THE EFFECTS OF PROTEIN TYPE AND ENERGY LEVEL IN RACEWAY CULTURE OF CHANNEL CATFISH

by

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INTRODUCTION

There are many factors which can affect the growth of fish in confinement including diet, water quality, and stocking density. The purpose of this study was to investigate the response of channel catfish (*Ictalurus punctatus*) fingerlings to various levels of dietary fat and different protein sources, to assess the nutritional effects of some feed processing methods, and to compare these results with results observed in pond and aquarium culture of channel catfish.

The total amount of energy contained in a feed directly affects the growth rate of the fish. A diet deficient in energy will prevent the full utilization of the protein and other nutrients in the feed, thereby reducing growth rates. An excess of energy in the diet can reduce feed consumption, which can also result in reduced growth rates.

Proteins comprise 65-75 percent of animal tissues on a dry weight basis and the amino acids necessary to produce them must be either synthesized from or provided by the proteins in the diet. Common feed ingredients contain these amino acids in varying amounts and the formulation of optimum feeds must include adequate amounts of the amino acids required for optimum growth.

Processing techniques used in manufacturing feeds also affect feed quality. Pelleting, the most common form of processing for feed, causes moderate temperature increases and some compression of the feed ingredients but little cooking or gelatinization of the starch portion of the feed. Extrusion processing utilizes much higher temperatures and pressures and cooks the feed, gelatinizes a higher percentage of the starch, and sterilizes the material. Some feed ingredients, particularly vitamins, are adversely affected by high temperature and moisture conditions and these effects must also be considered.

In this study experimental diets were formulated, and manufactured. Feeding trials were performed to determine the optimum dietary fat (or energy) level for rearing catfish in intensive raceway culture. The feasibility of replacing the animal protein in the diet with mixtures of vegetable proteins was assessed, and the effect of simple extrusion processing as opposed to pelleting on fish weight gains was studied.

LITERATURE REVIEW

PROTEIN AND AMINO ACID REQUIREMENTS

Proteins are large complex molecules composed of amino acids. They possess many properties and perform many functions in living tissues. These functions range from forming simple structural components to involvement in varied and complex chemical reactions performed or catalyzed by enzymes. Living organisms use amino acids to synthesize proteins for growth, replacement of dead tissues, and to participate in many biological functions. These amino acids are either synthesized by the organism or utilized directly from dietary components. There are 20 amino acids commonly found in most proteins. These are divided into two groups, those which can be synthesized by most organisms, and those considered as essential or required in dietary form. These essential amino acids for most vertebrates are arginine, histidine, isoleucine, leucine, methionine, phenylalanine, threonine, tryptophan, lysine and valine (1,2).

Fish require large amounts (25-45 percent) (1,2,3) of high quality dietary protein. Feeds containing 35% protein are recommended for optimum growth of fingerling catfish (2) Considerable research (1,2,3,4) has been conducted to determine the minimum amounts of certain amino acids which are required and may not be available in artificial diets. Based on these studies the National Research Council (1) has established amino acid requirements for channel catfish (Table 1).

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

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

Studies (5) have shown that fortification of diets with purified amino acids, particularly lysine, can be accomplished, but there is some difficulty in achieving effective utilization of these free chemical forms (6).

The utilization of amino acids depends on digestion and absorption into the system, and some amino acid sources are more effectively used by catfish than others. The apparent and actual availabilities of amino acids for some common feed ingredients have been studied (2) and must be considered in diet formula tion.

ENERGY REQUIREMENTS

The energy requirements of fish are met by three sources, proteins, lipids, and carbohydrates; but unlike most other vertebrates, the energy requirements of fish in nature are primarily satisfied by protein (7). Since protein is the most expensive component of manfactured diets, it is of economic importance to reduce the protein of the diets to the lowest level which will maintain optimum growth. Fish are well adapted to use protein as an energy source if their diets do not contain adequate non-protein energy. Considerable research (8,9,10,11,12,13) has been conducted to study the relationship between dietary protein and energy levels in catfish raised in ponds and aquaria. The two other main sources of energy, fat or lipid and carbohydrate can both be effectively utilized by catfish within a broad range in their diets (9).

Fish require less energy than other food animals for several reasons. They are poikilothermic and do not require energy for temperature maintenance, they excrete most of their nitrogenous waste as ammonia instead of converting it to urea or uric acid, and they exert less energy to maintain position than do land animals. Studies differ as to an optimum energy:protein ratio for optimum fish growth (8,9,10,12). Table 2 summarizes these data (2).

Table 2. Optimum Energy:Protein Ratios for Channel Catfish (2)

Kcal of Digestable 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 found in all living tissues and are defined as those compounds which can be dissolved in nonpolar solvents. Of the many different types of lipids, triglycerides are the most abundant in nature and are the most important sources of dietary energy. The energy in a gram of fat is approximately twice that contained in a gram of protein or carbohydrate (11). Some workers have shown animal fat to be more efficient than vegetable oil as a dietary energy source for fish (14). A further study (15) indicated that excessive amounts of linoleic or linolenic acids can inhibit oleic acid synthesis and reduce growth rates. In that study fish grew faster with beef tallow or fish oil as the dietary energy source (15) than with vegetable oil as the source. Aside from the observation that some sources of lipids which contain significant levels of linoleic or linolenic acids impair growth rates, the fatty acid requirements for channel catfish have not been determined.

