Determination of Optimum Lipid Levels in Channel Catfish (*Ictalurus punctatus*) Diets

by

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ABSTRACT

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Channel catfish (*Ictalurus punctatus*) fingerlings were reared in flow-through circular tanks on semipurified diets which consisted of 6, 8, 10, 12, and 14% lipid as beef tallow, unhydrogenated soybean oil, or fish oil. A commercially available catfish diet served as the control.

The most rapidly growing group of fish increased in body weight by 281% during the 20 week experimental period. There were no significant differences in growth between fish fed the 15 experimental diets, but the diets with 10% lipid were most consistent in producing high gains. The control diet was found to be deficient due to vitamin degradation. Fish in tanks receiving diets with the highest lipid level had the highest mortality rates, but the causes of death were not specifically determined.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The nutritional requirements of channel catfish (*Ictalurus punctatus*) have been broadly defined through the work of various investigators during the 1960's and 1970's (reviewed in National Academy of Sciences 1973, 1977; Stickney and Lovell 1977). Previous research has resulted in the development of practical channel catfish rations which will supplement or provide complete nourishment of the animals and rations which can be utilized at various life stages of the fish. Continuous refinement of diets to reduce expense while maintaining or improving product quality continues and considerable competition among feed companies exists with respect to fish feeds.

Protein, the most expensive component of a fish diet, has received a great deal of attention by researchers, both in the past and in recent studies. Lipids, while studied to some extent, remain to be completely investigated relative to their qualitative and quantitative impacts on catfish growth and body composition. Lipids are extremely important, however, in that they can be utilized to spare protein, they provide large amounts of energy per unit weight and they exert a great influence on product quality and shelf life.

The lipid studies of Stickney and Andrews (1972) revealed that the polyunsaturated fatty acids (PUFA) found in catfish are largely

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The citations follow the style and format of the *Transactions of the American Fisheries Society*.

in the form of linolenic ($\omega3$) and oleic ($\omega9$) family fatty acids, whereas the levels of linoleic ($\omega6$) family acids are relatively low. Lipids containing either $\omega3$ or $\omega9$ series fatty acids seem to fulfill the fatty acid requirements of channel catfish (Stickney 1976), but the optimum level which should be provided in catfish diets has not been determined. Dupree (1969) experimented with semipurified diets containing 8 and 16% of the ration as lipids. Channel catfish fed those diets exhibited no significant differences in growth. Excellent growth rates have been produced by feeding channel catfish diets containing 10% lipid (Stickney and Andrews 1971, 1972).

In order to define optimum lipid quantity, two separate factors must be taken into consideration: growth rate and tissue quality. Due to the sparing action of lipid on protein, manipulation of the amount of lipid that replaces dietary protein enables fish growth and tissue quality to be regulated. A diet in which lipid has replaced some dietary protein will often contain more available energy; therefore, more of the protein can be utilized in tissue production and less will be metabolized for energy. A specific amount of depot lipid also favorably affects texture and flavor of the fish flesh. But too much lipid in the diet would be harmful because lipids would be stored in the body and fats deposited in the visceral cavity. These excess deposits increase the amount of waste during processing and may adversely affect flavor (Stickney 1976). Thus it can be seen that a compromise must be reached between growth and tissue quality when determining the optimum lipid level.

The primary objective of this study was to more clearly define the lipid requirements of channel catfish with respect to the three major polyunsaturated fatty acid families, and to determine the level of dietary lipids that would produce the best growth and tissue quality. A secondary objective was to determine the dietary lipid levels that would adversely affect channel catfish health.

MATERIALS AND METHODS

Fifteen isocaloric, semipurified diets consisting of 6, 8, 10, 12, and 14% lipid as beef tallow, soybean oil, or fish oil were formulated at the Aquaculture Research Center of Texas A&M University and the Texas Agricultural Experiment Station. The diets were mechanically mixed and pressure pelleted. Purina Catfish Chow was utilized as a control diet. Tables 1, 2, and 3 present the constituents of the various diets.

