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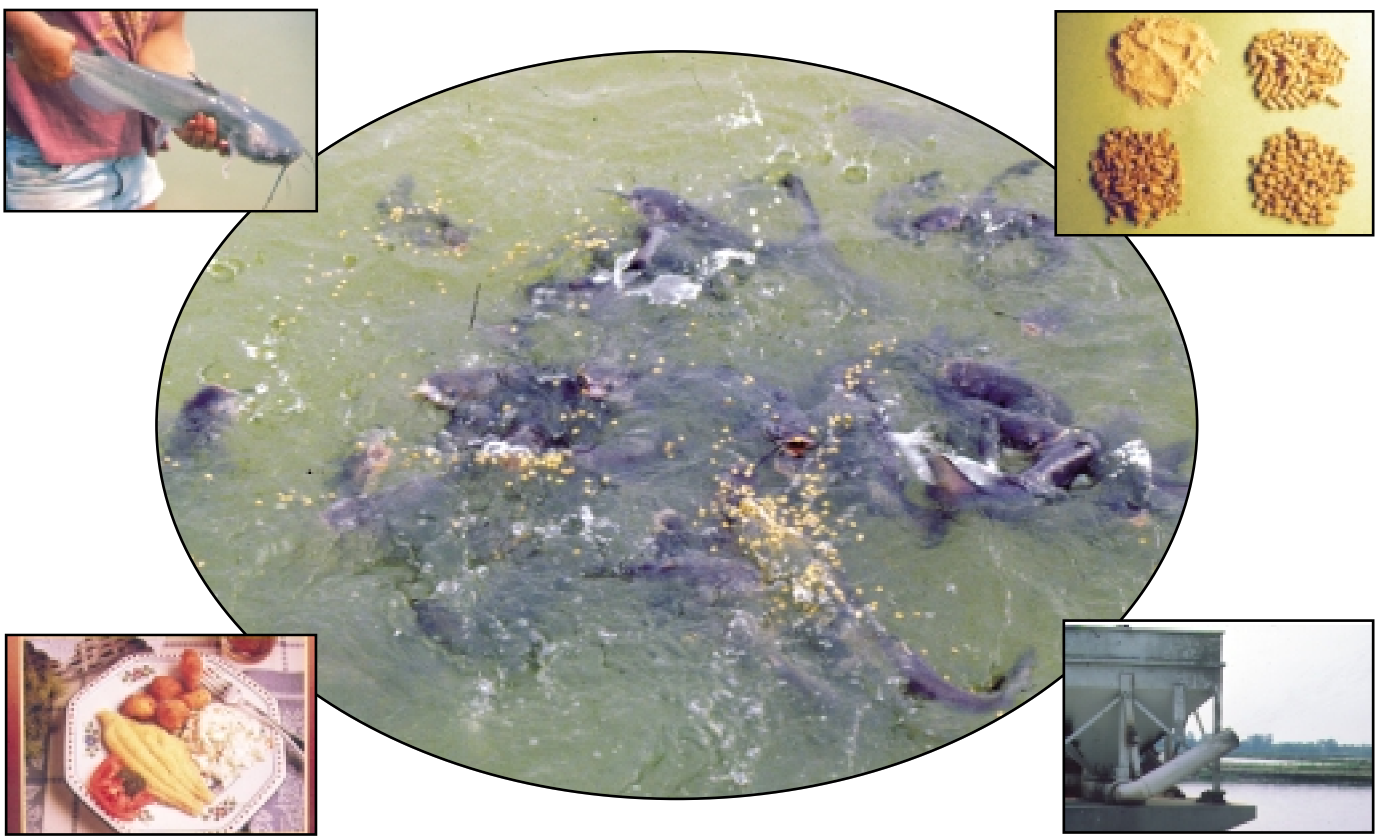
Effect of Nutrition on Body Composition and Subsequent Storage Quality of Farm-raised Channel Catfish



Final Project Report on the
SRAC Regional Research Project

Effect of Nutrition on Body Composition and Subsequent Storage Quality of Farm-raised Channel Catfish

SRAC No. 6000

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Contents

Preface

The project summarized in this report was developed and funded through the Southern Regional Aquaculture Center, one of five regional aquaculture research and Extension centers established by Congress in 1985 and administered by the United States Department of Agriculture. The five centers are located in the northeastern, north-central, southern, western, and tropical Pacific regions of the country. The Southern Regional Aquaculture Center began organizational activities in 1987, and the first research and Extension projects were initiated in 1988. The thirteen states and two territories included in the Southern Region are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, U.S. Virgin Islands and Virginia.

The regional aquaculture centers encourage cooperative and collaborative research and Extension educational programs in aquaculture having regional or national applications. Center programs complement and strengthen research and Extension educational programs provided by the Department of Agriculture and other public institutions.

The mission of the centers is to support aquaculture research, development, demonstration, and Extension education to enhance viable and profitable domestic aquaculture production for the benefit of consumers, producers, service industries, and the American economy. Projects developed and funded by the centers are based on regional industry needs and are designed to aid commercial aquaculture development in all states and territories. The centers are organized to take advantage of the best aquaculture science, education skills, and facilities in the United States. Center programs ensure effective coordination and a region-wide, team approach to projects jointly conducted by research, Extension, government, and industry personnel. Interagency collaboration and shared funding are strongly encouraged.