CARBOHYDRATES AS ENERGY SOURCES

Practical diets for catfish usually contain plant materials as the main ingredients. These materials contain large amounts of carbohydrates consisting of sugars, starches, and fiber. The utilization of these carbohydrates as energy sources is of interest because they are the least expensive component of the diet. Sugars and starches are efficiently digested by catfish (90% and 50-80%, respectively) (2). Cooking the starch apparently increases its digestibility by about 15 percent(2). Studies have shown that digestible carbohydrates can be utilized effectively by catfish when substituted for lipids in a 2.25 to 1 ratio to a maximum of 15 to 20 percent of the diet (9).

VITAMIN AND MINERAL REQUIREMENTS

The vitamin and mineral requirements for catfish have been fairly well established. Tables 3 and 4 list the minimum amounts of the vitamins and minerals that are considered to be required to ensure normal growth (1).

Table 3. Vitamin Requirements For Channel Catfish (1)

Vitamin	Requirement (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	1000-2000 (IU)
Vitamin D	500-1000 (IU)
Vitamin E	30
Vitamin K	R

R= required but quantitative level not known

Table 4. Mineral Requirements for Channel Catfish (1)

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
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

During the processing and storage of feed materials some nutrients, particularly vitamins, can be destroyed (2). Extrusion processing can destroy 40-60% of added vitamin C and 50% of added vitamins A and D3 (1). Most vitamins gradually decompose during storage. For these reasons it is common practice to include much higher levels of vitamins than the required amounts in the formulation of practical diets. Recommended amounts of vitamins to be added to extrusion-processed feeds are contained in Table 5. (2).

Table 5. Recommended Vitamin Supplement for Extrusion Processed Catfish Feed (2)

Vitamin	Recommended Amount (mg/Kg)
Thiamin	11
Ribflavin	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

FISHMEAL REQUIREMENT

Considerable research (2,6,16,17,18,19) has been conducted to investigate the apparent requirement for a minumum amount of animal protein, usually estimated to be 8-10%, in diets for channel catfish. Most studies have confirmed that diets that do not contain about 10% fishmeal perform poorly (6,17). Andrews and Page (6) attempted to isolate the factor(s) in fishmeal which contribute to the increased growth observed when it is included in diet formulations. They investigated the amino acids normally considered limiting, the lipid portions of the fishmeal, and the residual after ashing as separate dietary components but could not identify the factor(s) responsible for this effect. They postulated the factor(s) may be related to amino acid availabilty by causing another amino acid to become limiting or an amino acid balance which is critical. Robinson et al (18) obtained growth equivalent to a fishmeal-containing diet by substituting an extruded soy protein preparation for the fishmeal in the diet. They concluded that properly treated 'protein mixes' could be used as substitutes for the animal protein component in catfish diets.

THE EFFECT OF EXTRUSION PROCESSING

The use of extrusion processing in feed manufacture has a compound effect on the characteristics of the finished feed. The most dramatic effect is the characteristic expansion and reduction in specific gravity of the product. This normally results in a pellet which is less dense than water and floats. Catfish will accept feed on the surface and the culturist may observe them feeding. This is desirable as it gives an indication of the general health of the fish. Extrusion processing has been shown to increase the available energy in the carbohydrate portions of the diet (2) but no corresponding increase in growth rate has been demonstrated (20,21).

MATERIALS AND METHODS

Objectives

The objectives of this study were to compare diets containing 8% fishmeal and 5% blood meal with diets containing only vegetable proteins, to evaluate diets containing 3%, 6%, 9%, total fat in each group, and to evaluate the effect of extrusion processing on the 6% fat diet in each group.

Fish

The 12,000 fish used in this experiment were healthy channel catfish (*Ictalurus punctatus*) fingerlings obtained from the Kansas Fish And Game Commission stocks. Average initial weights of the fish were 15.9 + 5.7 gms. and the average weight of all 12,000 fish was 11.18 gms. Simple visual as well as microscopic inspection showed the fish to be free of infection.

Culture Facilities

The fish were grown at the Milford Hatchery (Kansas Fish and Game Commission, 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 1.22 meter (4 foot) long compartments by perforated screens. The screens consisted of 1.22 meter (4 foot) by 2.44 meter (8 foot) sheets of perforated aluminum surrounded by an aluminun frame. A rubber gasket was attached to the lower edge to insure a fish-tight seal. Each raceway was equipped with a variable-flow water supply line, surface and bottom outlets,and an air lift pump system capable of recirculating 757 liters (200 gallons) per minute.

Experimental Methods

Screens were placed every four feet in both raceways making a total of 48 compartments. Alternate compartments were numbered from one to 24 leaving an empty compartment downflow from each occupied compartment. This was done to prevent any feed which might be washed out of a compartment from being consumed by the fish in the downflow compartment. Before stocking with fish, the water was turned on in the raceways for 48 hours to allow them to stabilize and to flush oil and other chemicals from the screens.

The channel catfish fingerlings were counted individually and weighed in groups of 500. Five hundred fish were then placed in each of the numbered compartments and the weights recorded. This resulted in a stocking density of approximately 25% of the design capacity of the raceways. The fish were not fed the day before nor the day after stocking which occurred on the 18th of June to ensure all the fish had empty stomachs. The water level in the raceways was lowered on the first day to observe the fish and to ensure that the screens were preventing the fingerlings from leaving the compartments. Several designated empty compartments contained fish which were returned to their respective compartments, and gaps at the lower corners of the screens were sealed.