Thirty-two circular 76-liter capacity polypropylene tanks were stocked with ten Rio Grande strain channel catfish fingerlings. Water was pumped into the tanks at a rate of 0.95 liters/minute through flow regulators and exited by way of venturi drains. Supplemental aeration was provided in each tank by an airstone.

Water was supplied by two different wells at the Texas A&M University Aquaculture Research Center. The first well was abandoned two-thirds of the way through the experiment due to rapidly cooling temperature. The replacement well water had an iron concentration of 5 mg/liter, but this mineral did not outwardly affect the fish.

Water temperature and dissolved oxygen readings were taken several times each week throughout the experimental period with a YSI model 51B oxygen meter (Yellow Springs Instrument Co., Yellow Springs, Ohio). Ammonia levels were monitored twice weekly in the experimental tanks. An Orion model 701 digital pH meter (Orion Research Inc., Cambridge, Mass.) connected to an ammonia probe was used to determine total

Table 1. Percent Composition of Fish Oil Diets.

	Lipid Levels				
DIETARY INGREDIENTS	6	8	10	12	14
	%	%	%	%	%
CASEIN (95%)	33.68	33.68	33.68	33.68	33.68
CORN STARCH	46.32	41.18	36.03	30.88	25.73
AGAR	0.10	0.10	0.10	0.10	0.10
FISH OIL	6.00	8.00	10.00	12.00	14.00
ALPHACELL	8.10	11.24	14.39	17.54	20.69
VITAMIN, MINERAL MIX*	5.80	5.80	5.80	5.80	5.80

*Vitamin mix provides the following per kg feed: Vitamin A, 5500 I.U.; Vitamin D_3, 100,000 I.U.; Vitamin E, 5000 I.U.; thiamin, 2 g; riboflavin, 2 g; pyrodoxine, 2 g; folacin, 500 mg; ascorbic acid, 40 g; D-calcium pantothenate, 5 g; biotin, 10 mg; choline, 55 g; niacin, 10 g; vitamin B_{12}, 2 g; vitamin K, 1 g; inositol, 10 g; ethoxyquin, 0.150 g.

Mineral mix contains: Defluorinated phosphate (18% P, 30% Ca), 2.07% diet; sodium chloride, 0.60% diet; pulverized oyster shell, 1.12% diet; KH_2PO_4, 1.00% diet; KCI, 0.10% diet; $MgSO_4$, 0.30% diet; $FeSO_4$, 500 mg/kg; $MnSO_4$, 350 mg/kg; $ZnCO_3$, 150 mg/kg; $CuSO_4$, 30 mg/kg; KIO_3, 10 mg/kg; $CoCl_2$, 1.7 mg/kg; MoO, 8.3 mg/kg; $NaSeO_3$, 0.2 mg/kg.

Table 2. Percent Composition of Soybean Oil Diets.

	Lipid Levels				
DIETARY INGREDIENTS	6	8	10	12	14
	%	%	%	%	%
CASEIN (95%)	33.68	33.68	33.68	33.68	33.68
CORN STARCH	46.14	40.94	35.73	30.52	25.31
AGAR	0.10	0.10	0.10	0.10	0.10
SOYBEAN OIL	6.00	8.00	10.00	12.00	14.00
ALPHACELL	8.28	11.48	14.69	17.90	21.11
VITAMIN, MINERAL MIX*	5.80	5.80	5.80	5.80	5.80

*Same as in Table 1.

Table 3. Percent Composition of Beef Tallow Diets.

	Lipid Levels				
DIETARY INGREDIENTS	6	8	10	12	14
	%	%	%	%	%
CASEIN (95%)	33.68	33.68	33.68	33.68	33.68
CORN STARCH	46.11	40.99	35.68	30.46	25.24
AGAR	0.10	0.10	0.10	0.10	0.10
BEEF TALLOW	6.00	8.00	10.00	12.00	14.00
ALPHACELL	8.31	11.43	14.74	17.96	21.18
VITAMIN, MINERAL MIX*	5.80	5.80	5.80	5.80	5.80

*Same as in Table 1.

ammonia concentration. Temperature, dissolved oxygen and ammonia readings were taken from six tanks selected at random. There was only slight variation among the readings obtained from different tanks.