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List of Tables

List of Figures

Executive Summary

This document summarizes results of the Southern Regional Aquaculture Center project *Effect of Nutrition on Body Composition and Subsequent Storage Quality of Farm-raised Channel Catfish*. The primary goal of this project was to enhance the nutritional composition and storage quality of channel catfish by manipulating diet composition and feeding regimes. The effects of these various manipulations on catfish growth and body composition, production economics, and storage quality of edible products were delineated in several multidisciplinary studies. Based on the results of those studies, refinements in diet formulations, feeding practices and fish processing have been developed to optimize catfish growth and production economics while ensuring the quality of resulting products, especially in frozen storage.

Diet Formulations

Numerous studies conducted in association with this project showed that diets with protein concentrations of 28 to 32 percent and an energy to protein ratio of 9 to 10 kcal digestible energy/g protein will produce optimal growth and feed conversion in channel catfish with only slight detriments to processing yield and body composition. Thus, these dietary protein levels are recommended for optimal production economics.

Feeding Practices

Many feeding schedules and dietary manipulations were investigated in this project to identify the best feeding practices in terms of production economics and product quality. Feeding catfish once a day, to apparent satiation, appears to be adequate when diets contain 28 to 32 percent. Neither high-protein finisher diets nor other feeding schedules confer additional benefits.

Fish Processing

The study demonstrated that some processing techniques improve the quality of fresh and frozen catfish products. Treating fish with sodium acetate increases the shelf life of fresh catfish products. Vacuum packaging improves the keeping quality of fresh and frozen products. Supplementing diets with vitamin E above the minimum requirement level enhances the oxidative stability of catfish products, but generally is not warranted if products will be stored less than 6 months.

Project Background

The commercial catfish industry has expanded greatly over the past two decades and is now valued at well over $1 billion. This phenomenal growth has been accompanied by concern with product quality, primarily regarding the amount and quality of lipid in marketable fish. Excess lipid in fish decreases dress-out yield and reduces the shelf-life of the processed fish. The rancid flavor caused by oxidation of lipids in frozen catfish and the limited shelf life of frozen products prevent the markets for processed catfish from expanding. Both the amount of lipid in diets and the saturation level of the lipid affect the amount of lipid in the flesh of fish. Increased fattiness in catfish may be a result of several factors, but diet composition, feeding practices, and fish size are of primary importance.

Complicating the problem is the need for fast growth, usually accomplished by satiation feeding, which typically promotes lipid deposition. Also, larger fish that meet the demands of the fillet market naturally have more lipid than smaller fish. Solving these problems would improve catfish products and enable the industry to expand to new markets. This project, a series of multidisciplinary studies involving several institutions, was approved for funding in 1988 by the United States Department of Agriculture, Cooperative States Research, Extension and Education Service. The following report summarizes the project's findings and recommendations. Additional information may be obtained from the individual publications listed at the end of this report.

Project Objectives

Objective 1. Determine the effects of dietary digestible energy to protein ratio (DE/P ratio) on yield, dressing percentage, body lipid, frozen storage quality, and profitability of catfish grown to 0.5 to 1.0 kg (1 to 2 pounds) under conditions that reflect management practices used by most of the catfish industry.

Objective 2. Determine the effects of finisher diets and alternative feeding rates and schedules on yield, dressing percentage, body lipid, frozen storage quality, and profitability of catfish grown to 0.5 to 1.0 kg (1 to 2 pounds) under conditions that reflect management practices used by most of the catfish industry.

Objective 3. Determine the effects of diet components on chemistry and sensory qualities of lipid in fish flesh, and the stability of fish during frozen storage.

Objective I: Determine the Effects of Dietary Energy to Protein Ratio on Catfish Production, Composition and Frozen Storage Quality

It has been well established that the ratio of dietary digestible energy to protein (DE/P ratio) is a primary factor that influences growth, body composition and nutrient utilization of fish. If the DE/P ratio is unbalanced, with an excess of protein relative to non-protein energy, fish may not grow well and too much costly protein will be used for energy. If there is inadequate dietary protein relative to non-protein energy, fish growth also may be slowed, with excessive lipid being stored in the body. Several laboratory feeding trials have investigated DE/P ratio requirements of fingerling channel catfish. However, the optimum DE/P ratio, especially with regard to body composition and storage quality, has not been established for large 2- and 3-year-old channel catfish, which are the major age classes of processed fish. Therefore, a series of experiments was conducted to further investigate these relationships.

Methods

Controlled feeding trials were conducted at several of the participating institutions. Catfish were reared in earthen ponds with stocking, feeding and other management practices similar to those employed commercially. Diets were similar to those used commercially, with major ingredients being soybean meal, grain products, fish meal, and vitamin and mineral supplements. The test diets differed primarily in crude protein concentration and DE/P ratio (Table 1). These feeding trials were conducted for at least 140 days with 2- and 3-year-old fish. At termination, fish were of comparable size to those produced commercially. Responses measured included total yield, fish growth, dressing percentage, body fat, and frozen storage quality. In some of the experiments, various aspects of water quality and production profitability also were measured.

Table 1. Typical composition of diets fed in various experiments associated with this project.

