

Estimation of the Dietary Lipid Requirement Level of the White Crayfish *Procambarus acutus acutus*

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Abstract

Six isonitrogenous and isoenergetic diets containing graded levels of lipid (menhaden fish oil) were fed to juvenile white crayfish (*Procambarus acutus acutus*) over a 10 week period. A significant depression in weight gain was observed in crayfish fed diets containing 9% or more lipid. There were no significant differences in growth of crayfish fed diets containing 0 to 6% lipid. Whole-body percentages of lipid and dry matter decreased, and protein increased in crayfish fed high-lipid diets. Dietary lipid did not appear to influence survival or molting frequency. Whole-body lipids generally reflected dietary fatty acid composition.

Currently, most crayfish culture conducted in the United States is based on extensive methods that depend on a detrital system to provide food (Avault et al. 1972). Such systems are generally not capable of sustaining good growth of high density crayfish populations. Thus, the lack of a food source often leads to crayfish that are of submarketable size (Avault et al. 1974). The addition of supplemental nutrient sources to the culture system or feeding fish feed pellets has been shown to help alleviate stunting (Huner and Barr 1981). In general, offering fish feed to crayfish has not been cost effective even though production is improved.

The rapid expansion of crayfish into new markets accentuates the need for a year-round crop as well as the need to increase production to meet demands. If these objectives are to be accomplished, a radical change in the way crayfish are cultured must occur; i.e., intensive culture methods must be initiated which would require feeding much in the same way finfish are fed today. The success of such a culture system will depend, in a large part, on the availability of efficient and economical feeds, which in turn depends on the knowledge of certain critical nutritional parameters.

Very little information is available concerning the nutritional requirements of crayfish. Dietary protein requirements have

been estimated (Huner and Meyers 1979) as well as the optimum protein to energy ratio (Hubbard et al. 1986). There are no reports of the dietary lipid requirement for crayfish, though lipids are important in that they provide a concentrated source of energy and provide a source of essential compounds (i.e., fatty acids and sterols). There has been a report concerning the sterol requirement of *Pacifastacus leniusculus* (D'Abramo et al. 1985). The present study was designed to investigate the effects of varying levels of dietary lipid on the growth, proximate composition and fatty acid composition of the white crayfish (*Procambarus acutus acutus*).

Materials and Methods

Diets and Experimental Design

Six isoenergetic and isonitrogenous (30% protein) diets (Table 1) were formulated using casein and gelatin as protein sources. Menhaden fish oil was used as the lipid source. Dextrin and cellulose levels were varied to maintain isoenergetic diets. Since the extent of fiber utilization by crayfish is not known, cellulose was considered to be indigestible. Since neither digestible nor metabolizable energy values are available for crayfish, dietary energy values were calculated using standard vertebrate phys-

TABLE 1.—Percent composition (dry weight basis) of experimental diets.

Ingredient	Diet number					
	1	2	3 ^a	4	5	6
Casein ^b	28.1	28.1	28.1	28.1	28.1	28.1
Gelatin ^b	4.5	4.5	4.5	4.5	4.5	4.5
Dextrin ^b	33.8	27.1	20.3	13.6	6.8	0.0
Menhaden Fish Oil ^c	0.0	3.0	6.0	9.0	12.0	15.0
Carboxymethyl-cellulose ^a	2.0	2.0	2.0	2.0	3.0	3.0
Cholesterol ^b	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin Mix ^d	0.5	0.5	0.5	0.5	0.5	0.5
Mineral Mix ^d	4.0	4.0	4.0	4.0	4.0	4.0
Cellulose ^a	25.4	29.1	32.9	36.6	39.4	43.2
CaCO ₃	1.2	1.2	1.2	1.2	1.2	1.2

^a Conditioning diet.

^b U.S. Biochemical Corp., Cleveland, Ohio.

^c Zapata Haynie Corp., Cameron, Louisiana.

^d Robinson and Rawles 1983.

iological fuel values of 4 kcal/g for protein or carbohydrate and 9 kcal/g for lipid (Maynard et al. 1979). A diet similar to the one used in the present experiment has been routinely used for various finfish studies in our laboratory, as well as in other laboratories, and has been used for crayfish (Hubbard et al. 1986).