Fish in duplicate tanks were fed the experimental and control diets once daily for 20 weeks. Feeding rates ranged from 1 to 3% of body weight per day and were adjusted according to prevailing water temperatures. The fish from each tank were weighed collectively at two week intervals and feeding rates adjusted accordingly. Individual final weights were obtained.

An analysis of covariance was performed on the growth data with the Statistical Analysis System, SAS-79 (Barr et al. 1979), at the Texas A&M University Data Processing Center. Results were considered significant at the $P \leq 0.05$ level.

RESULTS AND DISCUSSION

Water Quality

Water temperature during the experimental period ranged from 18.5 to 27.2C, with a mean of 22.5C. For almost one-half of the study water temperatures were below 21C. Previous studies indicate that higher water temperatures are needed for optimum catfish growth. Stickney and Andrews (1971, 1972) found that fingerling channel catfish fed diets consisting of various lipid sources at different temperatures grew most rapidly at 30C. Excellent growth also occurred at 26C; whereas, poorest growth was seen at 20C, the lowest temperature tested.

Dissolved oxygen levels during the study ranged from 6.5 to 8.8 mg/liter, with a mean of 7.5 mg/liter. Supplemental aeration and turbulence created by inflowing water helped to maintain these suitable dissolved oxygen levels.

Total ammonia ranged from 0.1 to 2.0 mg/liter, with a mean of 1.2 mg/liter. These levels remained satisfactory because the continuous flow of water into the tanks allowed the water volume in each tank to be fully replaced about every 2 hours. The tanks were also frequently cleaned.

Growth

At the beginning of the experiment the average weight of fish in duplicate tanks ranged from 10.62 to 12.34 g. During the 20 week growth period, the most rapidly growing group of fish gained an average of 20.57 g (Table 4). One tank of fish receiving the diet with 8% fish oil exhibited the greatest growth by achieving a 281% increase in weight. The relatively low water temperatures slightly suppressed the growth of all fish.