Fish were fed the experimental diets for the first time on the 20th of June. They recieved 1.5% of the average weight of all the groups (84 gms.) twice each day.This feeding rate of 3% of body weight per day was continued throughout most of the experiment, and was recalculated after each weighing period with the exception of a period starting on September 11th when the water temperature reached about 85 degrees. The feed was then increased to 4% of fish weight per day.The feed was reduced to 3% of fish weight when the water temperature dropped to about 65 degrees and the fish no longer consumed the total amount fed. The feedings were performed as early in the morning and as late in the evening as possible.

Diet Formulation and Processing

Diets used in this experiment consisted of eight formulations. All the diets were 35% protein. Half of the diets contained animal proteins and the other half only vegetable protein (Table 6).

Table 6. Catfish Diets used in this experiment.

Diet	Protein Type	% Lipid	Processing
1	vegetable (1)	3	pelleted *
2	vegetable (1)	6	pelleted *
3	vegetable (1)	9	pelleted *
4	vegetable (1)	6	extrusion cooked
5	animal (2)	3	pelleted *
6	animal (2)	6	pelleted *
7	animal (2)	9	pelleted *
8	animal (2)	6	extrusion cooked

1 Contained no animal proteins.
2 Fish meal and Blood meal were included.
* First batch was crumbleized.

Diets 1-4 contained only proteins from vegetable sources, while diets 4-8 contained fish meal and blood meal as significant components. These two groups were then subdivided by energy level and processing method. Each group contained a diet that was low fat (3%), medium fat (6%) and high fat (9%). Each medium fat (6%) diet, which was formulated to meet the accepted energy requirements for channel catfish, was also processed by extrusion cooking. These were treated as a separate diet. All the diets were carefully formulated to meet the accepted nutrient requirements for channel catfish. The diets were formulated using a computerized least-cost diet formulation program. The ingredient and nutrient requirement lists are contained in Appendix 1. The formulations for the eight experimental diets are contained in Appendix 2.

The diets were processed by weighing the ingredients and mixing them in a horizontal ribbon mixer. The mixtures were then ground through a 1/16 inch screen in a hammer mill. The ground mixtures were returned to the mixer and the liquid fat was added and mixed again. Mixing times were 3-5 minutes for each mix. The fat in the diets was limited to 6% to avoid processing difficulties. The 9% fat diets were prepared by mixing as described, then spraying an additional 3% fat on the finished feed. The feed mixtures were pelleted and crumbled to approximate #4 crumbles or were extruded to a similar size. Before feeding the pelleted, crumbled feed was passed over a #10 screen to remove fines which tended to float and be carried into the next compartment.

Pelleted diets were processed at 80-85 C and extruded diets were processed to a maximum 140-150 C. The diets were prepared in two batches shortly before needed and none were more than 60 days old when fed. Pellet size for the second batch was increased to 3/16 inch for the larger fish and extruded diets extruded to a similar size.

Vitamin and Mineral Premix

The accepted amounts (2) of vitamins and minerals required for intensively-fed channel catfish were provided by a premix. This premix was prepared immediately before the diets were processed using readily available feed ingredients and purified chemical components. The formula for the premix is shown in Appendix 3.

Data Collection

The fish were weighed every two weeks for the first eight weeks of the study, then at eleven and fifteen weeks. The first weighing consisted of netting one hundred fish from each compartment and weighing them as a group. The remainder of the weighing were determined by netting two hundred fish from each group with the exception of the final weight which was determined from three hundred fish per group. The fish were counted into a strainer and then added to a tared bucket half-filled with water. Weights were recorded to the nearest ounce. Fish were weighed after each hundred had been counted in order to reduce the amount of stress. At each measurement period several fish were removed, dissected, and inspected for disease and to estimate their general health. The final measurement also consisted of individually measuring one hundred fish from each compartment (2400 fish) to the nearest 1.0 millimeter.

Treatment for Disease

Disease problems during the study were minimal. Treatment with formalin (150 ppm) was required on June 30th for a mild *Scyphydia* infection. Two treatments with copper sulfate (2 ppm) were performed on July 30th and August 12th for parasitic infections. A four-day treatment with Medamyacin (4 mg/100 lbs. fish) starting on August 12th for bacterial infection was accomplished by mixing the medicine with vegetable oil and spraying on the feed. All the treatments were effective.

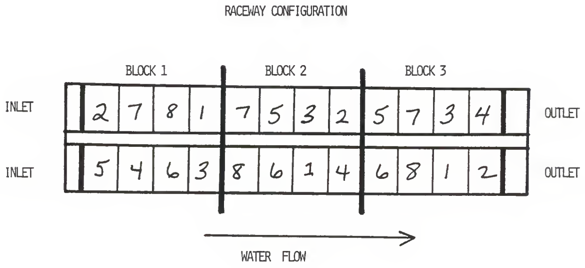
Experimental Design

This experiment was designed as a Random Complete Block experiment. The structure of the raceways and the fact that the fish at the bottom of the raceways were exposed to the wastes of the fish above them indicated a blocking design would be desirable to control for the effect of this water quality deterioration on the dependent variables. Personal communications with Dr. John Boyer (Assistant Professor, Kansas State University, Department of Statistics) indicated this would be the proper statistical experimental design for the physical arrangement of the raceway compartments. To achieve this design the raceways were divided across both raceways providing three blocks consisting of the first four compartments of both raceways as the first block, the second four compartments of each raceway as the second block, and the last four compartments of each raceway as the third block (Fig. 1). The eight compartments in each block were then randomly assigned to the eight treatments in the experiment. This design also allowed the effect of the position in the raceway to be statistically analysed.