Dietary lipid levels ranged from 0 to 15% in 3% increments. All experimental diets were prepared in our laboratory by mechanically mixing dry ingredients in a V-mixer for 30 minutes and then adding oil to the dry mix using a Hobart mixer. After the oil was dispersed into the dry mix, approximately 300 mL of distilled water was added per kg of dry diet to give a consistency that would facilitate pelleting. The dough-like mixture was then pelletized using a meat grinder to form 2 mm diameter pellets. The pellets were air dried to a moisture level of approximately 10%. The use of a binder (carboxymethyl cellulose) resulted in diets that were water stable. Prior to feeding, all diets were broken into particle sizes that were easily consumed by all crayfish. Particle size was increased as the crayfish grew.

One hundred twenty white crayfish (*Procambarus acutus acutus*) were individually maintained in 10 cm diameter cylindrical

PVC containers. Each container had 5 mm holes drilled in the sides to allow water circulation and had a screen on the bottom to allow feces and uneaten feed to fall through. Four containers were placed into 50 × 25 × 25 cm glass aquaria. Five aquaria were used for each treatment (20 crayfish per treatment). The number of crayfish used in the present study was limited due to space restrictions. A recirculating water system was used in which water flowed through individual aquaria and returned to a 120 L settling chamber via a common drain. Water passed from the settling chamber into a submerged sand and gravel biofilter before being returned to each aquarium. Each aquarium was equipped with an airstone and air was supplied by use of a low-pressure, high-volume blower.

Juvenile crayfish obtained from ponds at the Aquacultural Research Center, Texas A&M, were acclimated to experimental conditions. After acclimation, crayfish of uniform size, 41 to 42 mm total length, were stocked into individual containers. Each crayfish was fed a casein-gelatin conditioning diet (Table 1), for one week prior to start of the experiment.

Individual weights and total lengths (measured from tip of rostrum to the telson)

were recorded at the beginning of the experiment and every two weeks thereafter. Crayfish were fed to excess twice each ten weeks. Feces and uneaten feed were siphoned from each aquaria two or three times a week. Water was added to the biofilter needed to replace losses from siphoning. Aquaria were checked two to three times daily for ecdyses, and exuviae were removed to prevent consumption of additional nutrients. This method approach worked well in that a high percentage (estimated to be 90% or better) of ecdyses were removed. Mortalities were replaced during the first week of the experiment but were replaced subsequently. This was done to eliminate effects of mortalities due to handling during the initial stocking.

Water Quality

Dissolved oxygen and water temperature were measured two times a week in randomly selected aquaria with a YSI 51B oxygen meter and thermometer (YSI, Yellow Springs, Ohio). Temperature, nitrite, pH and calcium hardness were determined weekly using a Hach-DREL/20 spectrophotometer (Hach Chemical Co., Iowa). Calcium hardness was maintained above 50 mg/L through the use of CaCl₂. This level of hardness was in the range considered adequate for the growth of crayfish (De la Breuille 1969).

Sample Collection and Analysis

Upon termination of the experiment, crayfish were starved for 24 hours, collected and frozen at -15 C for chemical analysis of whole body composition. Crayfish were taken in all phases of the experiment; however, nearly all were in intermolt. Four whole crayfish were collected for each treatment and pooled samples for each treatment were homogenized using a Polytron (Brinkmann Instruments, Westborough, MA). Each analysis was conducted on a single pooled sample.

Dry matter and ash were

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Diet number	4	5	6
	28.1	28.1	28.1
	4.5	4.5	4.5
	13.6	6.8	0.0
	9.0	12.0	15.0
	2.0	3.0	3.0
	0.5	0.5	0.5
	0.5	0.5	0.5
	4.0	4.0	4.0
	36.6	39.4	43.2
	1.2	1.2	1.2

containers. Each container had 5 mm mesh screens on the sides to allow water circulation and had a screen on the bottom to prevent uneaten feed to fall through. Containers were placed into 50 × 25 × 25 cm aquaria. Five aquaria were used per treatment (20 crayfish per treatment). The number of crayfish used in the study was limited due to space restrictions. A recirculating water system was used in which water flowed through individual aquaria and returned to a 120 L settling chamber via a common drain. Water from the settling chamber into a submersible and gravel biofilter before being pumped back to each aquarium. Each aquarium was aerated with an airstone and air was supplied by a low-pressure, high-volume air compressor.

Crayfish obtained from ponds at the Texas Agricultural Research Center, Texas were acclimated to experimental conditions. After acclimation, crayfish of similar size (41 to 42 mm total length, were placed in individual containers. Each container was fed a casein-gelatin conditioned diet (see Table 1), for one week prior to start of the experiment.

