EFFECTS OF DIETARY ENERGY LEVEL, PROTEIN TYPE, AND FLAVORING AGENT IN EXTRUDED FEED FOR RACEWAY CULTURE OF CHANNEL CATFISH

by

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B.S. Kansas State University, 1984

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

Approved by:

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ACKNOWLEDGEMENTS

The author wishes to gratefully acknowledge the encouragement, support, and labor provided by Dr. Carol Klopfenstein, his major professor, during the course of this research and the preparation of this manuscript. The support and encouragement of Dr. Harold Klaassen and Dr. Charles Deyoe is also appreciated.

Special thanks are due to those people who donated their time and energy to this project, specifically Wayne Schope, Mark Klopfenstein, and the Kansas Department of Wildlife & Parks staff at the Milford Fish Hatchery. The author would also like to thank Dr. John Boyer, Dr. James Higgins, and Dr. Sallie McNulty of the Kansas State University Statistics Department.

This manuscript is dedicated to Lana McAfee, the author's wife, for her moral support and patience during the project.

INTRODUCTION

Warmwater fish culture facilities used today include raceways, ponds, and tank arrangements. In deciding which system to use, one must balance the cost of land, water and energy. Ponds are more cost-effective when water costs exceed land costs, whereas raceways are more effective when land is more expensive than water.

The raceway-type culture system is increasing in popularity for many reasons. This system makes it possible for increased production in a relatively small volume of water, as well as allowing for easier handling, feeding, grading, and observation of fish. With the use of flushing systems in which water can be changed on a daily (or even hourly) basis, the fish can be grown in higher quality water.

Gradual movement of the channel catfish industry to intensive production in raceways has inspired recent studies on factors affecting fish growth. These factors include diet, stocking density, and water quality. Although stocking density and water quality effects are fairly well documented, some dietery requirements for intensive production of channel catfish in raceways are still not well-defined. Recent studies on feeding stimulants indicate that a small group of chemicals including L-amino acids (L-proline and L-alanine), glycine betaine and inosine or inosine 5'-monophosphate are effective in increasing growth responses in several species of fish including rainbow trout, sea bass, European eel, Japanese eel, turbot, brill, yellow-tail, puffer, red sea bream and Dover sole (1). None of these studies involved channel catfish. The purpose of this study was to determine the growth response of channel catfish (Ictaluras punctatus) fingerlings to different levels of dietary fat and different protein sources, to assess the effect of adding a flavoring agent to vegetable protein based diets, and to compare these results to those observed in pond and tank culture of channel catfish.

The optimum energy level in fish diets is very important. Any diet deficient in energy will result in the use of protein for energy, and any diet with an excess of energy will result in a lower intake of protein, with both resulting in reduced growth rates (2). Studies have been conducted in which dietary lipid composition ranged from 6-16% with no conclusive results as to the level needed for optimum growth (3). However, most of the literature recommends the inclusion of 6% fat when formulating diets for channel catfish grown in ponds under intensive conditions. In a recent study done in the Kansas State University Department of Grain Science and Industry, pelleted catfish diets with 9% fat appeared to perform somewhat better than those containing 6% fat (4). Differences were not significant, however, due to large standard deviations in the data. Therefore, we felt that this area should be further investigated.

Presently, most commercial channel catfish fingerling diets are formulated to contain 35% protein (3). Many plant and animal protein sources have been used successfully in catfish diets although those containing animal protein were usually more effective, even though all-vegetable diets were formulated to contain all of the essential amino acids. Nelson (4) reported that 100% vegetable protein based diets were less efficient than those containing fishmeal and bloodmeal. It appeared that fish acceptance was a factor in that observation. It was suggested that a flavoring agent added to vegetable protein based diets might have a positive effect on feeding activity with those diets. Since vegetable protein sources are cheaper than animal protein sources we felt it was important to study this area in hopes of developing a less expensive channel catfish diet.

In the study described here, feeding trials were performed to determine the optimum dietary fat (or energy) level for intensive culture of channel catfish (Ictalurus punctatus) in raceways. We also studied the feasibility of replacing the animal proteins in the diet with mixtures of vegetable proteins and the use of bloodmeal as a flavoring agent in vegetable protein based diets.

LITERATURE REVIEW

PROTEIN AND AMINO ACID REQUIREMENTS

Proteins are large, complex molecules made up of amino acids. Animals must consume protein in order to provide a continuous supply of amino acids. After the organism consumes the protein, it is digested (or hydrolyzed) to release free amino acids. These amino acids are used to synthesize proteins for growth, replacement of dead tissues, and to participate in many biological functions. There are 20 amino acids commonly found in most proteins that are broken down into two groups, essential and non-essential. The non-essential amino acids can be synthesized by the animal, while essential amino acids are either syntheized in too small a quantity or not synthesized at all. The 10 essential amino acids that must be provided in a dietary form for most animals, including fish, are arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.

The protein requirements of fish are relatively high (25-45% of high quality dietary protein) with 35%

considered the level needed for optimum growth of channel catfish fingerlings (2,3,5,6). Several studies have been conducted to determine the minimum levels of certain amino acids required by channel catfish grown on artificial diets (2,3,5,6). From the results of these studies the National Research Council (2) has established the amino acid requirements for channel catfish listed in Table 1.