Feed Analysis

The feeds used in the studied were analysed for protein, moisture, fat, and ash using standard proximate analysis procedures at the Kansas State University Department of Grain Science analytical laboratory. Determinations on diets of special interest (2,4,6,8) were performed using 1-fluoro-2, 4-

FIGURE 1. Complete Random Block Design



dinitrobenzene (FDNB) reactive lysine proceedures (22). Total amino acid analysis was carried out after hydrolysis with p-toluene sulfonic acid using a Dionex D-300 Amino Acid Analyser (23). Lysine content and available lysine were analysed by P-toluene sulfonic acid hydrolysis and a D 300 Amino acid Analyser to determine lysine content and by FDNB-reactive lysine (25) proceedures to determine available lysine.

Statistical Analysis

The raw data obtained from the experiment were analysed by SAS (24) using GLM and PDIFF functions to determine the significance of the treatment effect and the blocking effect. The significance was tested for average individual weight gain, feed conversion rates, and average weight gain by block.

RESULTS AND DISCUSSION

EFFECT OF DIETARY FAT LEVEL ON FISH WEIGHT GAINS.

Although the data obtained for the overall average weight gains (Table 7) of the fish in this study indicate that higher weight gains are positively correlated with increased dietary fat levels in both the animal-and the vegetable-protein-containing diets, the statistical analysis (Appendix 4) of the data did not show the differences to be significant at $p < 0.05$ for either dietary grouping.

Table 7. Over-all fish weight gains.

Diet	Percent Fat	Protein Type	Grams gained per Fish	Statistical Comparisons *
1	3	veg.	11.83	A
2	6	veg.	14.05	A
3	9	veg.	16.34	A B
5	3	animal	21.92	B C
6	6	animal	25.79	C
7	9	animal	26.82	C

* Comparisons not having the same letters indicate that the means are significantly different (alpha=.05).

The purpose of this portion of the study was to determine if the energy requirements for channel catfish cultured in raceways were greater than the requirements for channel catfish cultured in non-intensive facilities. Many studies (8,10,12,25) have shown the optimum fat level in extensively cultured channel catfish to be in the range of 6 to about 10-12 percent, with a decrease in growth rate at the higher amounts. Voluntary feed consumption has been shown to be affected by the energy density of the feed with excessive energy levels preventing the consumption of adequate amounts of protein for optimum growth (2,10). Carling et al. (9) determined that digestible carbohydrates and fats can both be effectively used as energy sources for channel catfish. The results of this study indicate that fish gained weight slightly faster when fed 6% dietary fat as compared to 3% but very little additional weight gain was observed with the 9% fat diets. This suggests the 6% fat diets with 2860 Kcal/Kg. digestible energy provided adequate energy for growth under these conditions.

EFFECT OF DIETARY PROTEIN SOURCE ON FISH WEIGHT GAINS

Comparison of average weight gains of fish fed diets formulated to be isocaloric and isonitrogenous showed significantly greater weight gains in those fed the diet containing the animal proteins (Table 8 and Figure 2). This was true at all three fat levels and in the extruded as well as pelleted diets.

FIGURE 2. Weekly Weight Gains.

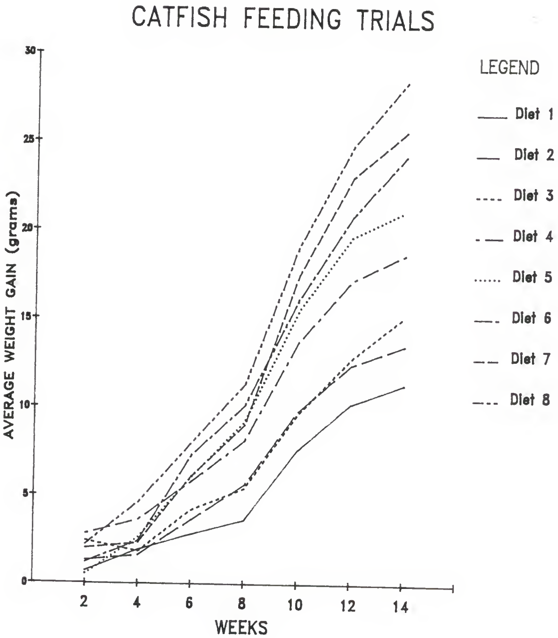


Table 8. Average weight gains by protein source

Diet	Percent Fat	Protein Type	Processing Method	Grams gained per Fish	Statistical Comparisons*
1	3	veg.	Pelleted	11.84	A
5	3	animal	Pelleted	21.92	B
2	6	veg.	Pelleted	14.05	A
6	6	animal	Pelleted	25.79	B
3	9	veg.	Pelleted	16.34	A
7	9	animal	Pelleted	26.83	B
4	6	veg.	Extruded	19.45	C
8	6	animal	Extruded	30.11	D
4	6	veg.	Extruded	19.45	C
6	6	animal	Pelleted	25.79	B **

* Comparisons not having the same letters indicate that the means are significantly different (alpha=.05).
** Significantly different at p = 0.061.