Initial weights and total lengths (from the tip of rostrum to the telson)

were recorded at the beginning of the experiment and every two weeks thereafter. Crayfish were fed to excess twice daily for ten weeks. Feces and uneaten feed were siphoned from each aquaria two or three times a week. Water was added to the biofilter as needed to replace losses from siphoning. Aquaria were checked two to three times daily for ecdyses, and exuviae were removed to prevent consumption of additional nutrients. This method appeared to work well in that a high percentage (estimated to be 90% or better) of ecdyses were removed. Mortalities were replaced during the first week of the experiment but not subsequently. This was done to eliminate the effects of mortalities due to handling during the initial stocking.

Water Quality

Dissolved oxygen and water temperature were measured two times a week in randomly selected aquaria with a YSI model 51B oxygen meter and temperature probe (YSI, Yellow Springs, Ohio). Total ammonia, nitrite, pH and calcium hardness were determined weekly using a Hach DR-EL/2 spectrophotometer (Hach Chem. Co., Ames, Iowa). Calcium hardness was maintained above 50 mg/L through the addition of CaCl₂. This level of hardness was in the range considered adequate for normal growth of crayfish (De la Bretonne et al. 1969).

Sample Collection and Analysis

Upon termination of the experiment, all crayfish were starved for 24 hours then collected and frozen at -15 C for subsequent chemical analysis of whole bodies. Crayfish were taken in all phases of the molt cycle; however, nearly all were in intermolt stages. Four whole crayfish were pooled (three pooled samples for each treatment) and homogenized using a Polytron homogenizer (Brinkmann Instruments, Westburn, NY). Each analysis was conducted in triplicate on each pooled sample.

Dry matter and ash were determined us-

ing the Association of Official Analytical Chemists (1980) methods. Whole body protein was determined by the macro-Kjeldahl method (AOAC 1980). Whole body lipid was determined by chloroform-methanol extraction (Folch et al. 1957). Fatty acid composition was determined on all pooled samples from each treatment using a Varian series 2400 gas chromatograph equipped with a flame ionization detector and SP 2330 wide bore, glass capillary column (Supelco, Inc., Bellefonte, Pennsylvania). A column temperature of 210 C and a 0.2 microliter sample with a fatty acid concentration of approximately 7 mg/mL were used. Fatty acids were identified by comparison with standards. Quantitative results were determined using a Spectra-Physics integrator (Spectra-Physics Co., Santa Clara, California).

Statistical Analysis

Prior to analysis all data were log transformed to normalize distribution of percentages. Log transformed growth and body composition data as well as the untransformed data associated with different treatments were then compared by the Statistical Analysis System, SAS-79 (Helwig and Council 1979) using the General Linear Models Procedure for a one-way ANOVA. Duncan's multiple range test was used to determine statistical differences between treatment means (Steel and Torrie 1960). Results were considered significant at the 0.05 level. There were no differences in results whether the data were analyzed as log transformed data or not.

Results and Discussion

Water Quality

Water quality remained relatively good throughout the experiment. Dissolved oxygen remained above 7.0 mg/L, temperature was maintained at 27-31 C and pH was 8.5. Ammonia nitrogen ranged from 0.04 to 0.58 mg/L but remained low for most of the experiment. Nitrite nitrogen did not exceed

TABLE 2. — Initial weights and lengths, percentage increase in weight and lengths, number of molts and percentage survival of crayfish fed experimental diets containing varying level of lipid.

Diet no.	Dietary lipid (%)	Initial weight (g)	Initial length (mm)	Weight increase (%)	Length increase (%)	Molts	Survival %
1	0	1.7	41.8	240.7 ^{x a}	39.1 ^x	3.1 ^x	80
2	3	1.6	41.2	240.8 ^x	44.0 ^x	3.3 ^x	85
3	6	1.6	41.4	217.7 ^{xy}	39.4 ^x	2.9 ^x	70
4	9	1.6	41.9	188.4 ^y	37.5 ^x	3.0 ^x	80
5	12	1.7	42.2	132.9 ^z	28.1 ^y	3.0 ^x	80
6	15	1.6	41.4	130.4 ^z	28.1 ^y	2.5 ^x	75

^a Means with the same superscript letters are not significantly different ($P \leq 0.05$). The pooled standard errors for weight increase, length increase, and molts were 6.15, 0.94 and 0.1, respectively.

0.007 mg/L. Water quality was not considered to be detrimental to the growth of crayfish in the present study.

