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9. ABSTRACT

Published reports have shown that the optimum level of protein in feeds for growth of intensively cultured channel catfish has ranged from 25 to 46 percent. The figures are based on the specific percentages of protein felt best for catfish growth under the particular experimental conditions. The most important factors affecting these growth responses of channel catfish when fed feeds containing variable levels of crude protein, based on several experiments, are discussed in this report. These factors are: 1) size of fish, 2) temperature, 3) natural food available, 4) amount of supplemental ration, 5) amount of non-protein energy in the diet, and 6) quality of protein. There are others (not examined here), such as physical properties of the feed (digestibility, for example), various stresses on the fish, and the list could be continued. But each of these must be considered when interpreting research data or developing productive diets in which quantitative protein requirements of channel catfish are concerned.

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FACTORS AFFECTING OPTIMUM PROTEIN PERCENTAGES IN FEEDS FOR GROWTH BY CHANNEL CATFISH IN PONDS

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INTRODUCTION

Reports from published literature have indicated that the optimum level of protein in feeds for growth of intensively cultured channel catfish has ranged from 25 to 46% (Hastings, 1967; Prather and Lovell, 1971; Tiemeire and Deyoe, 1969). In all of these studies the researchers were most likely justified in making their conclusions that a specific percentage of protein was optimum for growth of channel catfish under their experimental conditions. This is because a number of factors influence the growth response of channel catfish when fed feeds containing variable levels of crude protein. Some of the most important are in the list below:

1. Size of fish
2. Temperature
3. Natural food available
4. Amount of supplemental ration
5. Amount of nonprotein energy in the diet
6. Quality of protein

DISCUSSION

Size of fish

Fish, like warmblooded animals, generally have higher protein requirements during early growth than during later phases of growth. Page and Andrews (1973) found that small catfish responded to higher protein levels than did larger fish in raceways. However, in ponds, natural foods contribute significantly to the protein requirement of small catfish. This protein is primarily of animal origin, coming from insects, larvae, crustaceans and the like, and constitutes at least 50% of the moisture-free weight of the material the fish ingests from the pond (Hickling, 1962). Thus, a significant dietary contribution from this source would reduce the protein requirement of the supplemental diet for small catfish in ponds.

Temperature

DeLong et. al. (1958) found that the minimum percentage of dietary protein for maximum growth of chinook salmon was higher at 14 C than at 8 C. Andrews and Page (1973) reported that channel catfish in raceways did not respond to increased levels of protein in the diet at 23 C unless additional energy (corn meal) was included, but at 28 C the additional energy was not needed. Hastings (1974) reported that at temperatures below 24 C channel catfish in ponds grew no better on 35 than 25% protein feeds; however, when water temperature exceeds 24 C the fish gained more on 30 and 35% protein feeds than on the 25% protein feed. Hastings (1969) has contended that water temperature is a major reason for lower protein requirements being found for channel catfish grown in northern ponds (Tiemeire and Deyoe, 1969) than have been found with catfish grown in the lower Mississippi River delta (Hastings, 1969).

Natural pond food

As indicated previously, the natural pond food consumed by catfish is an excellent protein source. The importance of this supply is influenced by natural pond productivity and biomass of fish per unit of pond space. Obviously, natural food influences the optimum protein percentage of supplemental feed for small catfish more than it does that of feeds for larger fish which are more dependent on supplemental feed for their nutriment. Also, the number of fish stocked per acre will inversely affect the magnitude of contribution of the natural protein to the fish's diet. Data in Table 1 illustrate the effect of pond stocking density on growth response of channel catfish to diets containing two levels of protein of similar quality. In 1970, ponds at Auburn University were stocked with 4,000 fish per acre and fed supplemental feeds containing either 32 or 45% protein. The percentage of the total protein coming from animal sources was essentially the same for both feeds. In 1971, the same ponds were stocked with only 2,000 channel catfish per acre and the same experimental feeds and system of feed allocation were used as were applied the previous year. Under those cultural conditions, the difference in weight gains from the two feeds was appreciably greater when 4,000 fish were stocked per acre than when there were half that many fish per acre. One reason for this difference is that the natural productivity of the pond contributed more protein to the diets of the fish in the ponds where there were fewer fish.