	Protein (%)				
	24	**28**	**32**	**36**	**40**
Ingredients (%)					
Ground corn	65.1	50.4	41.0	31.4	22.0
Soybean meal, dehulled	26.0	39.4	47.5	55.7	64.8
Menhaden fish meal	5.7	7.1	8.6	10.1	10.6
Wheat middlings	15.0	0	0	0	0
Animal fat	1.5	1.5	1.5	1.5	1.5
Dicalcium phosphate	1.55	1.45	1.30	1.15	1.00
Trace mineral premix	0.05	0.05	0.05	0.05	0.05
Vitamin premix	0.1	0.1	0.1	0.1	0.1
Vitamin C	0.075	0.075	0.075	0.075	0.075
Composition					
Crude protein (%)	24.7	28.5	32.2	35.4	39.1
Digestible energy (kcal/g)	3.09	3.14	3.15	3.17	3.17
Digestible energy/protein	12.5	11.0	9.8	9.0	8.1

See Li and Lovell (1992) for more details.

Results

In one experiment, protein concentrations from 24 to 40 percent of diet had no significant effect on weight gain or feed consumption of 2-year-old fish (average final weight of 488 g) and produced a negative linear effect on weight gain and feed consumption of 3-year-old fish (final average weight of 1632 g) (Fig. 1). Weight gain was positively correlated with feed consumption in both size groups, and feed conversion was not significantly affected by dietary protein concentration. Efficiency of protein utilization decreased linearly as dietary protein increased. Dressing percentage increased as dietary protein increased from 24 to 36 percent and decreased as dietary protein increased from 36 to 40 percent in 2-year-old fish. However, dressing percentage was not affected by dietary protein concentration in 3-year-old fish. In both size groups, muscle lipid decreased linearly, while protein and moisture increased, as dietary protein increased. Two-year-old fish had lower feed conversion, lower dressing percentage, and less muscle lipid than 3-year-old fish. Thus, 2- and 3-year-old channel catfish gained maximally with diets containing no more than about 24 percent crude protein (with satiate feeding), although muscle fat content was higher and dressing percentage (of 2-year-old fish only) lower with this low-protein diet. Two-year-old fish had advantages over 3-year-old fish in terms of better feed efficiency and less muscle lipid, but they had the disadvantage of lower dressing yield. Fish

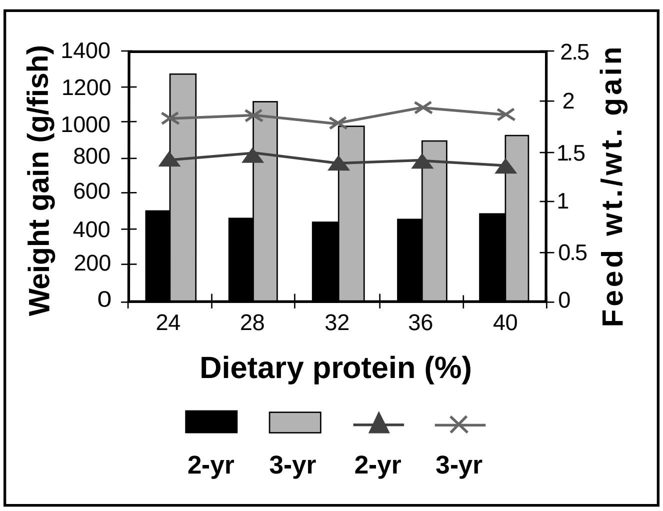

Figure 1. Weight gain (bars) and feed conversion ratio (symbols) of 2- and 3-year-old channel catfish fed diets with different concentrations of protein.

that had been fed diets containing five different DE/P ratios were evaluated for storage quality. Fillets from each treatment sample were overwrapped with polyvinylidene chloride (PVDC) film and stored on ice for 2 days. Quality was measured chemically, microbiologically and sensorily. Results showed that fish fed the lowest protein diet (24 percent) had significantly higher lipid content in the muscle; however, lipid content had no significant effect on the sensory acceptance scores given by a trained taste panel (Fig. 2). In general, taste panelists were unable to detect off-flavor in or differentiate acceptance among the fillet samples from fish fed different protein concentrations.

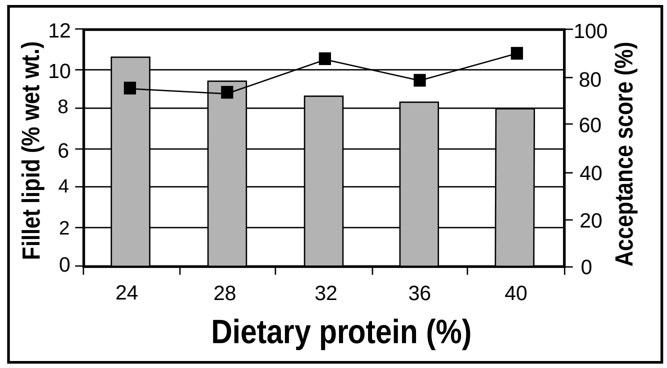

Figure 2. Fillet lipid content (bars) and sensory acceptance score (symbols) of fillets (after storage on ice for 7 days) from channel catfish fed diets with different concentrations of protein.