Table 1. Amino Acid Requirements for Channel Catfish (2)

Amino Acid	Percent of Dietary Protein
Arginine	4.3
Histidine	1.5
Isoleucine	2.6
Leucine	3.5
Lysine	5.1
Methionine	2.3
Phenylalanine	5.0
Threonine	2.3
Tryptophan	0.5
Valine	3.0

Formulating diets to correct for deficiencies of essential amino acids is generally done in two ways. The most commonly used method is to select combinations of proteins that meet the protein requirements of fish and also provide a balanced amino acid composition. The second method of correcting inadequate amounts of certain amino acids in the diet involves supplementing the diet with purified amino acids. When formulating channel catfish diets to meet amino acid requirements, it is very important to consider the apparent and actual availabilities of amino acids for some common feed ingredients which have been determined (3).

Considerable research has been conducted on establishing the apparent requirement for a minimum amount of animal protein in catfish diets. This is usually estimated to be 8-10% (3,7,8,9,10,11). Some of the studies indicate that diets with less than 10% fishmeal perform poorly (7,9). However, Robinson et al (10) concluded that properly treated 'vegetable protein mixes', such as preparations of extruded soy protein, could be used as substitutes for all of the animal protein component in channel catfish diets.

In trying to determine the factors in fishmeal which might contribute to increased growth rates, we must consider it's digestibility and amino acid content. Although both soybean meal and fishmeal are reported to be equally digestible in channel catfish (12), fishmeal provides the required amount of essential amino acids, whereas 44% soybean meal is limiting in methionine and phenylalanine. When synthetic amino acids were added to soybean meal diets, fish growth rates improved, especially when fish were fed several times a day, thus permitting continuous passage of the supplemented amino acids from the gut to the site of protein biosynthesis (12).

ENERGY REQUIREMENTS

Energy requirements of fish are met by proteins, lipids, and carbohydrates, with protein being the primary source used by fish in the wild (13). It is of major importance to meet the energy requirement in channel catfish feeds for the following reasons: (1) a diet deficient in energy means that protein and other nutrients will not be utilized to their fullest potential for growth, and (2) diets with too much energy can limit the intake of feed (3). In a recent report by Nelson (4) it appeared that weight gains of channel catfish were positively correlated with increasing dietary fat levels when comparing diets containing 3%, 6% and 9% dietary fat.

Energy requirements of fish are less than those of other food animals because: (1) fish are poikilothermic and do not have to maintain a constant body temperature, (2) they require less energy to maintain their position in water than do land animals, and (3) they require less energy to excrete nitrogen waste products because they excrete most of their nitrogenous waste as ammonia instead of converting it to urea or uric acid. Much research has been conducted to try and establish an optimum energy:protein ratio for optimum channel catfish growth in pond culture (14,15,16,17). The results are summarized in Table 2 in kcal of digestable energy per gram of protein depending on fish size in grams.

Table 2. Optimum Energy:Protein Ratios for Channel Catfish in pond culture (3)

Kcal of Digestible Energy (DE)/gram protein	Maximum Fish Size (grams)
9.6	32
8.3	114
8.4	500
7.9	182
7.3	364

DIETARY FAT REQUIREMENTS

Lipids, or fats, are substances found in living tissues which can be dissolved in non-polar solvents. Triglycerides are the most abundent type of lipids found in nature and are the most important sources of dietary energy. A gram of lipid has about twice the amount of gross energy found in the same weight of protein or carbohydrate. Stickney reported that, in general, total lipids in catfish diets can be kept at or below 6% of the total diet without causing nutritional problems, as long as the proper lipid source is used, with animal fat being more efficient than vegetable oil as a dietary energy source for fish (3). Essential fatty acid requirements for channel catfish have not been determined.

CARBOHYDRATES AS ENERGY SOURCES

Plant materials usually constitute the main ingredients in practical diets for channel catfish. These materials contain large amounts of carbohydrates consisting of sugars, starches, and fiber that can be used as energy sources. The level of carbohydrates in a diet is of economic importance, since they are the least expensive component of the diet. Garling and Wilson (15) stated that several studies indicate that digestible carbohydrates can be utilized effectively by catfish when substituted for lipids in a 2.25 to 1 ratio.

VITAMIN AND MINERAL REQUIREMENTS

The vitamin and mineral requirements for channel catfish have been fairly well established. Tables 3 & 4 list the minimum amounts of vitamins and minerals that are required to ensure normal growth (2).

Table 3. Vitamin Requirements For Channel Catfish (2)

Vitamin	Requirements mg/Kg feed
Thiamin	1.0
Riboflavin	9.0
Pyridoxine	3.0
Pantothenic Acid	10-20
Nicotinic Acid	14
Biotin	R
Vitamin B-12	R
Choline	R
Ascorbic Acid	60
Vitamin A	1,000-2.000 (IU)
Vitamin D	500-100 (IU)
Vitamin E	30
Vitamin K	R

R = required, but quantitative level not known

Table 4. Mineral Requirements for Channel Catfish (2)

Mineral	Requirement
Calcium	0.35%-0.45% (only if water is essentially free of Ca)
Phosphorus	0.45%
Magnesium	0.04%
Sodium	Probably required
Potassium	Probably required
Chlorine	Probably required
Zinc	20 mg/Kg feed
Selenium	0.5-1.0 mg/Kg feed
Manganese	Less than 13 mg/Kg feed (carp)*
Iodine	1-5 mg/Kg feed (salmon)*
Iron	Required (salmon)*
Copper	3 mg/Kg feed (carp)*

*Assumed to be similar for catfish

Some nutrients, especially vitamins, can be destroyed during processing and storage of feed materials (3). The extrusion of feeds can destroy 40-60% of added vitamin C and 50% of added vitamins A and D3 (2). These problems have led to the recommendation of including higher levels of vitamins in formulating diets used in extrusion-processed feeds. The recommended levels are shown in Table 5 (3).