Growth and Survival

The growth data presented in Table 2 indicate that these crayfish did not grow well when fed high levels of dietary lipid. This response was evident at four weeks. There were no significant differences in growth of crayfish fed diets containing 0 to 6% lipid, though there was a slight decrease in weight gain of crayfish fed 6% lipid. There was a significant decrease in weight gain of crayfish fed 9% lipid when compared to those fed 0 and 3% lipid; however, they were not significantly different from crayfish fed 6% dietary lipid. Crayfish fed diets containing 12 and 15% lipid had significantly lower weight and length increase compared to crayfish fed lower levels of lipid. This response appears to be rather typical of aquatic animals fed high-lipid diets (NRC 1983). Similar trends have been reported for other crustaceans. Andrews et al. (1972) showed that supplemental lipid levels greater than 10% adversely affected the growth and survival of *Penaeus setiferus*. Growth of *Palaeomon serratus* was reduced when the level of either dietary cod liver oil or corn oil was increased from 7.5 to 15% (Forster and Beard 1973). Poor growth was observed in *Penaeus japonicus* fed high-lipid diets (Deshimaru and Kuroki 1974; Deshimaru et al. 1979). D'Abramo (1979) found that

the productivity of *Moina macrocopa* was reduced when levels of various mixtures of dietary fatty acids were increased from 8.5 to 17%.

The mechanism underlying the growth depression observed in the present study is not known. The most probable explanations are that either food consumption was reduced or lipid utilization was altered in crayfish fed high-lipid diets, resulting in an insufficient amount of nonprotein energy. Though food intake is generally thought to be a function of the caloric density of the diet, excess dietary lipid may inhibit appetite (Church and Pond 1982). Consumption was not determined in the present study primarily because it was assumed that intake would be more or less equal between treatments since all diets were isoenergetic. It is possible that consumption was reduced in crayfish fed high dietary lipid, though it was not apparent from visual inspection of the amount of residual feed remaining after feeding.

If food consumption is assumed to be equal, lipid utilization may have been impaired by high lipid levels in the diets. Andrews et al. (1978) reported substantially reduced digestible energy and apparent lipid absorption for channel catfish fed 15% supplemental animal fat when compared to fish fed diets containing 0 to 10% supplemental lipid. As far as the authors know, there are no reports of the effects of dietary lipid levels on lipid digestibility in crayfish. A reduction

in lipid utilization would essentially result in a nonprotein energy deficit that could be reflected in growth. If there is a deficit in utilizable nonprotein energy, the dietary protein would be metabolized, resulting in inadequate protein for growth. Diets that were utilized in the present study contained highly digestible carbohydrate (dextrin) and relatively low levels of lipid, which suggests that carbohydrate is better utilized than lipid as an energy source. This indicates that the carbohydrate/lipid ratio is of importance. Deshimaru and Kuroki (1974) found that the growth of the prawn *Penaeus japonicus*, increased when carbohydrate (dextrin) was added to diets containing 0 and 12% lipid.

Based on growth data, it appears that there may be a dietary lipid level that is optimal; i.e., crayfish grew well when fed diets containing 0 to 6% dietary lipid. Growth frequency and survival were similar for all dietary treatments. However, a certain level of lipid is needed to provide essential nutrients (NRC 1983). It is possible that the growth depression in the present study had been of longer duration if the crayfish fed lipid-free diets. Crayfish fed lipid-free diets did not exhibit signs until the tenth week of the experiment (Robinson and Lovell 1978).

Body Composition

In general, as an animal grows, there is a decrease in body water; i.e., a negative relationship between body water and moisture. Also, the amount of lipid deposited is influenced by dietary lipid, with body lipid increasing as dietary lipid increases. This trend has been reported in various finfish (NRC 1983). In the present study, whole-body lipid increase in crayfish fed 6% dietary lipid was significantly greater than in crayfish containing in excess of 10% whole-body lipid (Table 2). This may have been due to either increased food consumption or impaired absorption of dietary lipid.

Weight and lengths, number of molts and percentage survival of lipid.

Weight increase (%)	Length increase (%)	Molts	Survival %
7 ^x a	39.1 ^x	3.1 ^x	80
8 ^x	44.0 ^x	3.3 ^x	85
7 ^{xy}	39.4 ^x	2.9 ^x	70
4 ^y	37.5 ^x	3.0 ^x	80
9 ^z	28.1 ^y	3.0 ^x	80
4 ^z	28.1 ^y	2.5 ^x	75

Different ($P \leq 0.05$). The pooled standard errors were 0.1, respectively.

