets (Experiment 10).

Dietary protein[1]	Animal protein	Weight gain[2]	Feed consumption[3]	FCR[4]	Survival	Dressout	Visceral fat	Fillet composition			
								Protein	Fat	Moisture	Ash
%	*%*	*lb/fish*	*lb/fish*		*%*	*%*	*%*	*%*	*%*	*%*	*%*
Individual treatment means[5]											
28	0	0.74	1.13	1.54	89.9	54.0	4.1	15.5	6.1 b	76.8	1.00
32	0	0.72	1.12	1.55	95.6	54.3	3.5	14.9	7.6 ab	75.6	0.96
28	8	0.78	1.15	1.47	93.7	53.2	4.0	14.7	8.6 a	74.6	1.01
32	8	0.74	1.05	1.43	95.0	53.7	2.6	15.6	6.3 b	76.4	0.99
Pooled means[6]											
28		0.76	1.14	1.50	91.8	53.6	4.0 a	15.1	7.4	75.7	1.00
32		0.73	1.08	1.49	95.3	54.0	3.1 b	15.3	7.0	76.0	0.97
	0	0.73	1.13	1.55	92.8	54.2	3.8	15.2	6.9	76.2	0.98
	8	0.76	1.10	1.45	94.4	53.5	3.3	15.2	7.5	75.5	1.00
Analysis of Variance[7]											
Dietary protein		NS	NS	NS	NS	NS	S	NS	NS	NS	NS
Animal Protein		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	NS	NS	NS	S	NS	NS

[1]Digestible energy to protein ratio of the 28% protein diet with animal protein was 10.1 kcal/g protein; without animal protein, 10.2 kcal/g. Digestible energy to protein ratio of the 32% protein diet with animal protein was 9.1 kcal/g protein; without animal protein, 9 kcal/g.
[2]Mean initial weight was 58 pounds per 1,000 fish. Stocking rate was 10,000 fish per acre.
[3]The fish were fed to satiation once daily.
[4]Feed conversion ratio.
[5]Means followed by different letters were different ($P \leq 0.05$, least significant difference test, LSD). The LSD test was not conducted for individual means if the interaction was not significant.
[6]Pooled means followed by different letters were different ($P \leq 0.05$, LSD test). The LSD test was not conducted for pooled means if the main effect was not significant ($P > 0.05$).
[7]S = significant ($P \leq 0.05$); NS = not significant ($P > 0.05$).

EXPERIMENT 11

Experiment 11 was conducted to compare diets containing graded levels of protein (26%, 28%, or 32%) and varying levels of animal protein (0%, 2%, 4%, or 6%). Meat and bone/blood meal was used as the source of animal protein. Fish were fed once daily to satiation.

There were no significant differences in feed consumption, feed conversion, or weight gain among fish fed the various diets (Table 16). Comparing the data averaged over all treatments, fish fed the 26% protein diet had a slightly lower carcass dressout as compared with fish fed the 28% and 32% protein diets (Table 17). These data indicate that animal protein is not essential for channel catfish, even when the dietary protein is reduced to as low as 26%.

Table 16. Mean of performance data of channel catfish fed experimental diets (Experiment 11).

Dietary protein[1]	Animal protein	Weight gain[2]	Feed consumption[3]	FCR[4]	Survival	Hematocrit
%	*%*	*lb/fish*	*lb/fish*		*%*	*%*
Individual treatment means[5]						
26	0	0.84	1.20	1.42	95.0	28.6
26	2	0.84	1.31	1.54	97.9	24.3
26	4	0.89	1.33	1.51	99.0	24.7
26	6	0.85	1.31	1.54	96.1	26.5
28	0	0.86	1.30	1.52	97.2	25.1
28	2	0.85	1.27	1.49	97.7	26.0
28	4	0.90	1.31	1.46	96.0	24.9
28	6	0.88	1.28	1.46	98.8	25.8
32	0	0.87	1.34	1.53	97.0	25.3
32	2	0.96	1.43	1.48	97.4	26.5
32	4	0.89	1.32	1.49	98.8	23.8
32	6	0.85	1.30	1.53	99.3	26.3
Pooled Means[6]						
26		0.86	1.29	1.50	97.0	26.1
28		0.87	1.29	1.48	97.4	25.4
32		0.89	1.35	1.51	98.1	25.4
	0	0.86	1.28	1.49	96.4	26.3
	2	0.89	1.34	1.50	97.7	25.6
	4	0.89	1.32	1.48	97.9	24.5
	6	0.86	1.29	1.51	98.0	26.2
Analysis of variance[7]						
Dietary protein		NS	NS	NS	NS	NS
Animal protein		NS	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	NS

[1]Animal protein level did not affect the digestible energy to protein ratios. The ratio of the diet containing 26% protein was 10.9 kcal/g protein; 28%, 10.2 kcal/g; and 32%, 9 kcal/g.
[2]Mean initial weight was 152 pounds per 1,000 fish. Stocking rate was 10,000 fish per acre.
[3]The fish were fed to satiation once daily.
[4]Feed conversion ratio.
[5]Least significant difference (LSD) test was not conducted for individual means because the interaction was not significant.
[6]The LSD test was not conducted for pooled means because the main effect was not significant.
[7]NS = not significant ($P > 0.05$).