Table 5. Recommended Vitamin Supplement for Extrusion Processed Catfish Feed (3)

Vitamin	Recommended Amount mg/Kg
Thiamin	11
Riboflavin	13.2
Pyridoxine	11
Pantothenic Acid	35.2
Nicotinic Acid	88
Folic Acid	2.2
Vitamin B-12	0.09
Choline Chloride (70%)	550
Ascorbic Acid	375.6
Vitamin A	4,400 (IU)
Vitamin D3	2,200 (IU)
Vitamin E	55
Vitamin K	11

Minimum requirements of trace minerals must also be adjusted in the formulation of experimental diets that are low in animal by-products. Lovell (3) reported that a trace mineral supplement, similar to those used in commercial poultry feeds, is recommended for catfish feeds that contain less than 15% animal by-products. These requirements are shown in Table 6 (3).

Table 6. Recommended Trace Mineral Supplement for Catfish Diets Low in Animal By-Products (3)

Mineral	Recommended Amount mg/Kg
Manganese	25
Iodine	5
Copper	3
Zinc	150
Iron	44
Cobalt	0.05

FEEDING STIMULANTS

One of the main concerns in fish production is converting the diet to live fish with minimal cost and maximum efficiency. The practice of adding feeding stimulants to low-cost diets is beginning to receive attention in the culture of a number of fish species. In a recent study by Mackie and Mitchell (1) a small group of chemicals including L-amino acids (L-proline and L-alanine), glycine betaine and inosine or inosine 5'-monophosphate were determined to be effective in increasing growth responses in several species of fish. The species studied included rainbow trout, sea bass, European eel, Japanese eel, turbot, brill, yellow-tail, puffer, red sea bream, and Dover sole. That study did not include channel catfish.

OBJECTIVES

The objectives of this study were to answer these questions;

1. Does increasing the dietary fat levels in channel catfish diets from 6% to 9% improve growth rates of channel catfish in intensive raceway culture?
2. Does the addition of 2% or 4% bloodmeal as a flavoring agent to vegetable protein diets improve the growth rates of channel catfish to levels obtained from animal protein diets?
3. Which one of the diets used in this experiment is the most cost-effective channel catfish feed?

MATERIALS AND METHODS

Fish

The 12,000 fish used in this experiment were healthy channel catfish (Ictalurus punctatus) fingerlings obtained from the Kansas Department of Wildlife & Parks. The average initial fingerling weight was 20.6 $\pm$1.5 gms. and average length was 8.9 cm.

Culture Facilities

The fish were grown at the Milford Hatchery (Kansas Department of Wildlife & Parks, Junction City, KS) in two raceways, each 30.48 meters (100 feet) long, 2.44 meters (8 feet) wide, and with a water depth of approximately 1.22 meters (4 feet). The raceways were divided into 2.44 meter (8 foot) long compartments by perforated screens. The screens consisted of 1.22 meter (4 feet) by 2.44 meter (8 feet) sheets of perforated aluminum surrounded by an aluminum frame. A rubber gasket was attached to the lower edge to insure a fish-tight seal, and a 20.3 cm (8 inch) by 2.44 meter (8 feet) long aluminum wire screen was attached to the top, with 10.2 cm (4 inches) of the wire screen above water level to insure that the floating feed stayed within the prescribed pen. Each raceway was equipped with a variable-flow water supply line with surface and bottom outlets. The water was pumped from the reservoir below the hatchery into a tower where it was forced over screens by gravity to reduce the nitrogen content. Gravitational flow was then used to run the water into the raceways at an approximate rate of 757 liters (200 gallons) per minute. An air lift pump system capable of recirculating 1514 liters (400 gallons) per minute was also used in each raceway.

Experimental Methods

Screens were placed every 2.44 meters (8 feet) in both raceways making a total of 24 pens numbered 1-24. The channel catfish fingerlings were counted individually and weighed in groups of 100. Five hundred fish were placed in each of the numbered compartments. This resulted in a stocking density of approximately 25% of the design capacity of the raceways.

The fish were fed the experimental diets on July 7, one day after the initial stocking date. Each group of 500 fish received 3% of their total body weight of feed on the first day of feeding. Throughout most of the remaining feeding period Swingle's (18) method of determining feeding rates was used to calculate a feeding schedule of 3% of the total weight of the growing fish population within each pen. This method involves the use of the formula $Wt = Wo\ e^{kt}$, where;

Wt = weight at time t
Wo = weight at time 0
e = natural logarithm
k = ratio of feed percentage to feed conversion ratio
t = time in days of adjusted period

This feeding schedule was adjusted after each weighing period and continued until September 19, when the water temperature dropped to 18.3 ^{o}C (65 ^{o}F) and feeding activity lessened. At this time the feeding percentage was reduced to 1.5% of total body weight and feeding schedules were calculated as described above. The feedings were performed as early in the morning as possible which usually occurred at 0600 hours.

Diet Formulation and Processing

All of the diets used in this experiment were formulated to contain 35% protein and are shown in Table 7.

Table 7. Catfish diets used in this experiment.