Productivity of *Moina macrocopa* was reduced when levels of various mixtures of fatty acids were increased from 8.5 to 15%.

The mechanism underlying the growth reduction observed in the present study is unknown. The most probable explanations are either food consumption was reduced or lipid utilization was altered in crayfish fed high-lipid diets, resulting in an increased amount of nonprotein energy. Food intake is generally thought to be related to the caloric density of the diet. Excess dietary lipid may inhibit appetite (Church and Pond 1982). Consumption was not determined in the present study because it was assumed that intake would be more or less equal between treatments since all diets were isoenergetic. It is possible that consumption was reduced in crayfish fed high dietary lipid, though it is not apparent from visual inspection of the amount of residual feed remaining after feeding.

Food consumption is assumed to be related to lipid utilization may have been influenced by high lipid levels in the diets. Anderson et al. (1978) reported substantially reduced digestible energy and apparent lipid utilization for channel catfish fed 15% supplemental fat when compared to fish fed diets containing 0 to 10% supplemental fat as the authors know, there are no reports of the effects of dietary lipid levels on food utilization in crayfish. A reduction

in lipid utilization would essentially result in a nonprotein energy deficiency which could be reflected in growth. If a deficiency in utilizable nonprotein energy occurred, protein would be metabolized for energy resulting in inadequate protein available for growth. Diets that were utilized well in the present study contained high levels of digestible carbohydrate (dextrin) and relatively low levels of lipid, which suggests that carbohydrate is better utilized as an energy source. This indicates that the dietary carbohydrate/lipid ratio is of importance. Deshimaru and Kuroki (1974) demonstrated that the growth of the prawn, *Penaeus japonicus*, increased when carbohydrate (glycogen) was added to diets containing 0, 6 and 12% lipid.

Based on growth data, there does not appear to be a dietary lipid level that is optimal; i.e., crayfish grew well on diets containing 0 to 6% dietary lipid, and molting frequency and survival were unaffected by dietary treatments. However, some dietary lipid is needed to provide essential fatty acids (NRC 1983). It is possible that if the present study had been of longer duration a reduction in growth could have been induced in crayfish fed lipid-free diets. Channel catfish fed lipid-free diets did not exhibit deficiency signs until the tenth week of the trial (Robinson and Lovell 1978).

Body Composition

In general, as an animal fattens there is a decrease in body water; i.e., there is an inverse relationship between body lipid and moisture. Also, the amount of tissue lipid deposited is influenced by dietary lipid, with body lipid increasing as dietary lipid increases. This trend has been demonstrated in various finfish (NRC 1983). Although whole-body lipid increased significantly in crayfish fed 6% dietary lipid, those fed diets containing in excess of 6% had reduced whole-body lipid (Table 3). This response may have been due to either reduced consumption or impaired absorption of dietary lipid.

TABLE 3.—Body composition (dry weight basis) of juvenile crayfish fed experimental diets.

Diet no.	Dietary lipid (%)	Whole body composition ^a			
		Protein (%)	Lipid (%)	Ash (%)	Dry matter (%)
1	0	47.53 ^x b	3.39 ^{xy}	19.77 ^x	24.02 ^x
2	3	46.82 ^x	3.79 ^{xy}	22.58 ^x	23.75 ^x
3	6	47.36 ^x	5.53 ^y	22.08 ^x	25.07 ^x
4	9	49.18 ^x	4.94 ^{yz}	21.94 ^x	21.82 ^y
5	12	54.13 ^y	3.85 ^{xy}	21.88 ^x	19.29 ^y
6	15	54.60 ^y	3.43 ^x	22.30 ^x	18.79 ^z

^a Means of triplicate determinations of pooled samples (4 crayfish/sample).

^b Means with the same superscript letters are not significantly different (Alpha 0.05). The pooled standard errors for protein, lipid, ash and dry matter were 0.59, 0.13, 0.43 and 0.21, respectively.

Percentage of whole-body protein was significantly increased and dry matter decreased in crayfish fed diets containing 12 and 15% lipid. This response may be a reflection of crayfish size rather than diet; i.e., a higher ratio of tail (muscle tissue) to whole body in the smaller crayfish. Whole-body ash was not affected by dietary lipid.