Animal protein sources such as fish meal and blood meal comprise the most expensive major component in practical fish diets. The price and availability of these ingredients also fluctuates with market conditions. For these reasons it is of continuing interest to determine if substitutions for animal protein with vegetable proteins can be achieved. Considerable research (2,6,17,18) has been conducted to investigate various alternate sources of protein as replacements for the fish meal component in catfish diets. Andrews et al (6) attempted to isolate the growth factor(s) in the fish meal responsible for its superior performance. They concluded the growth factor(s) were contained in the non-lipid residue of the fish meal and were destroyed by ashing. Some researchers have reported good growth rates with diets that contain only vegetable proteins (2,6,17), but the comparison diets containing higher percentages of animal proteins have generally produced significantly better growth. Robinson et al (18) studied growth rates resulting from diets containing extruded soy proteins and obtained significantly better growth than a control diet containing 8% fish meal. The comparison of the 6% fat extruded vegetable protein diet, which contained a mixture of soy,corn and wheat proteins and the 6% animal protein diet indicated that the animal protein containing diet produced better growth (Table 8) though no statistical differences were apparent.

PELLETING VS. EXTRUSION PROCESSING.

Diets formulated to be isocaloric and isonitrogenous were either pelleted or extrusion processed to compare the effects of processing on nutritional quality. The over-all weight gains (Table 9) of fish fed extrusion processed diets appeared to be somewhat higher than those of fish fed the pelleted 6% fat diets, but the difference was not significant at $p < 0.05$.

Table 9. Average weight gains by processing technique.

Diet	Percent Fat	Protein Type	Processing Method	Grams gained per Fish	Statistical Comparisons *
2	6	veg.	Pelleted	14.05	A
4	6	veg.	Extruded	19.45	A B
6	6	animal	Pelleted	25.79	B C
8	6	animal	Extruded	30.11	C

* Comparisons not having the same letter are significantly different (alpha=.05).

Some investigators have reported that extrusion cooking of starchy grains such as corn and wheat increases the available energy of these grains by 5 to 30% (1,2,25) in catfish, while others have found no improvement of feeds by extrusion processing (20,21). Although the increases were not statistically significant our data reflects increased weight gains by fish fed practical extruded diets. Robinson et al (18) found that extrusion of soy proteins allowed for good growth in a vegetable protein diet in aquaria. While the results of the present experiment did not indicate statistical differences between the pelleted and extruded diets of similar composition, the fish receiving the extruded 6% fat vegetable diet (Diet 4) gained 38.4% more than the fish recieving the pelleted 6% fat vegetable diet (Diet 2). The fish receiving the extruded 6% fat animal diet (diet 8) gained 16.8% more than the fish recieving the pelleted 6% fat animal diet (Diet 6). The extruded diets also had better feed conversion ratios than the pelleted diets of similar composition (Table 12).

EFFECT OF EXTRUSION PROCESSING ON AVAILABLE LYSINE

A comparison of total dietary lysine and available lysine in the diets (Table 10) confirms that the diets all contained the minimum required amount of lysine (1). All the diets were formulated to contain the required minimums for all essential amino acids and analyses of the diets indicate that they, in fact, meet these requirements. The comparison of the total lysine in the diets with the available lysine analytical data indicated some differences in the available lysine (Table 10). These differences are small but are positively correlated to the weight gains observed in the study. Since all the diets contained the minimum amount of lysine required for growth it is unlikely the small differences seen in the lysine content of these diets were responsible for the large differences observed in weight gain.

Table 10. Analysis of lysine in the 6% fat diets.

Diet	Type	Total Lysine (g/100g pro.)	Available Lysine (g/100g pro.)	Percent Available
2	Pelleted veg.	1.86(.05)*	1.48(.01)	79.6%
4	Extruded veg.	1.78(.04)	1.53(.03)	85.6%
6	Pelleted anim.	1.85(.01)	1.57(.02)	84.9%
8	Extruded anim	1.98(.06)	1.66(.02)	83.8%

* Numbers in parenthesis indicate the variance of the results

Comparison of the percent available lysine in the pelleted diet and the extruded diet in each group indicated that extrusion processing of the vegetable-based diets resulted in an increase in percent available lysine, while extrusion of the animal-protein diets resulted in a slight decrease in lysine availability. Increased lysine availability might therefore partially explain this better performance of the extruded vegetable-protein diets, but not of the extruded animal-protein diets. These results indicate that it is not possible to generalize about the effects of extrusion processing of feeds and feed materials. These effects appear to vary with feed composition.

EFFECT OF POSITION IN THE RACEWAY ON WEIGHT GAINS.

The use of a random complete block design allows for the comparison of the average weight gain by all the fish in each block. The over-all weight gains (Table 11) indicated a negatively correlated, statistically significant effect of raceway position on average weight gain.

Table 11. Average weight gains by block.

Block	Grams gained per Fish	Statistical Comparisons *
Block 1.	26.29 gms.	A
Block 2.	19.75 gms.	B
Block 3.	15.81 gms.	B **

* Comparisons not having the same letters indicate that the means are significantly different (alpha=.05).
** Significantly different at p = 0.0719.