Samples also were kept in frozen storage for 0, 3, 6 and 9 months under fluctuating temperatures (-6 to -18 ºC). Levels of hydroperoxides, conjugated dienes, thiobarbituric acid reactive substances, fluorescent pigments, and volatiles were monitored at various storage intervals. Alpha-tocopherol equivalents were lost slowly during the first 6 months of storage. Accelerated degradation of alpha-tocopherol after 6 months of storage coincided with increased lipid oxidation, indicating that the alpha-tocopherol concentrations of samples stored for 6 months were no longer sufficient to protect membrane lipids and prevent oxidation. Higher activities of phospholipase and lipase also appeared to affect oxidative stability.

In another experiment, dietary protein concentration ranging from 24 to 40 percent had a negative linear effect on weight gain of channel catfish. The total ammonia-nitrogen (TAN) in pond water increased linearly as dietary protein concentration increased, and was positively correlated with the total protein fed. However, unionized ammonia-nitrogen (NH_3-N) was not influenced by protein concentration in the diet. Dietary protein had a positive linear effect on nitrite-nitrogen (NO_2-N) concentration, which was positively correlated with total protein fed and TAN (Fig. 3). There was no significant correlation between NO_2-N and fish weight gain, although there was a significant positive correlation between the NO_2-N/chloride molar ratio in pond water and the concentration of methemoglobin in the fish. Results from this study indicated that when the feeding rate was as high as 100 kg/ha/day, or 3,000 kg protein/ha/season, dietary protein concentrations of 36 percent and higher can cause harmful concentrations of NO_2-N when chloride concentration in the water is 2-3 mg/L.

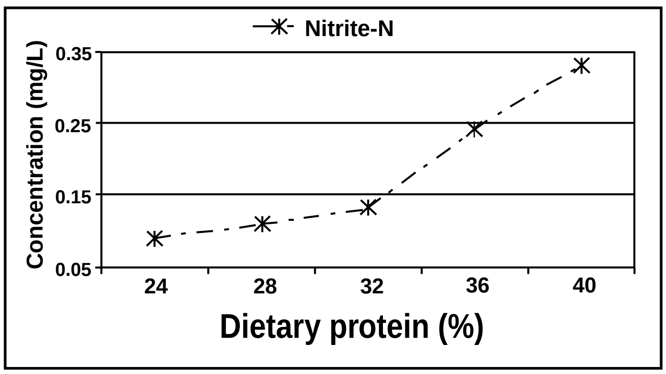

Figure 3. Concentrations of nitrite-nitrogen in water from ponds in which channel catfish were fed diets containing graded concentrations of protein.

In another experiment to investigate the effects of fish age on production characteristics, 2- and 3-year-old channel catfish were fed a 32 percent protein practical-type diet once daily to satiation for a 145-day growing period. The younger fish were grown from an average size of 20 g to 462 g and the older fish were grown from an average size of 594 g to 1,579 g. The feed conversion ratio was significantly better for 2-year-old fish than for 3-year-old fish; dressing yield was significantly higher for 3-year-old fish than for 2-year-old fish. Two-year-old fish had lower fillet fat (6.7 percent) than 3-year-old year fish (9.2 percent), but muscle protein was not different between the groups. This study indicates that 2-year-old channel catfish have better feed efficiency and lower muscle fat than 3-year-old fish, but the older fish have higher dressing yield.

Another study was conducted to evaluate the effects of two dietary protein levels on the weight gain and body composition of juvenile blue and channel catfish during the winter. Fish of both species were reared in ponds and fed diets containing either 25 or 35 percent protein according to a winter feeding schedule. Both species lost weight during the winter period, at both protein levels. At harvest, fat levels were significantly higher and protein levels significantly lower in blue catfish than in channel catfish. Channel catfish appeared to rely more on fat stores during the winter than blue catfish, but blue catfish did not grow more than channel catfish during the winter. Carcass characteristics and quality changes during refrigerated storage also were evaluated with channel catfish and hybrid channel x blue catfish. Fillets from channel and hybrid catfish reared in the same pond were overwrapped or vacuum-skin packaged and stored 13 days at 4 ^{o}C. No significant differences in body weight and proximate composition between the two genotypes were found. However, the visceral fat of hybrids was significantly higher than that of channel catfish. Vacuum-skin packaged fillets had much lower levels of free fatty acid and psychrotrophic bacteria than did overwrapped fillets on the 13th day of refrigerated storage.

Conclusions

These studies show that dietary protein concentrations of 28 to 32 percent of diet with a DE/P ratio of 9 to 10 kcal DE/g protein produce optimal growth and feed conversion in channel catfish. Fish on such diets also have acceptable processing yield and body composition. Thus, these dietary protein levels are recommended when feeding catfish for optimal production economics.

Objective II: Determine the Effects of Alternative Feeding Schedules, Feeding Rates and Finisher Diets on Catfish Production, Composition and Frozen Storage Quality

Methods

Several experiments were conducted to evaluate the individual and combined effects of various feeding rates, feeding schedules and dietary protein levels on growth, body composition, and storage quality of channel catfish. Fish were reared mainly in earthen ponds, using stocking, feeding and other management practices similar to those used commercially. Diets were similar to commercial diets with major ingredients being soybean meal, grain products, fish meal, and vitamin and mineral supplements. Dietary protein concentration was altered primarily by substituting a fixed ratio of soybean meal and fish meal for corn. The energy concentration of the diets was not regulated.