Diet	Protein Source	Fat	Flavoring Agent
1	Vegetable (1)	6	0
2	Vegetable (1)	9	0
3	Vegetable (1)	6	2% Bloodmeal
4	Vegetable (1)	6	4% Bloodmeal
5	Animal (2)	6	--
6	Animal (2)	9	--

(1) Contained no animal proteins other than the bloodmeal in Diets 3 & 4. Protein sources were soybean meal, corn gluten meal and corn.
(2) Contained fishmeal (12%) and bloodmeal (4%).

Diets 1& 2 contained proteins from vegetable sources only, which were soybean meal, corn gluten meal and corn. Diets 3 & 4 contained the same vegetable protein sources with the addition of 2 and 4% bloodmeal as a flavoring agent, and Diets 5 & 6 contained 12% fishmeal and 4% bloodmeal as significant components. Vegetable and animal protein diets were then subdivided by energy level with Diets 1 and 5 containing 6% fat and Diets 2 and 6 containing 9% fat. All diets were formulated to meet the nutritional requirements of channel catfish using a computerized least-cost diet formulation program (19). The ingredient and nutrient requirement lists are contained in Appendix 1. The formulations for the six experimental diets are contained in Appendix 2.

The diet ingredients were weighed and then mixed in a horizontal ribbon mixer. These mixtures were ground through a 1/16 inch screen in a hammer mill and returned to the mixer where melted fat was added with additional mixing. All mixing times were 3-5 minutes each, and to avoid difficulty in processing, all diets were limited to a 6% fat level. The diets were then processed in a Wenger extruder at 129 ^{o}C and the final 3% fat sprayed on the finished product in Diets 2 & 6.

Vitamin and Mineral Premix

Vitamin and mineral requirements of the intensive-cultured channel catfish were provided by a premix, which was prepared by using readily available feed ingredients and chemical components. The formula for the premix is shown in Appendix 3.

Data Collection

The fish were weighed every three weeks of the 12 week study. The first two weighings consisted of netting 200 fish from each pen and weighing them in groups of 100. The final two weighings consisted of weighing 200 fish in groups of 50. The fish were counted into a strainer, then added to a tared bucket of water and the weights recorded to the nearest ounce. The final measurement also consisted of measuring 20 individual fish from each compartment (480 fish) to the nearest 1.0 millimeter. Dissolved oxygen, temperature and pH were measured at the beginning and end of each block every day.

Treatment for Disease

A minor disease problem occurred during the first 3-week segment of the study. A 15-day treatment with Terramycin 50 for a bacterial infection of (*Edwardsiella ictaluri*) was started on July 17, and was accomplished by processing 100 lbs. of each diet containing 2.7% of the medication. The fish received 3% of their body weight each day for the treatment period, which effectively stopped the infection.

Experimental Design

This experiment was designed as a Random Complete Block experiment because of the structure of the raceways.

To achieve this design, the raceways were divided in half, providing four blocks consisting of the first six compartments in raceway 1 as the first block, the last six compartments in raceway 1 as the second block, the first six compartments in raceway 2 as the third block, and the last six compartments in raceway 2 as the fourth block (Fig. 1).

The six compartments in each block were then randomly assigned to the six diet treatments in the experiment using a randomized number table. This design allowed for the statistical analysis of the effect of position in the raceway on fish growth.

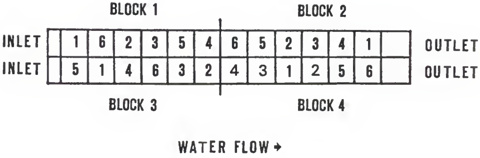
Feed Analysis

Total amino acid analysis was performed after hydrolysis with p-toluene sulfonic acid using a Dionex D-300 Amino Acid Analyzer at the Kansas State University Department of Grain Science amino acid laboratory. All of the amino acids satisfactorily met the requirements of channel catfish.

Statistical Analysis

The data obtained from the experiment were analysed by SAS (20) using GLM and Anova with test functions to determine the significance of the treatment effect and blocking effect differences. Significant differences were

FIGURE 1. Complete Random Block Design



determined for average individual weight gain, feed conversion ratios, average weight gain by block and fish condition factor.

RESULTS AND DISCUSSION

EFFECT OF DIETARY FAT LEVEL ON FISH WEIGHT GAINS

The purpose of this portion of the study was to determine if intensively cultured channel catfish in raceways have higher energy requirements than those cultured under intensive conditions in ponds. The data obtained for the overall average weight gains of this study in Table 8 indicate that there is no significant difference between 6% and 9% dietary fat levels in both the animal and the vegetable protein based diets at the $p < 0.05$ level. In fact, it appeared that the fish actually grew slightly less well when fed the 9% fat diets.

Table 8. Average weight gains by energy level.

Diet	Protein Source	Fat	Grams gained per Fish	Statistical Comparisons *
5	Animal	6%	74.34	A
6	Animal	9%	68.13	A B
1	Vegetable	6%	60.63	B C
2	Vegetable	9%	55.54	C

* Comparisons not having the same letters indicate that the means are significantly different (alpha = 0.05).

This suggests that diets containing 6% fat with 2800 Kcal/Kg. digestible energy provide adequate energy for fish grown in raceways under intensive conditions. This finding agrees with the current literature on recommended dietary fat levels in channel catfish diets used for fish grown in ponds under intensive conditions (3). These results indicate that the apparent slight improvement seen by Nelson (4) in weight gain with the higher dietary fat level was indeed not significant.