Table 17. Mean of dressout and body composition data of channel catfish fed experimental diets (Experiment 11).

Dietary protein[1]	Animal protein	Carcass dressout	Visceral fat	Fillet composition			
				Protein	Fat	Moisture	Ash
%	%	%	%	%	%	%	%
Individual treatment means[2]							
26	0	55.8	3.3	16.4	7.6	74.3	1.11
26	2	54.9	3.5	16.0	7.0	75.8	1.10
26	4	55.3	3.5	15.8	6.8	75.0	1.11
26	6	55.6	3.9	16.9	7.2	74.3	1.05
28	0	56.0	3.3	15.7	6.2	76.1	1.12
28	2	56.9	3.2	16.6	6.8	75.0	1.10
28	4	56.6	3.5	17.0	6.5	75.3	1.11
28	6	55.8	3.5	17.4	6.4	74.8	1.10
32	0	56.2	3.0	17.2	6.1	75.6	1.13
32	2	56.1	2.8	16.3	5.5	76.6	1.12
32	4	56.9	2.9	17.6	6.7	74.4	1.11
32	6	56.1	2.9	17.4	5.1	75.9	1.06
Pooled means[3]							
26		55.4 b	3.6 a	16.3	7.1 a	74.8	1.09
28		56.3 a	3.4 a	16.7	6.5 ab	75.3	1.11
32		56.3 a	2.9 b	17.2	5.8 b	75.6	1.11
	0	56.0	3.2	16.4	6.6	75.3	1.12
	2	56.0	3.2	16.3	6.4	75.8	1.11
	4	56.3	3.3	16.8	6.7	74.9	1.11
	6	55.8	3.4	17.2	6.2	75.0	1.07
Analysis of variance[4]							
Dietary protein		S	S	NS	S	NS	NS
Animal protein		NS	NS	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	NS	NS

[1]Digestible energy to protein (DE/P) ratios: 26% protein diet, 10.9 kcal/g protein; 28%, 10.2 kcal/g; and 32%, 9 kcal/g. Animal protein level did not affect the DE/P ratio of the diet.
[2]Least significant difference (LSD) test was not conducted for individual means because the interaction was not significant.
[3]Pooled means followed by different letters were different ($P \leq 0.05$, LSD test). The LSD test was not conducted for pooled means if the main effect was not significant ($P > 0.05$).
[4]S = significant ($P \leq 0.05$); NS = not significant ($P > 0.05$).

Summary

A 32% crude protein feed containing 8% animal protein has generally been accepted as the standard for the commercial catfish industry. However, a sizeable body of evidence supports the contention that dietary protein in catfish feeds can be reduced and the amount of animal protein can be decreased or eliminated without limiting fish growth. Data presented in this bulletin support these arguments.

Regarding the optimum level of dietary protein in catfish diets, it is difficult to make a blanket recommendation since management practices vary greatly among catfish producers. However, a 28% protein diet appears to be a good economical choice if feed is not restricted to less than 80 to 100 pounds per acre per day. Although lower levels of dietary protein can support rapid catfish growth, reducing dietary protein too much will increase fish fattiness to an unacceptable level.

Fattiness is inevitable since it is an integral part of growing animals for meat. However, increasing body fat beyond the level set by heredity is undesirable. High levels of body fat may negatively affect processing yields. In addition, there are negative connotations linked to animal fat consumption because of associated health risks. There are no significant differences in body fat and processing yields between fish fed a 28% protein diet and those fed a 32% protein diet.

Fish meal is a high-quality protein source considered indispensable in catfish diets because of its superior complement of indispensable amino acids and its value as an attractant. However, data presented in this bulletin demonstrate that other less expensive animal protein sources can be used to replace fish meal in catfish diets. A blend of meat and bone and blood meals is as effective as fish meal in promoting catfish growth. Also, data indicate that plant protein sources can be used to replace or reduce the use of animal protein.

There are indications from work at other universities that animal protein may be needed in catfish diets, particularly for fish fed low-protein diets. However, our data suggest that all-plant-protein diets are adequate for catfish fed diets containing as little as 26% protein. Based on amino acid composition, solvent-extracted dehulled soybean meal is the best plant protein supplement available for use in catfish feeds. All-plant-protein diets prepared from soybean meal are highly palatable to catfish and meet all amino acid requirements. Also, properly balanced mixtures of soybean meal, cottonseed meal, and supplemental lysine can be used to supply indispensable amino acids.

In conclusion, data presented in this bulletin indicate that levels of dietary protein and animal protein can be reduced in commercial catfish feeds. Although a diet containing 24% or 26% dietary protein is adequate for rapid catfish growth, we recommend using a 28% protein feed with or without an animal protein supplement. The 28% protein diet provides a margin of safety and will not result in accumulation of excessive body fat. We recognize that some catfish producers may insist animal protein be included in the diet. If an animal protein supplement is used, we recommend that feed processors use no more than 3% fish meal or a blend of meat and bone/blood meal. The choice between the fish meal and blend should be based on which product is the most economical.

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