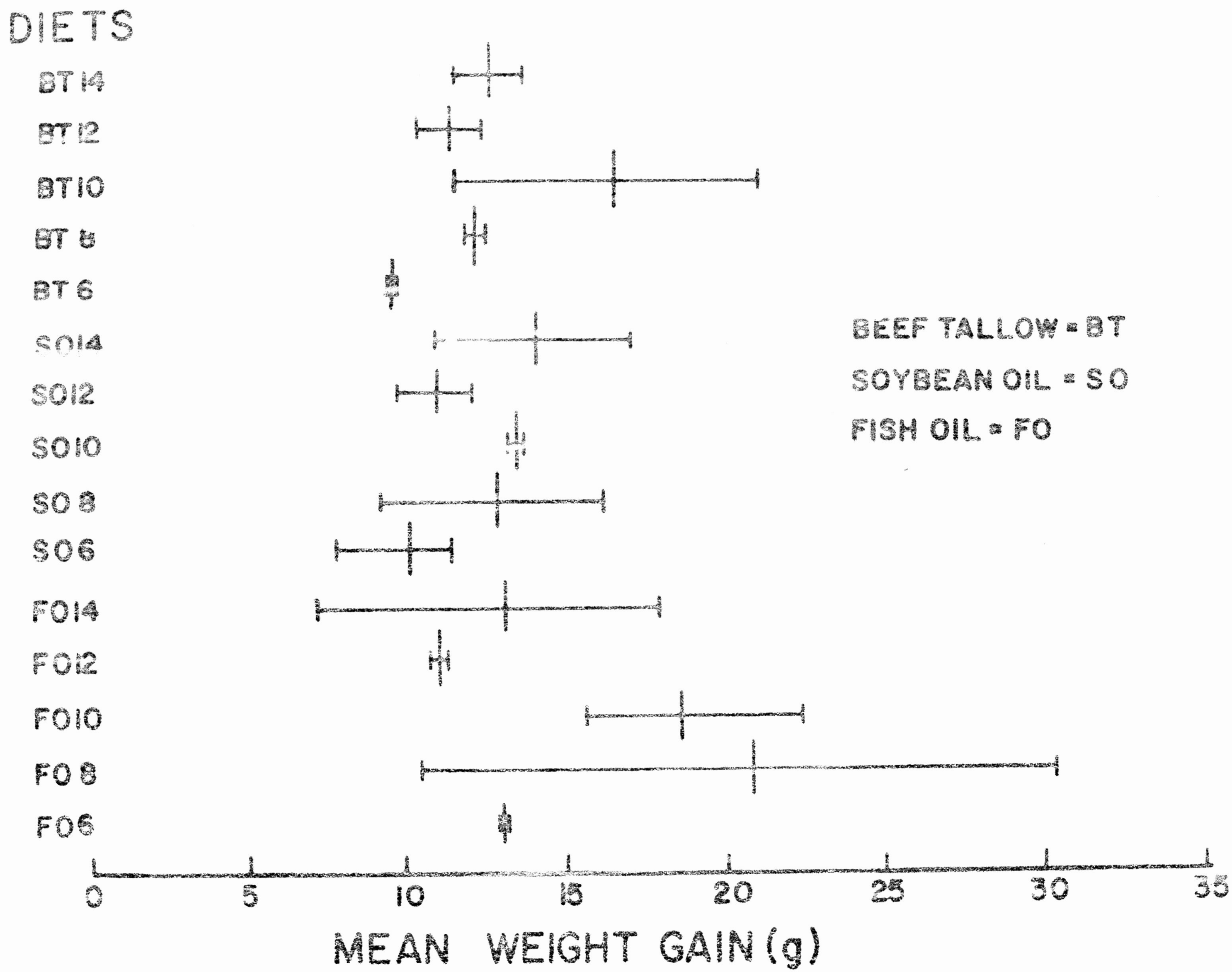
The control diet was found to be nutritionally deficient probably due to vitamin degredation. Once vitamin deficiency symptoms such as emaciation were noted, many fish receiving that diet began to die; therefore, data obtained from control fish were considered to be invalid with respect to this study.

An analysis of covariance revealed that there were no significant differences in growth of the fish on any of the 15 experimental diets; however, a trend was seen in which the 10% lipid level had the best overall performance (Figure 1). These finding are not in complete agreement with those of Stickney and Andrews (1971). Their study showed that at 20, 24, 26, 30, and 33C, significantly higher gains in channel catfish were obtained from beef tallow (a lipid which contains a high level of ω9 family fatty acids) and menhaden fish oil (a lipid which contains a high level of ω3 family fatty acids) supplemented diets as compared to diets supplemented with safflower oil (a lipid which contains a high level of ω6 family fatty acids). Yingst (1978) also found that channel catfish fry fed a fish oil supplemented diet grew significantly larger than fry fed a diet supplemented with soybean oil (a lipid which contains a high level of ω6 family fatty acids).

Table 4. Pooled initial average weight, final average weight, average weight gain, and percent survival of channel catfish fingerlings reared in duplicate tanks on experimental diets with various lipid levels and lipid sources.

Type of Diet	Mean Initial Wt (g)	Mean Final Wt (g)	Mean Wt Gain (g)	Percent Survival (%)
Fish Oil (FO) 6%	12.27	25.45	13.18	100
FO 8%	11.06	31.63	20.57	100
FO 10%	12.34	31.22	18.88	90
FO 12%	10.72	21.68	10.96	100
FO 14%	11.48	24.75	13.27	80
Soybean Oil (SO) 6%	11.34	21.27	9.93	95
SO 8%	12.06	24.82	12.76	95
SO 10%	11.22	25.30	14.08	100
SO 12%	11.64	22.78	11.14	95
SO 14%	11.79	25.88	14.09	95
Beef Tallow (BT) 6%	10.86	20.60	9.74	100
BT 8%	11.51	23.56	12.05	95
BT 10%	11.14	27.30	16.16	90
BT 12%	10.62	21.70	11.08	90
BT 14%	11.52	23.66	12.14	90