EFFECT OF DIETARY PROTEIN SOURCE ON FISH WEIGHT GAINS

The purpose of this portion of the study was to determine if animal protein based diets could be replaced by vegetable protein based diets for intensive culture of channel catfish in raceways. Comparison of average weight gains in Table 9 indicates that fish fed diets containing animal proteins showed significantly greater average weight gains than fish fed vegetable protein based diets at the $p < 0.05$ level. These results support the current literature that recommends the inclusion of a minimum of 8-10% of animal protein in channel catfish diet formulation (3,4,7,8,9,10,11) .

Table 9. Average weight gains by protein source.

Diet	Protein Source	Fat	Grams gained per Fish	Statistical Comparison *
6	Animal	9%	68.13	A B
2	Vegetable	9%	55.54	C
5	Animal	6%	74.34	A
1	Vegetable	6%	60.63	B C

* Comparisons not having the same letters indicate that the means are significantly different (alpha = 0.05).

EFFECT OF A FLAVORING AGENT ON FISH WEIGHT GAINS

The purpose of this portion of the study was to determine if the addition of a flavoring agent to vegetable protein based diets could increase the weight gain of channel catfish to the level obtained in animal protein based diets. Comparisons of average weight gains for all six diets in this study are shown in Table 10.

Table 10. Average over-all weight gains for all groups.

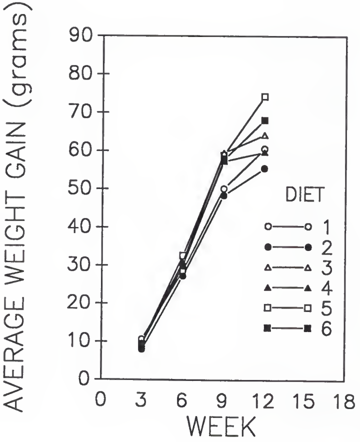
Diet	Protein Source	Flavoring Agent % Bloodmeal	Fat	g gain per fish	Statistical Comparison *
5	Animal	--	6%	74.34	A
6	Animal	--	9%	68.13	A B
3	Vegetable	2	6%	64.22	A B C
1	Vegetable	0	6%	60.63	B C
4	Vegetable	4	6%	59.76	B C
2	Vegetable	0	9%	55.54	C

* Comparisons not having the same letters indicate that the means are significantly different (alpha = 0.05).

In this experiment bloodmeal was used as a flavoring agent in Diets 3 & 4 at levels of 2 and 4%, respectively. The results indicate that Diet 3 is not significantly different than Diets 5 & 6, which are animal protein based diets, and that Diet 4 is not significantly different than Diet 6. This suggests that vegetable protein based diets that contain a flavoring agent, such as bloodmeal, at a low percentage can be effectively used to replace animal protein based diets without a significant loss in weight gain for culture of channel catfish under intensive conditions.

The average period weight gains (Figure 2) of the fish fed the diets in this experiment indicate that there is no difference between the animal protein diets and the vegetable protein diets containing bloodmeal up to week 9 of the study. However, during the final 3 weeks of the experiment the growth rates of the fish fed Diets 3 & 4, the vegetable protein based diets with 2% & 4% bloodmeal, slowed dramatically when compared to Diets 5 & 6, the animal protein based diets. This may have been due to the drop in water temperature causing the bloodmeal in Diets 3 & 4 to be less soluble and not allowing the fish to smell or taste it as readily as they did during the earlier part of the study, when the water was warmer.

FIGURE 2. Cumulative Fish Weight Gains.



Diet 1	Vegetable Protein	6% Fat	
Diet 2	Vegetable Protein	9% Fat	
Diet 3	Vegetable Protein	6% Fat	2% Bloodmeal
Diet 4	Vegetable Protein	6% Fat	4% Bloodmeal
Diet 5	Animal Protein	6% Fat	
Diet 6	Animal Protein	9% Fat	

EFFECT OF POSITION IN THE RACEWAY ON WEIGHT GAINS

Since the experimental design in this study was a Randomized Complete Block, the comparison of the average weight gain by all the fish in each block can be made. The weekly weight gains by block in Table 11 indicate that there was no significant difference between raceways until the final weighing period, when raceway 1 appeared to be better than raceway 2. The over-all weight gains in Table 11 also indicate that there was a decrease in weight gain of fish in the downflow positions of the raceway, independent of the diet the fish received, although not all the differences were significant. These results indicate that fish in block 4, which was the end block in raceway 2, gained significantly less than fish in all other blocks. This analysis supports the results by Nelson (4) and indicates the importance of good water quality in intensive culture of channel catfish.

Since the water quality parameters tested in this study, which included dissolved oxygen, temperature, and pH, indicated no difference between raceways or position in the raceways, the exact reason for difference in weight gain by block cannot be explained. The water quality values for both raceways are contained in Appendix 4. These measurements indicate normal accepted values (13) for all parameters tested (less than 0.5 mg/l for total ammonia when pH and temperature values are acceptable, above 2-3 mg/l for dissolved oxygen, a range of 6.5-8.5 for pH and a temperature range of 20-30 C). Early in the experiment (week beginning July 12) the dissolved oxygen content fell below 3 mg/l but was the same in both raceways, and was well above accepted levels during the rest of the study. Since these values were monitered during the early morning period of the day, there should have been no problems with fish stress because of rising dissolved oxygen content during the daylight hours.