The results of this analysis indicate the importance of good water quality in intensive culture of catfish. Significantly less weight gain was observed in the fish in the downflow postions independent of which diet they received. While the mortality rate for this experiment was low (approx. 6%), the majority of the mortalities occurred in the lower six compartments in one raceway with the remainder of the compartments having very few deaths. This was evident even though the stocking rate used in the experiment was approximately 25% of the design capacity of the raceways used. During the study the water supply of the hatchery underwent considerable fluctuations in both quantity and quality. The hatchery personel were in the process of placing the hatchery in full operation and dealing with serious disease problems in some of the other raceways. While the trend to reduced weight gains in the lower parts of the raceways will probably continue, the magnitude of the difference will be less once these operational problems are solved.

EFFECT OF FAT CONTENT AND PROCESSING METHOD ON FEED EFFICIENCY.

Feed coversion ratios for the diets in the study were calculated using the formula;

Feed conversion ratio = weight feed fed/weight gained

The feed conversion ratios (Table 12) ranged from 3.78 to 5.56 for the vegetable protein diets and 2.14 to 3.79 for the animal protein diets. Statistically the extruded vegetable diet had a better feed conversion ratio than the 3% and 6% fat vegetable protein diets and the extruded animal protein diet had a better feed conversion ratio than any other diet.

Table 12. Feed Conversion Ratios

Diet	Percent Fat	Protein Type	Processing Method	Feed Efficiency	Statistical Comparisons *
1	3	veg.	Pelleted	5.56	A
2	6	veg.	Pelleted	5.44	A
3	9	veg.	Pelleted	4.06	A B
4	6	veg.	Extruded	3.78	B
5	3	animal	Pelleted	3.79	B C
6	6	animal	Pelleted	2.50	B C
7	9	animal	Pelleted	2.49	B C
8	6	animal	Extruded	2.14	C

* Comparisons not having the same letters indicate the means are significantly different (alpha = .05).

In general the feed conversion ratios in this study indicated that feed conversion is negetively correlated to increasing fat level with the extruded diets producing the best feed efficiency in both the animal and vegetable protein groups.

EFFECT OF DIETARY FAT AND PROCESSING METHOD ON CONDITION FACTOR.

Condition factor is a ratio of length to volume for individual fish. The condition factor for wild fish of a particular species is very consistant and can be used to indicate overall condition of fish in the wild. Large differences in the condition factor of the groups of fish in the study might provide an indication of diet performance. However, no significant differences or trends were indicated by the analysis of these data.

The average condition factor for the fish in each treatment was calculated using the formula;

K= 100000 X average weight (g) / average total length (mm) cubed

The condition factors obtained for the different diets ranged from 0.781 for Diet 2 to 0.831 for Diet 6. The statistical analysis of these values indicated no statistical differences between the eight treatments in the study.

EFFECT OF DIET ON LENGTH UNIFORMITY

The results of the length measurement showed there was a trend toward greater variation in length down the raceway but no trends or correlation was observed between the diet the fish recieved and the uniformity of fish length. The data observed and the variations calculated are contained in Appendix 5.

GENERAL DIET PERFORMANCE

The results of this experiment indicate the most efficient diet in the study was Diet 8, which was an extruded 6% fat diet containing 8% fish meal and 5% blood meal. This diet produced the best average weight gain, the best feed conversion rate and produced fish of consistent size and good condition. The increased weight gain observed in the fish on Diet 8 (extruded 6% fat animal protein) indicates that the use of extrusion cooking may have a more positive effect on weight gain than the inclusion of more fat in the diet. The slight difference between Diet 6 (6% fat, animal protein) and Diet 7 (9% fat, animal protein) also supports this idea.

The vegetable diets in all cases performed poorly when compared to animal diets of similar composition and processing. These vegetable diets were formulated to meet all of the accepted nutritional requirements of catfish. The extruded diets floated when fed and the extruded diet containing animal proteins was much more actively consumed than that containing only vegetable proteins. This factor may indicate the lack of performance by the vegetable diets was due to the feed being less readily accepted by the fish. The use of fish oil in place of the rendered beef fat in the diet formulation may have improved the performance of the vegetable diets. Fish oils may impart undesirable flavors to the fish but this would not be a factor in fish raised for a stock, grow and catch program.

The weekly weight gain of all the dietary groups (Figure 2) indicated that trends shown by analysis of the final weight gains were evident throughout the study with the exception of the first few weeks. These early results were based on smaller samples and some problems with the collection of the weights, such as weighing considerable amounts of water with the fish before a strainer was used to prevent the transfer of water on the hands of the counters into the weigh bucket, may explain the inconsistant results observed.

DIETARY COST COMPARISONS

One of the major considerations in the culture of fish is the cost of the feed needed to produce a weight of fish. This information takes into account the conversion rate of the feed and the cost of the feed. The three diets of greatest interest in this study are the 6% fat pelleted animal protein diet, and the 6% fat extruded diets, both animal and vegetable protein. The cost of the diet, the feed conversion rates and the cost per pound of fish raised for these diets (Table 13) indicate that the extruded animal protein diet was the most cost effective feed in the study. The processing costs in the calculations come from the Kansas State Pilot Feed Mill charges and should indicate relative costs.

Table 13. Feed costs for the production of catfish in this study.