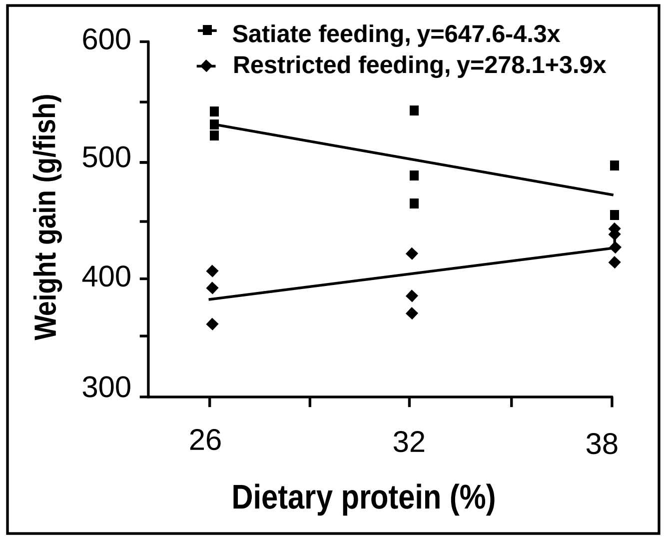

Figure 4. Weight gain of channel catfish fed diets containing different concentrations of protein under satiate or restricted regimes.

Results

One study was conducted to compare satiate feeding and restricted feeding of channel catfish with diets containing protein concentrations of 26, 32 or 38 percent. Fish in the satiation feeding group were fed as much as they would consume each day for the 125-day spring/summer experimental period. Fish in the restricted feeding group were not fed more than 60 kg/ha/day, which was reached at approximately day 70 of the feeding trial. There was a significant interaction between feeding regime and dietary protein concentration in terms of fish growth. The weight gain of fish fed to satiation decreased linearly as dietary protein content increased, while the weight gain of fish under restricted feeding increased linearly with increasing dietary protein (Fig. 4). In addition, the weight gain of fish fed to satiation was positively correlated with feed consumption, which decreased linearly as dietary protein concentration increased. Dietary protein concentration had no influence on feed conversion under satiate feeding, but had a positive effect on feed conversion under restricted feeding. Feed conversion of fish fed to satiation was higher than that of fish under restricted feeding. Dietary protein had a quadratic effect on dressing percentage, in that it increased as dietary protein increased from 26 to 32 percent, then decreased as dietary protein increased from 32 to 38 percent for both satiate and restricted feeding. The lipid content of fish in both feeding regimes was negatively correlated with the DE/P ratio of the diets.

Lipid content of fish fed to satiation was higher than that of fish fed at the restricted rate. Thus, feeding rate significantly influenced weight gain and body composition of channel catfish. With satiate feeding, channel catfish reached maximum weight gain on a diet containing 26 percent protein, whereas with restricted feeding, higher protein diets were required.

In another study, older (3-year-old) channel catfish were fed to satiation either once or twice daily with diets containing either 32 or 38 percent protein for 170 days. There were no significant differences in growth or body composition of fish when analyzed by protein level, feeding frequency, or their interaction.

The effects of satiate and restricted feeding of diets with different protein quality was evaluated in another study. Three diets containing 32 percent crude protein of low, medium and high quality were prepared by substituting peanut meal and cottonseed meal for soybean meal, thus altering the concentration of lysine, the first-limiting amino acid (Table 2). Each diet was fed to satiation or at a restricted rate. Fish in the satiation treatment were fed as much as they would consume each day for the 15-week experimental period. Fish in the restricted group were fed as much as they would consume until the daily feed allowance reached 65 kg/ha, which occurred at approximately week 5. There was no significant interaction between feeding regime and dietary protein quality as they affected weight gain or feed conversion, although both responses were improved as protein quality increased (Fig. 5). Protein quality had no influence on protein efficiency ratio (PER) under satiate feeding but had a positive effect on PER under restricted feeding. In addition, dietary protein quality had a positive linear effect on dressing percentage under restricted feeding, but in those fish fed to satiation, dressing percentage increased only between the low and high quality protein treatments. Protein quality had a negative linear effect on fillet lipid and a positive effect on fillet protein with both satiate and restricted feeding (Fig. 6).

Table 2. Ingredient and nutrient composition of diets varying in protein quality.

	Protein quality		
	Low	**Medium**	**High**
Ingredients (%)			
Ground corn	29.9	29.4	31.4
Soybean meal, dehulled	0	20.0	50.5
Peanut meal	38.0	22.5	0
Cottonseed meal	15.0	10.0	0
Menhaden fish meal	5.0	5.0	5.0
Wheat middlings	9.0	10.0	10.0
Poultry fat	1.5	1.5	1.5
Dicalcium phosphate	1.4	1.4	1.4
Trace mineral premix	0.05	0.05	0.05
Vitamin premix	0.1	0.1	0.1
Vitamin C	0.05	0.05	0.05
Composition			
Crude protein (%)	32.5	32.7	33.6
Digestible energy (kcal/g)	2.9	2.9	2.9
Digestible energy/protein	8.9	8.9	8.6
Available lysine	1.14	1.33	1.61

See Munsiri and Lovell (1992) for more details.