Ammonia is present in water in both the ionized (NH_4) and un-ionized (NH_3) forms. Although the ionized form of ammonia is relatively harmless to fish, ammonia in the un-ionized form is very toxic. The form in which ammonia is present in water is dependent upon temperature and pH, with the un-ionized form being present in high levels during high temperature and pH periods of the day. This concept, combined with the fact that fish excrete most of their nitrogenous waste in the form of ammonium ion (NH_4) underlines the importance of monitoring water quality parameters. The total ammonia content for both raceways measured for the week beginning August 2 is present in Appendix 4. Although these values were below the acceptable range when the measurements were taken in the morning, it is possible that the un-ionized (NH_3) form of ammonia reached a toxic level in the lower end of the raceways later in the day due to rising pH levels and increased ammonia excretion as fish metabolized the feed. From August 30 until the end of the experiment pH values were near the high end of the acceptable range, but were also the same in both raceways.

Table 11. Average weight gains by block.

Block	Grams gained per Fish			
	WK 3	WK 6	WK 9	WK 12
1	10.2 a	32.1 a	59.6 a	74.1 a
3	9.4 a	30.5 ab	57.7 a	63.2 b
2	9.3 a	29.6 ab	57.0 a	67.9 ab
4	8.3 a	27.9 b	47.2 b	50.0 c

*Comparisons not having the same letters indicate that the means are significantly different (alpha = 0.05).

FEED CONVERSION RATIOS

The feed conversion ratios (FCR's) for all of the diets used in this study were calculated by dividing the amount of feed fed to each pen of fish by the weight gained by those fish. This ratio tells us how much feed it takes to produce one pound of fish, so the lower the number the better. The FCR'S (Table 12) ranged from 1.51 to 1.94 for all diets. These values fall within the accepted range of 1.5 to 2.0 for commercially processed diets.

Table 12. Feed Conversion Ratios

Diet	Fat %	Protein Source	Flavoring Agent %	FCR	Statistical Conparisons *
5	6	Animal	--	1.51	A
6	9	Animal	--	1.60	A B
3	6	Vegetable	2	1.70	A B C
1	6	Vegetable	0	1.76	B C
4	6	Vegetable	4	1.83	B C
2	9	Vegetable	0	1.94	C

*Comparisons not having the same letters indicate that the means are significantly different (alpha = 0.05).

These results indicate that diet 3, which was a vegetable protein based diet containing 2% bloodmeal as a flavoring agent, produced a feed conversion ratio that did not significantly differ from those obtained with animal protein diets. However, Diet 5 was significantly better than Diets 1, 2, & 4, the other vegetable protein diets.

FISH CONDITION FACTOR

The ratio of length to volume is used to calculate the condition factor of individual fish. In wild fish populations the condition factor of a particular species is very useful in indicating the condition of the fish because of the consistency exhibited by this measurement. In this study any large differences observed in condition factors of the groups of fish would provide an indication of diet performance. The formula used to calculate the average condition factor for the fish in each treatment was;

$$K = 100{,}000 \times \text{average wt (g)} / \text{average total length (mm)}^3$$

The condition factors obtained for the diets in this study are shown in Table 13. The average lengths used to calculate these value are contained in Appendix 5.

Table 13. Fish condition factors.

Diet	Protein Source	Fat %	Flavoring Agent	Condition Factor	Statistical Comparisons*
3	Vegetable	6	2% Bloodmeal	.93	A
5	Animal	6	--	.87	A B
4	Vegetable	6	4% Bloodmeal	.86	A B
1	Vegetable	6	0	.81	B
6	Animal	9	--	.81	B
2	Vegetable	9	0	.78	B

* Comparisons not having the same letters indicat that the means are significantly different (alpha = 0.05).

The major difference observed was that Diet 3, the vegetable protein diet with 2% bloodmeal, produced fish with a condition factor significantly greater than those fish fed Diets 1, 2, & 6. These results also indicate that both of the vegetable protein diets, that contained no flavoring agent, and both 9% dietary fat diets, animal and vegetable protein based, produced fish with lower fish condition factors.

DIETARY COST COMPARISONS

One of the major concerns in any feeding study is the cost of weight production. That figure is determined by the feed conversion ratio and the cost of the feed. The cost per diet, feed conversion ratios, and cost per pound of fish raised for all the diets used in this experiment are shown in Table 14.

Table 14. Feed cost for the production of channel catfish in this study.

Diet	Protein Source	Fat %	Feed Cost* $/CWT	Feed** Conversion Ratio	Production Costs $/lb. Fish
1	Vegetable	6	16.01	1.76	.28
2	Vegetable	9	17.60	1.94	.34
3	Vegetable a	6	16.22	1.70	.28
4	Vegetable b	6	16.25	1.83	.30
5	Animal	6	17.26	1.51	.26
6	Animal	9	18.00	1.60	.29

*These costs include a processing cost of $ 2.00 / CWT for the extruded feed. (Pilot Feed Mill, Department of Grain Science & Industry, Kansas State University).

** Pounds of feed / pound of weight gained

a with 2% bloodmeal

b with 4% bloodmeal

The vegetable protein based diets cost less to produce, but feed conversion ratios with those diets were higher. Therefore, Diet 5 the animal protein based diet with 6% fat, was the most cost-effective diet used in this study. Although the vegetable protein diets cost less to make, fish production costs are lower using the more efficient animal protein based diets. These results support the study by Nelson (4) which showed that animal protein diets containing 6% dietary fat are the most cost-effective channel catfish diets produced.