Figure 1. Average weight gain of channel catfish fingerlings reared on experimental diets with different lipid levels and lipid sources. Small vertical lines represent average gains for each tank of fish. Larger vertical lines represent the average between mean weight gains of fish in duplicate tanks receiving the same diet.


DIETS
BT 14
BT 12
BT 10
BT 8
BT 6
SO14
SO12
SO10
SO 8
SO6
FO14
FO12
FO10
FO 8
FO6
0
5
10
15
20
25
30
35
MEAN WEIGHT GAIN (g)
BEEF TALLOW = BT
SOYBEAN OIL = SO
FISH OIL = FO

The manner in which the ω6 supplements were processed may be responsible for the difference in results seen in this study as compared with the two previously mentioned studies. In this experiment the soybean oil was unhydrogenated; whereas, in the other two experiments the soybean and safflower oil were hydrogenated and thus had a higher level of saturation. This was done to improve shelf life. The unhydrogenated soybean oil remained unsaturated and produced growth similar to the beef tallow and fish oil supplemented diets.

In this study none of the lipid sources tested produced a significant difference in catfish growth, but the 10% level consistently performed somewhat better than higher or lower lipid percentages. Dupree (1969) found that channel catfish fed diets with 8% lipid deposited more protein than those fed diets with 4% lipid; however, a catfish fed diets with 16% lipid exhibited reduced protein deposition. In that study lipid levels of 8 and 16% did not produce significant differences in growth. Stickney and Andrews (1971,1972) experimented with diets containing 10% lipid and found that they produced excellent catfish growth and good feed conversion. At this time a specific lipid level that will produce statistically significant weight gains has not been determined.

Since fish diets high in lipid are quite difficult to manufacture commercially, most available feeds contain only about 8% lipid (Stickney 1979). The findings of this and other studies reveal that the problems associated with high lipid supplementation need not be confronted because diets with lipid levels higher than 10% have not been shown to produce favorable responses such as higher growth rates.

Mortality

None of the lipid levels in the experimental diets were high enough to adversely affect fish health to a great extent; however, highest mortality was observed in tanks receiving the diets highest in lipid (Table 4). The actual cause of death in each case was not determined. It appears as if lipid levels above 14% are required to produce acute fish mortality.

Proximate and Fatty Acid Analyses

Proximate and fatty acid analyses were not performed on the fish due to a restrictive time limit. These analyses will be completed at a later date and the resulting information will be used to determine tissue quality characteristics produced by each experimental diet.

SUMMARY AND CONCLUSIONS

This study demonstrated that the processing of lipid supplements may affect their utilization by channel catfish fingerlings. The use of hydrogenated $\omega 6$ lipid supplements has been shown to produce significantly lower catfish growth as compared to $\omega 9$ and $\omega 3$ lipid supplements (Stickney and Andrews 1971, 1972; Yingst 1978). In this study the use of an unhydrogenated $\omega 6$ lipid supplement demonstrated improved utilization as evidenced by catfish growth not significantly different from that obtained from fish reared on diets high in $\omega 3$ and $\omega 9$ lipid supplements.

Although this study did not statistically determine the optimum lipid level for channel catfish, it did substantiate the limited experimental work conducted in this area.

The present study also demonstrated that fish health is not acutely affected by lipid levels as high as 14%.

The qualitative and quantitative lipid requirements of channel catfish must be further investigated. The optimum lipid level and essential fatty acid requirements of channel catfish have not been fully determined at this time. Further investigations in these areas will enhance the growth of the channel catfish farming industry by allowing the catfish culturist to produce fish more economically while providing commercial feed manufacturers the opportunity to determine least cost formulas.

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