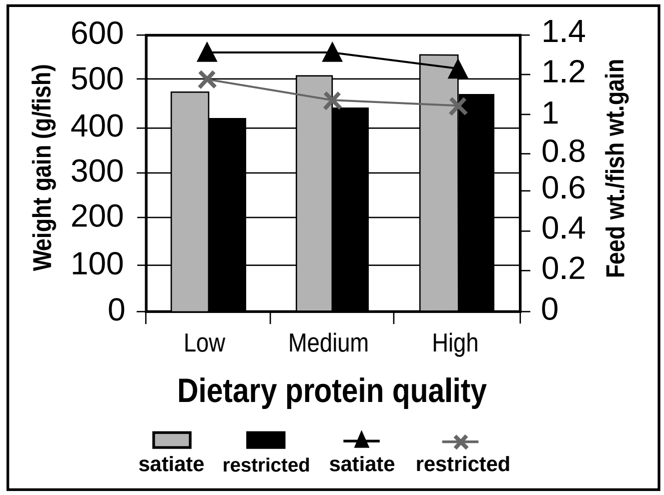

Figure 5. Weight gain (bars) and feed conversion ratio (symbols) of channel catfish fed diets of different protein quality under satiate and restricted regimes.

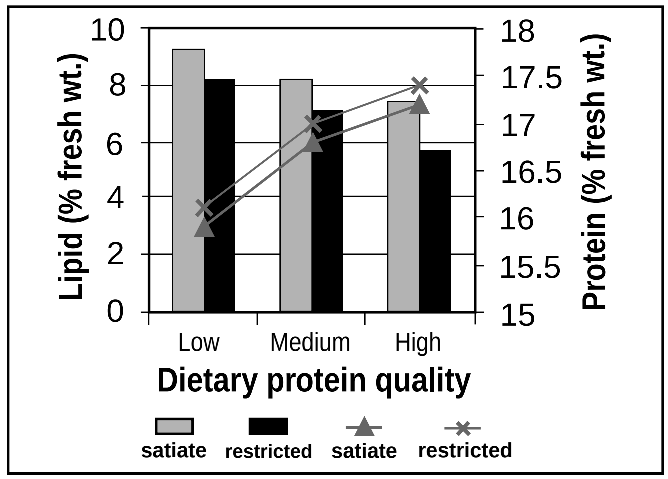

Figure 6. Lipid (bars) and protein (symbols) content of fillets from channel catfish fed diets of different protein quality under satiate and restricted regimes.

These results indicate that channel catfish are sensitive to protein quality differences in practical feeds at both satiate and restricted feeding rates, and that lower quality protein reduces dressing yield and increases muscle lipid in food-size fish.

The effects of two protein concentrations and two feeding frequencies also were evaluated. Fish were fed diets containing either 34 or 38 percent protein. They were fed to satiation either once or twice daily for 170 days. No significant differences in growth and body composition were found when analyzed by protein level, feeding frequency, or their interaction. A similar evaluation of dietary protein level and feeding frequency was conducted with channel catfish reared in cages. Fish fed the diet containing 38 percent protein gained much more weight than fish fed the diet containing 34 percent protein. Feeding once or twice daily did not affect growth and body composition, but did affect dressing percentage—fish fed twice daily had a higher percentage than those fed once daily. No significant differences were found when body composition was analyzed in relation to dietary protein level, feeding frequency, and their interaction. These data indicate that channel catfish reared in cages may require a diet with a higher percentage of protein than fish reared in ponds, and that feeding more than once a day is not particularly beneficial.

The time of feeding was evaluated in another study. Channel catfish were fed the same diet either: 1) once daily at 0830 hours; 2) once daily at 1600 hours; 3) once daily at 2000 hours; or 4) on demand by mechanical feeder. Fish on the timed treatments were fed to satiation. When channel catfish were fed once daily to satiation, the time of feeding had no significant impact on water quality, feed consumption, feed conversion, weight gain, or body composition (Table 3). Fish fed on demand consumed more feed than fish fed once daily to satiation, but this did not result in greater weight gain. Although feeding at night was not detrimental in this study, night feeding generally is not recommended in large ponds unless there is sufficient aeration to provide oxygen quickly in an emergency.

Another series of experiments evaluated the effects of high-protein "finishing" feeds on production and lipid content of channel catfish. In one experiment, fish were fed either: 1) a 32 percent protein diet for 150 days; 2) a 28 percent protein diet for 150 days; 3) a 28 percent protein diet for 90 days and then a 38 percent protein diet for 60 days; 4) a 28 percent protein diet for 90 days and then a 35 percent protein diet for 60 days; 5) a 28 percent protein diet for 120 days and then a 38 percent protein diet for 30 days; or 6) a 28 percent protein diet for 120 days and then a 35 percent protein diet for 30 days. Fish in all diet regimes were fed once daily to satiation. There were no significant differences in feed consumption, weight gain, final weight, feed conversion ratio, survival, or percentage visceral lipid with the various treatments. However, fillets from fish fed the 28 percent protein diet for 150 days contained more fat than those from fish on the other treatments. There was no advantage in finishing channel catfish on high-protein diets as compared to feeding either a 28 or 32 percent protein diet for the entire grow-out period.

In another experiment, the effects of feeding a high-protein (38 percent) finisher feed to satiation for 30, 45, 60 or 90 days prior to harvest were evaluated over a 2-year production period. There were no significant differences in total yield, dressed yield, or muscle lipid, regardless of feeding regime. However, visceral lipid was reduced by feeding a high-protein diet, and females generally had a higher percentage of visceral lipid than males regardless of diet. During the second year of production fish generally had a higher percentage of visceral lipid than in the first year. Fish size and/or age appeared to influence fattiness more than diet or feeding regime.