Daily feed allowance

For optimum growth, channel catfish need a given quantity of protein (as well as other nutrients) in their daily food intake, this quantity being dependent upon characteristics of the fish, the water, and the diet. Thus, it follows that the protein percentage in the supplemental feed must be higher in order to meet the fish's daily protein need when the daily feed allowance is, for example, 1.5% of fish weight, assuming that the supplemental feed is the fish's primary source of protein.

Swingle (1959), in the early years of catfish culture concluded that 30 to 35 pounds per acre per day was the maximum amount of Auburn No. 2 feed to put into ponds stocked at 1,500 to 4,000 fish per acre in Alabama. He stated that this quantity was the maximum amount of feed that a catfish pond could safely "handle"; higher inputs of feed were more likely to cause oxygen depletions and excessively dense phytoplankton blooms. Granting that the fish and bacteria in ponds can probably "safely" oxidize more feed than 30 to 35 lbs per day, it is the phytoplankton, with their extreme diurnal oxygen demands and susceptibility to die-off, that are the culprits. However, at the present time most fish culturists are in agreement that around 35 lbs per acre per day is the maximum safe level of food input for static ponds. The schedule in Table 2 has been followed at Auburn University for the last several years where we have stocked 3,000 to 4,000 fish per acre in static ponds and anticipated an average harvest size of 0.9 to 1 lb in 200 days. As shown in the table, as fish approach maximum size, the feeding rate decreases to 1.5% or less of fish weight. By feeding floating feeds and observing feeding activity, we have found that during the latter phase of the growing period when water quality is poorest, channel catfish intensively stocked in static ponds will effectively comsume less than 2% of their weight in feed allowance per day. It is our opinion that the accummulation of metabolic byproducts and the extreme diurnal variation of oxygen concentration (2 p.p.m., A.M. vs. 10 p.p.m., P.M.) in static ponds restricts the appetite of channel catfish during the latter phase of the growing period.

Thus, the limitations of static pond culture essentially confine feeding to an allowance schedule not greatly different from that in Table 2. Using this schedule, channel catfish fingerlings stocked at densities of 4,000 per acre were fed 32 or 40% protein diets for 200 days. Growth responses of the fish, represented by the 1970 data in Table 1, are evidence that when high stocking densities are used and the maximum daily feed allowance is limited to 30 to 40 lbs per acre, the 32% protein diet did not provide enough protein. In 1971 (Table 2), when there were only 2,000 fish per acre the effect of the difference in diet protein percentage upon growth was not nearly so great.

In subsequent catfish feeding studies at Auburn University we have found that 3,000 channel catfish per acre can be grown to 1 lb size in 200 days in static ponds, following the feeding schedule shown in Table 2 and using feeds containing 35% good quality protein. Studies at other stations where lower protein levels were found to be optimum involved either less fish production per acre or higher feeding rates.

Nonprotein energy in the diet

Nail (1962) demonstrated that 0.23 g of available carbohydrate (dextrin) would spare 0.05 g of protein (casein) in channel catfish diets over a range of dietary protein percentages. Andrews and Page (1973) reported that corn meal spared protein in diets of catfish fed in raceways.

A study was conducted at Auburn University in 1972 to evaluate the effects of various dietary protein-energy ratios on growth and body composition of channel catfish in ponds receiving a maximum daily feed allowance of 35 pounds per acre. The experimental design, a 3 x 2 factoral model, included diets of three protein percentages (42, 36 and 29), each fed at two energy levels (1,000 and 1,300 kcal ME/lb). The primary sources of nonprotein energy were corn and animal fat. The protein sources were fish meal and equal parts of peanut meal and soybean meal. The nonnutritive bulk was supplied by soybean mill-feed. The ratio of animal to plant protein was kept constant in each diet.

The effects of energy level on growth response by channel catfish fed various levels of dietary protein are summarized in Figure 1. At the lower energy level, the difference in growth response among fish fed the 29, 36 or 42% protein diets was not statistically significant ($P < .05$). At the higher energy level, the fish showed successive growth increases when dietary protein was increased to 36% and to 42%. Interestingly, the poorest response was from the fish fed the high protein - low energy diet. Apparently, this diet contained too little nonprotein energy for this level of protein. The fact that the growth response from this diet was poorer than those from diets of the same energy level but lower protein percentages indicates that there was perhaps a metabolic anomaly caused by the large amount of protein in the presence of the small amount of nonprotein energy.