Diet	Feed Cost* $/Cwt	Feed Conversion Rate	Production Costs $/lb. fish
Diet 4 (6% fat extr.veg.)	15.52	3.78	$.59
Diet 6 (6% fat pel.anim.)	14.53	2.50	$.36
Diet 8 (6% fat extr. anim.)	15.53	2.14	$.33

* These costs include processing costs of $1.00/CWT for the pelleted feed and $2.00/CWT for the extruded feed.

The combination of the reduced costs for the production of catfish with the extruded diet and the management advantages of observing the feeding behavior of the fish indicate diet 8, the extruded 6% animal protein diet, was the best overall diet that was evaluated.

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APPENDIX 1. Ingredient and Nutrient Lists

ANIMAL PROTEIN CATFISH DIET INGREDIENT LIST

INGREDIENTS	MINIMUM	MAXIMUM
Soybean Meal 44%	30.0%	60.0%
Bloodmeal	5.0%	15.0%
Ground Wheat	10.0%	25.0%
Corn Gluten Meal	---	20.0%
Fish Meal	8.0%	12.0%
Rendered Beef Fat	---	10.0%
Wheat Bran	10.0%	20.0%
Dist Dri Sol	---	5.0%
Catfish V+M Premix	.65%	.65%

VEGETABLE PROTEIN CATFISH DIET INGREDIENT LIST

INGREDIENTS	MINIMUM	MAXIMUM
Soybean Meal 44%	30.0%	60.0%
Wheat Gluten Meal	5.0%	20.0%
Ground Wheat	10.0%	25.0%
Corn Gluten Meal	2.0%	20.0%
Soy Protein Conc.	2.0%	12.0%
Rendered Beef Fat	---	10.0%
Wheat Bran	10.0%	20.0%
Lysine (78%)	---	2.0%
Catfish V+M Premix	.65%	.65%

NUTRIENT LISTS

LOWFAT CATFISH DIET

NUTRIENT	UNITS	MINIMUM	MAXIMUM
Protein	%	35.00	36.0
Fiber	%	----	7.0
Fat	%	2.90	----
DE, Catfish	Kcal/lb.	1190.00	1200.0
Lysine	%	1.80	----
Methionine	%	0.32	----
Meth-Cys	%	0.81	----
Arginine	%	1.50	----
Tryptophan	%	0.25	----
Histidine	%	0.52	----
Isoleucine	%	0.91	----
Leucine	%	1.20	----
Phenylalan	%	1.75	----
Threonine	%	0.80	----
Valine	%	1.05	----

MEDIUM FAT CATFISH DIET

NUTRIENT	UNITS	MINIMUM	MAXIMUM
Protein	%	35.00	36.00
Fiber	%	----	7.00
Fat	%	5.50	6.00
DE,Catfish	Kcal/lb.	1300.00	1330.00
*		---------	---------

HIGH FAT CATFISH DIET

NUTRIENT	UNITS	MINIMUM	MAXIMUM
Protein	%	35.00	36.00
Fiber	%	-----	7.00
Fat	%	9.00	10.00
DE,Catfish	Kcal/lb.	1430.00	1450.00
*		---------	---------

* These lists contain the same minimums for amino acids.

APPENDIX 2. Diet Formulations

INGREDIENT*	DIET 1	DIET 2	DIET 3	DIET 4	DIET 5	DIET 6	DIET 7	DIET 8
Soybean Meal (44%)	52.0%	52.9%	54.0%	52.1%	50.0%	41.5%	32.2%	48.4%
Bloodmeal	---	---	---	---	4.9%	4.9%	4.9%	4.9%
Fishmeal	---	---	---	---	7.9%	7.9%	7.9%	7.9%
Ground Wheat	25.0%	21.4%	15.6%	24.9%	25.1%	25.2%	25.3%	25.1%
Wheat Gluten	5.1%	10.2%	5.1%	5.1%	---	---	---	---
Wheat Bran	10.1%	10.2%	10.2%	10.1%	11.7%	10.2%	10.3%	10.5%
Corn Gluten Meal	2.0%	2.4%	3.2%	2.0%	---	5.0%	10.5%	---
Lignin Sulfonate	2.4%	1.8%	1.8%	---	1.9%	1.9%	1.9%	---
Soy Protein Concentrate	2.0%	2.0%	2.0%	2.0%	---	---	---	---
Rendered Beef Fat	0.7%	3.7%	7.4%	3.2%	---	2.8%	6.3%	2.7%
Catfish Vit. and Min. Premix	.65%	.65%	.65%	.65%	.65%	.65%	.65%	.65%
Cost $/CWT	13.74	14.12	14.61	14.02	13.25	13.53	13.90	13.53

*All ingredients on an as fed basis

APPENDIX 3. Vitamin and Mineral Premix

INGREDIENT	GRAMS/TON FEED
Thiamin	10
Riboflavin	12
Pyridoxine	10
Vitamin B Complex *	2270
Folic Acid	2
Vitamin B-12	182
Vitamin C	341
Vitamin A	267
Vitamin D3	90
Vitamin E	1136
Vitamin K	30
Z-10 Mineral Mix **	454

* Choline Chloride 50%(95.9 gms/lb.),d Calcium Pantothenate 45% (12.6 gms/lb.),Niacin(23.9 gms/lb),Riboflavin 50% (7.9gms/lb.)