GENERAL DIET PERFORMANCE

The average weekly weight gains (Figure 2) of the fish fed the diets in this experiment indicate that average weight gains of channel catfish fingerlings fed diets containing 6% fat do not differ significantly from those obtained from diets containing 9% fat (Diets 1 vs. 2 and 5 vs. 6). This suggests that the recommendation of formulating diets containing 6% fat for channel catfish fingerlings in intensive pond culture (3) also holds true for the intensive culture of channel catfish in raceways.

The results of the experiment with regard to protein-type differences indicate that animal protein based diets are superior to vegetable protein based diets. Although, the addition of a flavoring agent, such as bloodmeal, to the vegetable protein based diet improved it to a level that was not significantly different from the animal protein based diets (when considering average weight gains, feed conversion ratios and fish condition factors) the 6% fat animal protein diet was still the most cost-effective diet used in the study. This suggests that one of the limiting factors in performance of channel catfish fingerlings fed vegetable protein based diets may be poor acceptance by the fish.

CONCLUSIONS

The results of this study indicate that;

1. Increasing dietary fat levels from 6 to 9% does not improve diet performance.
2. The 6% fat animal protein diet was the most cost-effective diet in the study.
3. Addition of 2% bloodmeal as a flavoring agent in a vegetable protein diet improved its performance. Data indicate that more research with flavoring agents might make it possible to produce more cost-effective diets using vegetable protein sources than animal protein sources.

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APPENDIX 1. Ingredient and Nutrient Lists for Least Cost Diet Formulation

ANIMAL PROTEIN CATFISH DIET INGREDIENT LIST

INGREDIENTS	MINIMUM	MAXIMUM
Soybean Meal 44%	---	---
Corn Grain	25.0%	---
Fishmeal, Menhaden	12.0%	---
Bloodmeal	4.0%	---
Corn Gluten Meal	3.5%	3.5%
Rendered Beef Fat	3.0%	8.0%
Dicalcium Phosphate	---	2.5%
Catfish V+M Premix *	1.3%	1.3%
Methionine	---	---
Lysine	---	---
Wheat, Hard	---	---
Wheat Bran	---	---

* Vitamin and mineral premix. See Appendix 3.

VEGETABLE PROTEIN CATFISH DIET INGREDIENT LIST

INGREDIENTS	MINIMUM	MAXIMUM
Soybean Meal 44%	---	---
Corn Grain	25.0%	---
Corn Gluten Meal	---	30.0%
Rendered Beef Fat	---	8.0%
Dicalcium Phosphate	2.4%	2.7%
Catfish V+M Premix *	1.3%	1.3%
Methionine	---	---
Lysine	---	---
Cottonseed Meal 41%	---	10.0%

* Vitamin and mineral premix. See Appendix 3.

2% B1OODMEAL CATFISH DIET INGREDIENT LIST

INGREDIENTS	MINIMUM	MAXIMUM
Soybean Meal 44%	---	---
Corn Grain	25.0%	---
Corn Gluten Meal	17.5%	17.5%
Rendered Beef Fat	---	6.0%
Dicalcium Phosphate	2.4%	2.7%
Bloodmeal	2.0%	2.0%
Catfish V+M Premix *	1.3%	1.3%
Methionine	---	---
Lysine	---	---

* Vitamin and mineral premix. See Appendix 3.

4% BLOODMEAL CATFISH DIET INGREDIENT LIST

INGREDIENTS	MINIMUM	MAXIMUM
Soybean Meal 44%	---	---
Corn Grain	25.0%	---
Corn Gluten Meal	15.5%	15.5%
Rendered Beef Fat	---	6.0%
Dicalcium Phosphate	2.4%	2.7%
Bloodmeal	4.0%	4.0%
Catfish V+M Premix *	1.3%	1.3%
Methionine	---	---
Lysine	---	---

* Vitamin and mineral premix. See Appendix 3.

NUTRIENT LISTS

6% FAT CATFISH DIET

NUTRIENT	UNITS	MINIMUM	MAXIMUM
Protein	%	35.00	36.00
Fiber	%	----	7.00
Fat	%	6.00	6.01
DE, Catfish	Kcal/KG	2800.00	3150.00
Calcium	%	0.50	1.50
Avail Phos	%	0.50	----
Avail Lysine	%	1.84	----
Avail Methionine	%	0.81	----

9% FAT CATFISH DIET

NUTRIENT	UNITS	MINIMUM	MAXIMUM
Protein	%	35.00	36.00
Fiber	%	----	7.00
Fat	%	9.00	9.10
DE, Catfish	Kcal/KG	2800.00	3150.00
Calcium	%	0.50	1.50
Avail Phos	%	0.50	----
Avail Lysine	%	1.84	----
Avail Methionine	%	0.81	----

APPENDIX 2. Diet Formulations

INGREDIENT*	DIET 1	DIET 2	DIET 3	DIET 4	DIET 5	DIET 6
Soybean Meal (44%)	46.8%	33.9%	45.2%	46.1%	42.5%	43.4%
Corn	25.0%	25.0%	26.5%	25.7%	31.7%	27.7%
Corn Gluten Meal	19.4%	29.0%	17.5%	15.5%	3.5%	3.5%
Rendered Beef Fat	4.1%	7.0%	4.1%	4.2%	3.0%	6.1%
Dicalcium Phosphate	2.5%	2.6%	2.5%	2.5%	1.6%	1.6%
Bloodmeal	---	---	2.0%	4.0%	4.0%	4.0%
Fishmeal	---	---	---	---	12.0%	12.0%
Lysine	0.5%	0.8%	0.5%	0.3%	---	---
Methionine	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Catfish Vit. and Min. Premix	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
% Protein	35.0	35.0	35.0	35.0	35.0	35.0
Minimum DE (Kcal/Kg)	2800	3029	2800	2800	2855	3062
Cost** ($/CWT)	16.01	17.60	16.22	16.25	17.26	18.00

*All ingredients on an as fed basis

**These costs include processing costs of $2.00/CWT for extruded feed processed at the Pilot Feed Mill, Department of Grain Science & Industry, Kansas State University, Manhattan, KS.