Fatty Acids

Tissue fatty acid patterns (Table 4) generally reflected that of menhaden fish oil. Crayfish fed the lipid-free diet had whole-body fatty acid profiles generally similar to those fed diets containing lipid; however, there were a few exceptions. Crayfish fed diets containing from 6 to 15% lipid exhibited higher levels of total saturated fatty acids and lower levels of total monounsaturated fatty acids than crayfish fed a lipid-free diet. Saturated and monounsaturated fatty acid levels of crayfish fed a fat-free diet were comparable to fatty acid levels reported for other species of crayfish (Collatz 1969; Zandee 1966). Apparently the white crayfish has the ability to synthesize saturated and monounsaturated fatty acids from carbohydrate precursors, which has been demonstrated in all other crustaceans studied (Castell 1983).

TABLE 4.—Fatty acid composition of crayfish whole-body lipids and menhaden fish oil expressed as percentage of total fatty acids.

Fatty acids	Dietary lipid (%)						Fish
	0	3	6	9	12	15	
C14:0	2.1	2.5	4.6	4.4	3.1	2.3	11.0
C16:0	23.1	23.2	24.2	24.2	23.0	24.3	21.1
C16:1n7	18.4	16.4	16.1	13.6	9.7	8.9	13.9
C18:0	5.5	5.9	4.8	5.7	8.1	8.8	3.1
C18:1n9	31.2	29.3	25.4	24.0	24.9	25.2	12.6
C18:2n6	2.9	2.3	1.5	1.1	0.7	0.6	0.8
C18:3n3	0.3	0.3	0.2	0.2	0.2	0.1	0.4
C20:1n9	1.0	1.1	1.3	1.5	1.6	1.4	1.4
C20:4n6	1.1	1.1	0.6	0.9	1.3	1.2	0.6
C20:5n3	0.1	0.1	0.3	0.3	0.2	0.1	0.8
C22:0	7.8	10.4	11.5	13.7	16.8	17.4	13.7
C24:0	0.1	0.1	0.3	0.3	<0.1	<0.1	1.5
C22:6n3	1.0	1.4	1.6	1.9	2.0	1.7	4.8
Saturated	38.5 ^{wa}	42.2 ^{wx}	45.4 ^{xy}	48.3 ^{yz}	50.3 ^{yz}	52.8 ^z	50.4
Monounsaturated	50.6 ^x	46.7 ^{xy}	42.8 ^{yz}	38.9 ^y	36.3 ^z	35.6 ^z	27.6
Polyunsaturated	5.4 ^x	5.2 ^x	4.2 ^x	4.4 ^x	4.3 ^x	3.7 ^x	7.4
n3/n6	0.67 ^x	0.57 ^x	0.97 ^y	1.25 ^y	1.17 ^y	1.06 ^y	4.31

^a Means with the same superscript letters are not significantly different (Alpha 0.05). The pooled standard errors for saturated, monounsaturated and polyunsaturated and n3/n6 were 0.77, 0.94, 0.25, and 0.03, respectively.

Tissue polyenoic fatty acids were not significantly affected by the level of dietary lipid, presumably because they comprised a small fraction of the total fatty acid composition of menhaden oil.

Ratios of n3/n6 fatty acids in whole-body lipids increased significantly as dietary lipid was increased to 6% or greater (Table 4). This is generally reflective of the increased level of marine fish oil in the diet which contains relatively high levels of n3 fatty acids. There were no differences in the n3/n6 ratio in crayfish fed diets containing from 6 to 15% lipid. The absence of an increase in the n3/n6 ratio as dietary lipid increased from 6 to 15% suggests that diets containing high lipid levels were not well utilized.

Conclusion

Although the optimum dietary lipid level was not ascertained, we would recommend that diets used for growth of white crayfish contain lipid at levels of 6% or less. Some lipid is presumably needed to provide essential fatty acids, though growth of crayfish in the present study was not adversely af-

ected by the lack of lipid in the diet. A study of longer duration may have demonstrated a need for dietary lipid.

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oil expressed as percentage

15	Fish
2.3	11.0
24.3	21.1
8.9	13.9
8.8	3.1
25.2	12.6
0.6	0.8
0.1	0.4
1.4	1.4
1.2	0.6
0.1	0.8
17.4	13.7
<0.1	1.5
1.7	4.8
52.8'	50.4
35.6'	27.6
3.7 ^x	7.4
1.06 ^y	4.31

0.05). The pooled standard deviations were 0.94, 0.25, and 0.03, respec-

lipid in the diet. A study may have demonstrated lipid.

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