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

APPENDIX 4. Statistical Comparison by Diet

(Prob > lTl HO: LSMEAN (I)=LSMEAN (J)

DIET (LSMEAN)	1	2	3	4	5	6	7	8
1 11.83 gm.	--	--	--	--	--	--	--	--
2 14.Ø5 gm.	Ø.484	--	--	--	--	--	--	--
3 16.34 gm.	Ø.22	Ø.52	--	--	--	--	--	--
4 19.45 gm.	Ø.Ø29	Ø.1Ø4	Ø.389	--	--	--	--	--
5 21.92 gm.	Ø.Ø14	Ø.Ø43	Ø.163	Ø.492	--	--	--	--
6 25.79 gm.	Ø.ØØ1	Ø.ØØ2	Ø.Ø19	Ø.Ø61	Ø.289	--	--	--
7 26.83 gm.	Ø.ØØØ	Ø.ØØ1	Ø.Ø11	Ø.Ø33	Ø.185	Ø.741	--	--
8 3Ø.11 gm.	Ø.ØØØ	Ø.ØØØ	Ø.ØØ2	Ø.ØØ5	Ø.Ø37	Ø.184	Ø.3Ø1	--

APPENDIX 5. Actual weight gains (gms/ fish)

Diet	Raceway Position	Weight Gains 1	2	3	4	5	6
1	1-7	.18	1.74	2.16	2.44	9.40	10.39
1	1-11	.96	1.67	3.94	4.37	7.77	10.61
1	2-4	1.08	2.22	2.22	4.06	12.01	14.51
2	1-12	2.21	1.65	3.49	4.62	8.88	8.83
2	2-1	1.48	1.48	4.31	8.99	18.78	23.04
2	2-8	0.07	1.64	3.19	3.19	7.74	10.29
3	1-4	2.10	1.10	5.51	8.06	11.89	19.60
3	2-11	2.67	2.10	3.09	3.23	11.42	13.59
4	1-2	1.70	2.41	7.38	12.20	21.28	27.62
4	1-8	3.74	5.02	5.30	8.57	16.51	19.44
4	2-12	3.07	3.52	4.77	3.78	11.58	11.30
5	1-1	0.17	2.58	7.83	14.07	24.71	32.70
5	2-10	0.80	2.21	4.48	4.91	13.14	11.66
6	1-3	0.96	2.09	9.19	10.75	19.90	28.30
6	1-6	1.53	2.53	6.78	10.05	19.69	25.94
6	1-9	1.19	2.61	6.01	9.42	18.07	23.13
7	2-3	1.93	1.51	5.91	10.73	24.07	31.25
7	2-5	2.33	2.76	5.74	8.57	25.17	29.38
7	2-10	1.59	2.73	6.70	7.69	15.78	19.85
8	1-5	2.67	5.37	9.34	11.89	22.67	29.53
8	1-10	2.84	4.40	7.80	10.36	20.00	27.52
8	2-4	1.03	4.15	6.84	11.52	26.42	33.28

APPENDIX 6. Average Lengths and Standard Deviation (cm)

Diet	Block 1 Ave. Length	Block 2 Ave. Length	Block 3 Ave. Length
1	14.7 (1.8)	14.1 (1.9)	14.3 (4.6)
2	16.5 (1.8)	14.0 (1.9)	13.5 (1.7)
3	15.3 (1.7)		14.8 (3.8)
4	16.8 (1.6)	15.6 (2.0)	14.0 (1.7)
5	17.6 (2.2)	----------	14.3 (1.9)
6	16.5 (2.2)	16.6 (2.0)	16.1 (2.5)
7	17.5 (2.2)	16.8 (2.4)	16.0 (2.5)
8	17.8 (2.3)	17.0 (2.3)	16.9 (2.3)

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This manuscript is dedicated to Cindy Huggins who suffered through every trial.

THE EFFECTS OF PROTEIN TYPE AND ENERGY LEVEL IN RACEWAY CULTURE OF CHANNEL CATFISH

by

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Eight diets were formulated and manufactured to evaluate the effect of dietary protein source, dietary fat level and extrusion processing on the weight gain of intensively cultured catfish. Twenty four groups, each containing five hundred catfish fingerlings, were fed for fifteen weeks in raceway compartments. The fish were weighed periodically and the results used to evaluate the growth response of catfish fingerlings to diet and position in the raceway.

The diets consisted of two groups of four, one group with animal protein components in the diet and the other group containing only vegetable proteins. Each group contained pelleted diets with three, six, and nine percent fat and a six percent fat extruded diet. The diets were isonitrogenous and contained the required amounts of vitamins, minerals, energy, and amino acids with the exception of the three percent fat diets which were energy deficient.

The results indicated that the diets containing animal protein components performed significantly better than those containing only vegetable proteins regardless of energy level or the processing technique used to produce the feed. The diet with the best growth response in the study consisted of a six percent fat diet containing animal protein components and processed by extrusion processing.

The effect of the position of the fish in the raceway on growth was also significant with the fish in the block nearest the fresh water inlet gaining significantly more than those in the block below them. This also seen regardless of protein source, energy level, or processing technique.

The growth response to dietary fat level idicated that weight gain was positively correlated to increasing fat level but the differences seen were not large enough to be significant.

Comparison of the extruded diets to pelleted diets of similar composition indicated increased growth on the extruded diet in both groups but the differences were not large enough to be statistically significant.