APPENDIX 3. Vitamin and Mineral Premix

INGREDIENT	GRAMS/TON FEED	% of mix
Thiamin (10g/lb)	456.35	3.84
Riboflavin	22.72	0.19
Pyridoxine	10.05	0.08
D-Calcium Pantothenate	71.11	0.60
Niacin	81.02	0.68
Folic Acid	2.01	0.02
Vitamin B-12	0.08	0.0007
Vitamin C	343.57	2.89
Vitamin A (10,000 IU/g)	401.26	3.38
Vitamin D-3 (15,000 IU/g)	133.74	1.13
Vitamin E (125,000 IU/lb)	180.93	1.52
Vitamin K	10.05	0.08
Choline Chloride (50%)	604.14	5.08
Z-10 Mineral Mix*	273.57	2.30
Zinc Oxide	109.43	0.92
Selenium (0.02%)	2279.75	19.18
Rice Hulls	6907.52	58.11

*Zinc 10%, Manganese 10%, Iron 10%, Copper 1%, Iodine 0.3% Cobalt 0.1%, Calcium 4-5%.

APPENDIX 4. Weekly Average Water Quality in Raceways

Week Beginning	Raceway #	Temperature (oC)	Dissolved Oxygen (mg/l)	pH	Ammonia (mg/l)
7/5/87	1	22.3	4.7	8.1	
	2	22.1	4.9	8.0	
7/12/87	1	22.1	2.6	8.2	
	2	22.2	2.3	8.2	
7/19/87	1	24.4	3.6	8.1	
	2	24.3	3.4	8.0	
7/26/87	1	25.7	4.3	8.0	
	2	25.5	4.1	8.0	
8/2/87	1	22.2	5.9	7.8	.242
	2	22.1	6.0	7.8	.253
8/9/87	1	23.9	5.1	8.6	
	2	23.8	5.1	8.5	
8/16/87	1	20.7	7.0	8.3	
	2	20.8	6.9	8.2	
8/23/87	1	18.9	5.5	8.3	
	2	18.9	5.6	8.3	
8/30/87	1	20.2	6.3	8.6	
	2	20.3	6.2	8.6	
9/6/87	1	20.2	6.1	8.5	
	2	20.2	6.1	8.5	
9/13/87	1	18.3	6.0	---	
	2	18.3	6.2	---	
9/20/87	1	17.5	6.7	8.5	
	2	17.5	6.9	8.5	
9/27/87	1	16.9	6.2	8.6	
	2	16.8	6.5	8.6	

APPENDIX 5. Average Lengths and Standard Deviation (cm)

Diet	Block 1 Ave. Length	Block 2 Ave. Length	Block 3 Ave. Length	Block 4 Ave. Length
1	23.2 (2.9)	20.6 (1.7)	20.5 (2.0)	21.7 (2.4)
2	22.3 (2.2)	21.9 (2.4)	21.3 (3.1)	19.8 (2.8)
3	21.2 (2.5)	20.7 (2.4)	20.6 (2.1)	21.0 (3.0)
4	22.1 (2.8)	21.0 (2.4)	20.2 (2.3)	21.2 (2.1)
5	23.0 (2.5)	22.8 (2.8)	23.3 (2.7)	19.7 (1.7)
6	23.0 (2.5)	23.5 (2.6)	20.9 (2.6)	21.2 (2.5)

EFFECTS OF DIETARY ENERGY LEVEL, PROTEIN TYPE, AND FLAVORING AGENT IN EXTRUDED FEED FOR RACEWAY CULTURE OF CHANNEL CATFISH

by

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B.S. Kansas State University, 1984

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

Six diets were formulated and manufactured to investigate the effects of dietary energy level, dietary protein source and a flavoring agent on the weight gain of intensively cultured channel catfish fingerlings in raceways. Twelve thousand channel catfish were stocked in 24 pens, (500 fish/pen) and fed for a 12-week period. The fish were weighed every three weeks to determine the effect of diet and raceway position on fish weight gain.

Diets 1 & 2 contained protein from vegetable sources only which were soybean meal, corn gluten meal and corn. Diets 3 & 4 contained the same vegetable proteins with the addition of 2 and 4% bloodmeal, respectively as a flavoring agent, and Diets 5 & 6 contained 12% fishmeal and 4% bloodmeal as significant components. Diets 1,2,5, and 6 were then subdivided by energy level with 1 and 5 containing 6% fat and 2 and 6 containing 9% fat. The diets were all formulated to be isonitrogenous and contain the required amounts of vitamins, minerals, energy, and amino acids.

Growth response to dietary fat level indicates that there is no significant difference between 6% and 9% dietary fat. Protein source differences indicate that animal protein based diets are superior to vegetable protein based diets. However, the addition of a flavoring agent, such as bloodmeal, to a vegetable protein diet improves it to a level that is not significantly different from animal protein based diets when considering average weight gain, feed conversion ratio and fish condition factor.

The effect of raceway position on fish weight gain indicates that there is a decrease in weight of the fish in the downflow position of the raceway, independent of the diet they received.