Conclusions

A variety of feeding schedules and dietary manipulations were investigated to identify optimal feeding practices for catfish in terms of production economics and product quality. Feeding catfish once a day to apparent satiation appears to be adequate when using diets containing 28 to 32 percent protein. Neither high-protein finisher diets nor other feeding schedules conferred additional benefits.

Table 3. Responses of channel catfish fed once daily at different times in earthen ponds for 145 days.

Feeding time (h) or method	Weight gain (g/fish)	Feed conversion ratio	Visceral lipid (%)	Fillet lipid (%)
0830	443	1.41	2.43	6.20
1600	418	1.52	2.58	5.27
2000	433	1.48	2.44	5.11
On demand	473	1.53	2.59	5.24

See Robinson et al. (1995) for more details.

Objective III: Determine the Effects of Various Dietary Components on Chemistry and Sensory Qualities of Fish Lipids and Stability During Frozen Storage

Methods

Several feeding trials were conducted in ponds and aquaria to investigate the effects of various diet additives on growth, body composition and storage quality of channel catfish. These diet additives were evaluated because they have been shown to increase the oxidative stability of meat products or reduce the lipid content of tissues in other animals.

The substances evaluated were dietary vitamin E, a natural antioxidant, and various synthetic antioxidants such as ethoxyquin, butylated hydroxyanisole, and butylated hydroxytoluene. None of the antioxidants tested significantly altered growth, feed efficiency, or the composition of whole-body or fillet tissues. Diets containing 240 mg vitamin E/kg (as dl-alpha-tocopheryl acetate) produced much higher levels of alpha-tocopherol in fillet samples than diets containing 60 mg vitamin E/kg, but synthetic antioxidants in the diet did not affect tissue levels of alpha-tocopherol. Storage quality was not significantly reduced over 6 months with any of the additives. However, when fillets were flushed with oxygen to force oxidation, the storage quality of fish fed the higher level of vitamin E was better than the quality of other samples. Thus, supplementing the fish diet with 240 mg/kg of vitamin E gave the most protection from lipid oxidation in fillet tissue.

In a follow-up experiment, researchers studied the effects of dietary vitamin E concentration and the duration of supplementation. Fillets of fish fed 240 and 1000 mg dl-alpha-tocopheryl acetate/kg had progressively higher concentrations of alpha-tocopherol after 2, 4 and 6 weeks of feeding; concentrations of alpha-tocopherol in plasma and liver reached the highest levels by week 2. With the diet containing 240 mg alpha-tocopherol/kg, it took 6 weeks for fillets to contain a protective level of vitamin E. With the diet containing 1000 mg alpha-tocopherol/kg, it took just 2 weeks.

In another experiment, catfish were fed diets containing 5 and 10 times the normal level of vitamin E for 45 or 60 days prior to harvest. Then the quality of the fillets was evaluated after long-term storage. The content of alpha-tocopherol in muscle was higher in fish fed diets containing supplemental vitamin E than in fish fed the control diet containing 66 mg vitamin E/kg. Oxidation stability and sensory analysis of fillets did not differ with the two vitamin E supplements. Lipid oxidation increased with storage time because of autooxidation (Fig. 7). Dietary vitamin E levels up to 10 times the normal amount did not improve the overall quality of catfish fillets. However, these diets and/or feeding regimes may be used before harvesting and processing to improve the storage quality of channel catfish.

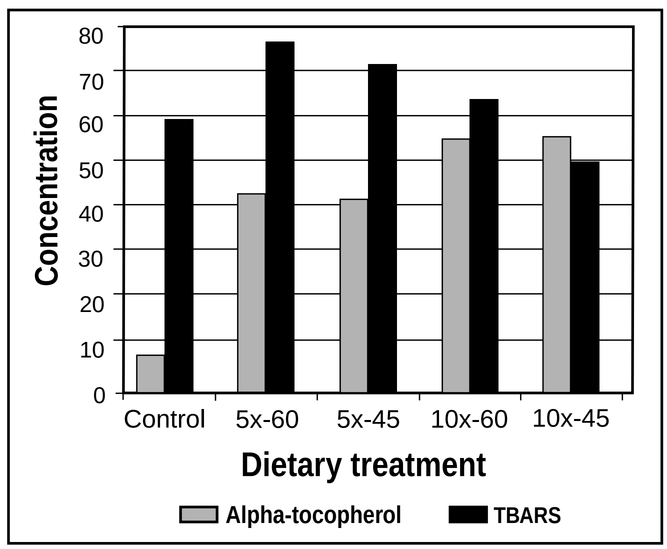

Figure 7. Alpha-tocopherol concentration (mg/g) and 2-thiobarbituric acid reactive substances (TBARS; mg/100kg) in fillets of channel catfish fed diets with 5 or 10 times the required concentration of vitamin E for 45 or 60 days prior to harvest. The control diet contained 66 mg vitamin E/kg.