Quality of protein

There is relatively little information available concerning interrelationships between quantity and quality of protein in catfish diets, especially in pond culture systems. A study was designed at Auburn University in 1973 to provide more information on the effect of the quality of protein in the ration on the optimum level of protein. Nine experimental diets were fed to channel catfish, stocked 3,000 per acre in earthen ponds, over a 198-day growing season. The daily feed allowance followed the schedule shown previously (Table 2). The nine diets (Table 3) contained three percentages of protein (28, 36 and 43), each fed either in an all-plant diet, a diet containing only 1/6 fish meal protein, or a diet containing 1/3 fish meal protein.

Table 4 summarizes the production responses of the fish fed the experimental feeds. Under our stocking and feeding conditions, i.e., 3,000 fish per acre and not feeding over 35 pounds per acre per day, all-plant diets provided for relatively satisfactory yields. As percentage of protein increased in the all-plant diets, yield per acre significantly increased. However, when a small amount of fish meal was included in the diets, very little additional growth resulted when total protein was increased from 36 to 43%. Increasing the fraction of fish meal protein to 1/3 of the total protein was a significant improvement over the 1/6 fish meal diets only at the 29% protein level. At the lowest protein level (28 or 29%), the small (1/6) substitution of fish meal for plant protein did not result in a great improvement in fish growth, but the larger (1/3) fraction of fish meal protein was necessary to affect significant improvement in growth. At the two higher total protein levels (36 and 43%), the lower fraction of fish meal protein was adequate to balance the essential amino acids in the fish's diet under these conditions. These data generally agree with other data from our station indicating that a 35% protein diet, containing 8.8% fish meal and good quality plant protein (soybean and peanut meal) and a total of 545 kcal/kg (1,200 kcal/lb) of ME, is optimum for the management and yield conditions discussed previously. However, if we had stocked 4,000 fish per acre instead of 3,000, the 43% protein diets would probably have shown superiority.

CONCLUSION

To reiterate, several factors have a profound influence on the optimum protein level for growth for channel catfish. Those discussed, size of the fish, water temperature, natural pond food, amount of supplemental ration, protein-energy relationships, and quality of protein are all important. There are others, such as physical properties of the feed (digestibility, for example), various stresses on the fish, and the list could be continued. But each of these must be considered, when interpreting research data or developing productive diets, where quantitative protein requirements of channel catfish are concerned.

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Table 1

Average Yields per Acre and Feed Conversion Ratios for Channel Catfish in Ponds at Two Stocking Densities and Fed Diets of Two Protein Percentages

Date	Dietary Protein (%)	Stocking Density (Fish/acre)	Yield (lb/acre)	Feed Conversion Ratio
1970	45	4,000	3,412	1.16
	32	4,000	2,446	1.65
1971	45	2,000	2,200	1.34
	32	2,000	2,030	1.45

Table 2

Daily Feed Allowance Schedules for Channel Catfish Stocked in Ponds at 3,000 to 4,000 Fish per Acre and Fed from Fingerling (4-inch) to Harvest (1-pound) Size at the Auburn Fishery Research Unit[1]

Date	Daily Feeding Rate as Percentage of Fish Weight	Pounds of Feed per Acre per Day
April 15-June 24	4	3-12
June 25-August 31	3	15-29
September 1-October 15	2.5-1.5	35
October 15-October 31	1.5-1.3	40-30

[1] Feed allowances adjusted biweekly.

Table 3

Experimental Diets Containing Three Percentages of Protein and Three Levels of Fish Meal at Each Protein Percentage Fed to Channel Catfish in Ponds (3,000/Acre) for 198 Days

Diet	Percentage Crude Protein	Fraction of Protein from Fish Meal	Estimated M.E. (kcal/kg)
1	28	0	545
2	36	0	545
3	43	0	545
4	29	1/6	545
5	36	1/6	545
6	43	1/6	545
7	29	1/3	545
8	35	1/3	545
9	43	1/3	545

Table 4

Average Production Responses from Channel Catfish in Ponds Fed Experimental Diets of Three Protein Percentages Containing Three Levels of Fish Meal

Diet	Yield (lb/acre)[1]	Percentage of Fish ≥ 12 Inches	Return Above Feed Cost/Acre ($)
28% Protein, all plant	2,300^{a}	86	748
36% Protein, all plant	2,475^{b}	94	773
43% Protein, all plant	2,640^{c}	87	787
29% Protein, 1/6 F.M.	2,440^{a,b}	90	759
36% Protein, 1/6 F.M.	2,910^{d}	96	920
43% Protein, 1/6 F.M.	3,010^{d}	91	925
29% Protein, 1/3 F.M.	2,760^{c,d}	96	861
35% Protein, 1/3 F.M.	2,940^{d}	98	847
43% Protein, 1/3 F.M.	3,030^{d}	96	843

[1] All means not followed by the same superscript are statistically different (P .05).

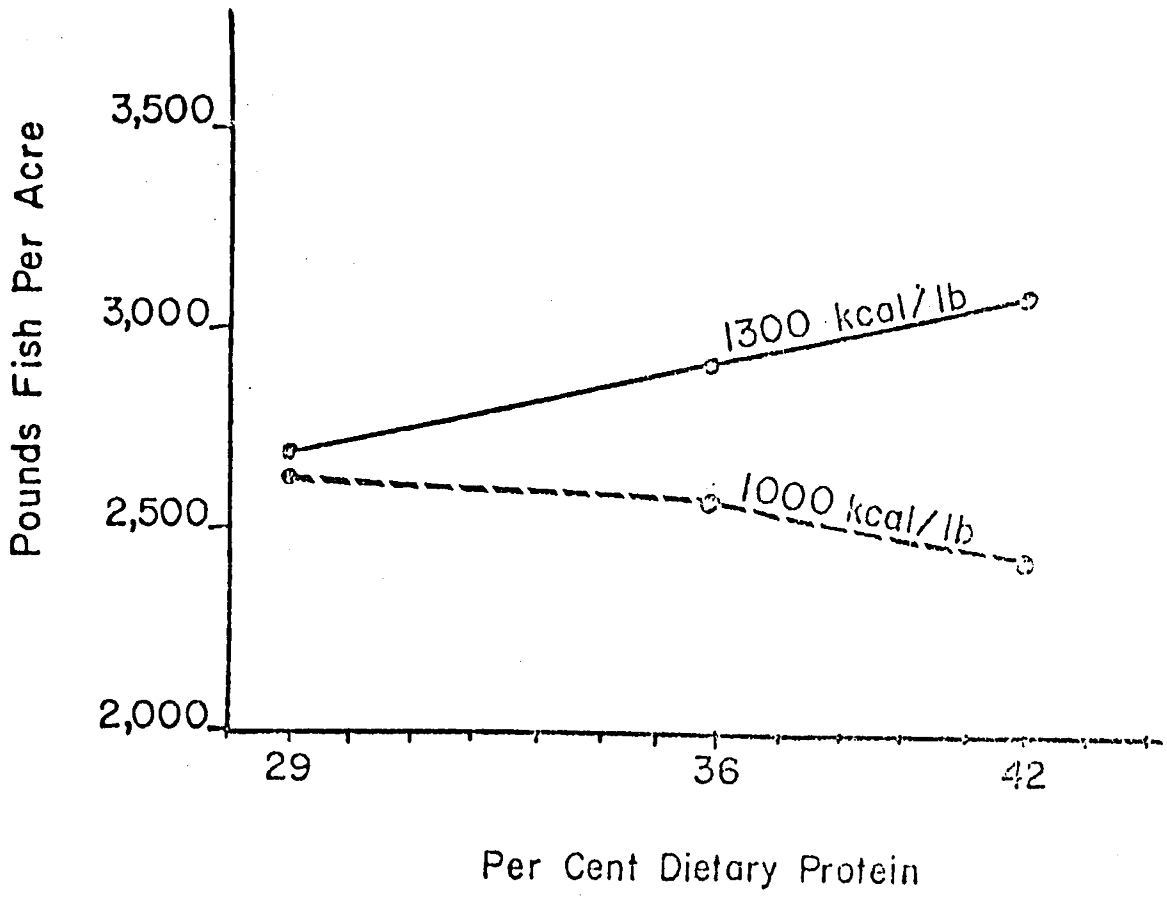

Figure 1. Yield of catfish per acre from diets containing three protein percentages at high and low energy levels fed for 165 days in earthen ponds.