The antioxidant effects of vitamin C and the flavonoid compound rutin were investigated in another feeding trial with fingerling channel catfish. Fish fed diets without supplemental vitamin C showed signs of deficiency after 10 to 12 weeks. These signs included lower weight gain, deformed spinal columns, external hemorrhages, and fin erosion. Levels of vitamin C in the liver, fillet and plasma were correlated with dietary vitamin C levels. Forced oxidation of fillet samples accelerated oxidation when fish had not been fed vitamin C and rutin. However, this study showed little synergy between dietary rutin and the vitamin C nutrition of channel catfish.

Additional trials evaluated the effects of dietary lipid and other biochemicals, such as reduced glutathione and pantethine, on the composition and storage quality of channel catfish. Two levels of lipid (5 or 10 percent of diet) and various levels of glutathione and pantethine were supplemented in diets and fed to fingerling channel catfish in separate trials. In both experiments, dietary lipid had significant effects on growth, feed efficiency, and body composition, with diets containing 10 percent lipid generally producing better weight gain and feed efficiency and higher levels of visceral lipid. The 10 percent level of dietary lipid also produced lower moisture levels and higher lipid levels in whole-body and fillet tissues. Fish fed 10 percent dietary lipid were of lower quality after storage. Glutathione did not have any effect. Therefore, dietary lipid level altered growth and body composition of channel catfish as well as the oxidative stability of fillets, while dietary glutathione was generally ineffective. Pantethine supplementation had no effect on weight gain and feed efficiency, but increased the level of oleic acid in fillet lipids. Based on results from these studies, dietary lipid improved performance and lipid deposition of channel catfish, whereas other supplements had negligible effects.

Dietary lysine supplementation was investigated as a possible way to increase growth and reduce lipid deposition in channel catfish. The most positive effect of lysine supplementation on weight gain, protein conversion efficiency, and feed efficiency was noted when fish were fed a diet containing 25 percent crude protein. However, supplemental lysine did not affect either body condition or composition of whole-body and fillet tissues of fish fed the different diets.

Another series of experiments evaluated dietary supplementation with beta-agonist biochemicals. These supplements have increased weight gain and decreased fat deposition in various livestock species. One such compound, ractopamine, increased weight and decreased muscle lipid in channel catfish when added to the diet at 20 mg/kg. The beta-agonist L644,969, supplemented at 3 mg/kg in diets containing 27 or 36 percent crude protein, reduced muscle and visceral lipid in blue catfish and enhanced protein deposition, but had no effect on weight gain. Carnitine, a biochemical involved in lipid catabolism, did not affect growth but did reduce muscle and liver lipid (in contrast to some studies with other fish species).

The effects of feeding, starvation and refeeding on fatty acid composition of channel catfish tissues, and potential effect on oxidative stability, also were investigated. Levels of n-3 fatty acids were significantly elevated in the white muscle of fish not fed for 28 days compared to fish that were fed throughout. However, such changes in fatty acid composition were expected to have little effect on the frozen storage quality of catfish fillets.

Another investigation evaluated processing techniques to see if they improved the quality of catfish fillets during refrigerated and frozen storage. Fillets treated with either sodium acetate, *Bifidobacterium adolescentis, B. infantis,* or *B. iongum* had longer shelf life during refrigeration. Treatment with both sodium acetate and bifidobacteria reduced aerobic bacterial counts more than either alone, extending shelf life by 3 days (Table 4). The odor and appearance of treated fillets

Table 4. Specifications of various packing materials and measures of their ability to preserve channel catfish.

Packing method	Composition	Rate of oxygen transmission ($cc/m^2/24$ h/atm)	Free fatty acid content (mg/g) after 21 d
Overwrap	Polyvinylidene chloride	5	0.44a
Vacuum bag	Low-density ethylene and vinyl acetatecopolymer	4,000	0.38ab
Vacuum skin pack	Surlyn (low-density poly-ethylene)	930	0.15b

Means in a column followed by different letters are significantly different at $p < 0.05$. See Huang et al. (1992) for more details.

resembled that of fresh fillets for up to 6 days, while untreated fillets were unacceptable after 3 days.

In another study, microbial and chemical changes during iced storage of catfish fillets processed with film overwrapping, vacuum packaging, or vacuum skin packaging were determined. Vacuum-packaged fillets had the highest quality, as indicated by significantly lower bacterial counts and free fatty acid content. However, the pH and ammonia production of vacuum-packaged fillets was similar to that of overwrapped fillets throughout 3 weeks of storage.

Microbiological assessment of channel catfish grown in cage and in pond culture also was done. Bacterial indicators and pathogens of pond water and fish samples were assessed. Microbial changes in processed catfish packaged with overwrapping or vacuum packaging were analyzed during 16 days of refrigerated storage. Differences in water and bacteria from cage- and pond-cultured fish were reflected in the microbial populations in skin rinse fluid. On the eighth day of cold storage, both cage- and pond-raised catfish packaged in vacuum bags had lower bacterial counts than catfish packaged with overwrapping.

Conclusions

A number of processing techniques were shown to improve the quality of fresh and frozen catfish products. Treating fish with sodium acetate increased shelf life, while vacuum packaging improved the keeping quality of fresh and frozen products. Adding more than the minimum requirement of vitamin E to the diet kept catfish products fresh longer, but generally is not warranted if storage time is less than 6 months.

Publications and Presentations

The following publications and presentations were developed as part of this Southern Regional Aquaculture Center project.

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